PRESIDENT BRUCE USREY: To start the meeting I thought we could have a kind of self-introduction. So if each of you would stand up, give your name, where you are from, and your speciality, the thing you really enjoy doing, then we will get the program going. This will help us get acquainted right from the start.

Thank you. Now Bruce Briggs, our first Moderator, will start the program.

MODERATOR BRUCE BRIGGS: We will now hear from the first speaker, Steve Wong, introducing our first session on "Tissue Culture after the Test Tube":

DIRECT ROOTING OF TISSUE-CULTURED RHODODENDRONS INTO AN ARTIFICIAL SOIL MIX

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Abstract. Direct rooting of tissue-cultured rhododendrons into an artificial soil mix was highly successful. By by-passing the standard test tube pre-rooting stage in the laboratory, production costs are markedly reduced. If a suitable environment is maintained in the propagation tent, root initiation will occur within 3 to 4 weeks of planting.

It has been accepted by most propagators that tissue culture propagules must be placed into a pre-rooting stage to condition them for transfer to a soil medium. In the pre-rooting stage the propagules are placed in a charcoal medium in the test tube for about 4 to 6 weeks to allow for an increase in size, uniformity, and hardiness. This makes for easier planting, but in our experience, only slightly higher survival rates. Motivation for bypassing this pre-rooting was to reduce costs by eliminating this one additional operation and the attendant use of expensive test tubes and media, aseptic techniques, and laboratory equipment and space. In our initial attempts at rooting directly into an artificial soil mix, the planted flats were in styrofoam boxes with a glass top (1). Humidity was maintained with manual misting throughout the day. Results were promising so we decided to try this on a larger scale in a propagation tent. Results have been outstanding, convincing us that direct rooting in an artificial soil mix is both physically possible and economically feasible.

MATERIALS AND METHODS

The process of establishing the unrooted tissue culture propagules directly into an artificial soil mix involves four operational stages:

1. cutting up the propagules
2. planting in the artificial soil mix
3. rooting and growth in the propagation tent
4. potting

1. Cutting up the propagules. The clumps of shoots are removed from the test tubes with forceps, washed, and then cut for planting. Callused growth and undersized, deformed, and watersoaked propagules are discarded. Well-formed shoots 75 mm and up are used for planting. On the average, 15 to 30 plantable shoots are obtained per test tube. With this method, the cutting does not need to be done aseptically in the laboratory.

2. Planting in the artificial soil mix. This is extremely meticulous and visually straining work and workers should be hired with this in mind. The inside of our planting flat measures 47 cm × 30 cm × 4 cm, with plantlets at a high density spacing of 2.0 cm × 2.5 cm. It takes approximately 45 minutes to plant a flat of 285 propagules. A peat/perlite/sawdust mix is used, sieved to accommodate the small propagules. After planting, the propagules are given a hand mist of 20:20:20 fertilizer solution plus Benlate, then put into the propagation tent.

3. Rooting and growth in the propagation tent. It is imperative that there be strict control over the temperature, humidity, and light levels in the propagation tent. We arrived at the style of our present propagation tent through a series of preliminary trials. The tent consists of a plastic sheet supported over a 2.4 m × 19 m heated concrete bench, which accommodates 277 flats, or 79,000 propagules. The air temperature is maintained at 21 to 24°C during the day and 18°C at night. The soil temperature is kept at 24 to 27°C. Ventilation is with an exhaust fan and cooling pad arrangement.

We use high pressure sodium lamps as supplemental light to increase the daylength to 16 hours and the intensity to 5400 lux. To prevent an excessive heat load in the summer we blocked out the daylight with opaque plastic and have gone exclusively to the artificial lights. We have found that the moderate expense of operating these lights is more than offset by the increased rooting and growth.

Because these propagules are without roots and a cuticle layer, the humidity within the tent must be kept high to

prevent desiccation. This is achieved through frequent misting and use of a cooling pad. Our misting is automated and set for a short duration of 2 seconds every half hour during the day; however, if the weather is hot and the exhaust fan is on, the misting is increased to as much as every 8 minutes.

Under these conditions, some of the easier rooting cultivars, as 'The Hon. Jean Marie de Montague', 'Daphnoides' and 'Vulcan', will initiate roots after only 3 weeks. Cultivars like 'Britannia', 'Scintillation' and 'Cynthia', will take approximately 4 weeks. A flat of 285 'Daphnoides' was checked 35 days after planting and 64 percent of them had rooted. Almost all cultivars tested are ready for transplanting within 3 months of planting, with vigorous growers like 'Daphnoides' or 'Jean Marie de Montague' ready within 2 to 2½ months (Table 1). At transplanting time, the roots are well branched and in most cases over 1.5 cm long.

We have noticed that rooting will only occur if the propagule is in a succulent, juvenile stage. If there is environmental stress the tissue quickly hardens and root formation becomes extremely difficult, if not impossible.

A hormone powder was tested but did not seem to cause earlier root initiation although it did seem to cause a greater proliferation of roots. Further experimentation is needed to justify the additional labour of dipping the base of the propagules into the hormone powder.

Table 1. Rooting percentage of propagules at transplanting.[1]

Cultivar	Days from planting to transplanting	Percent Rooted
The Hon. Jean Marie de Montague	56	90
Daphnoides	62	89
Britannia	62	81
Les Clay	75	73
Scintillation	75	79
Vulcan	76	66
Golden Witt	77	89
Cotton Candy	83	80
Rainbow	84	73

[1] 285 propagules of each cultivar planted in May and June, 1981.

4. Potting. The rooted plants are put into a peat/perlite/sawdust mix in 2¼" pots. They are kept under mist for about 1 month before moving into shade houses. Tissue-cultured plants grow much more vigorously and are better branched than cutting-propagated plants. They are ready for sale approximately 3 months after potting.

RESULTS AND DISCUSSION

From our experience so far, we feel that it is feasible to bypass the pre-rooting stage and have the propagules go directly into an artificial soil mix. If a suitable environment is maintained there is a high percentage of root initiation within 3 to 4 weeks. To include the pre-rooting test tube stage would mean handling the plantlets an additional time in the laboratory, increasing production costs.

LITERATURE CITED

1 Anderson, W.C. 1978. Rooting of tissue-cultured rhododendrons. *Proc. Inter. Plant Prop. Soc.* 28:135-139.

TRANSPLANTATION AND POST-TRANSPLANTATION OF MICROPROPAGATED TREE-FRUIT ROOTSTOCKS

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Abstract. The principal factors that have affected success at transplantation of micropropagated tree fruit rootstocks are presented. The factors discussed include pre-transplantation conditions (laboratory culture) and the conditions at transplantation and field-planting; examples are taken from the Kelowna Nurseries production.

Abbreviations used in the text:

NAA	naphthalenacetic acid
IBA	indolebutyric acid
IAA	indoleacetic acid
BA	benzyladenine
MS	Murashige and Skoog nutrient formulation (8)

The use of micropropagation as a propagation tool is often viewed with skepticism. More specifically, it is the rooting and transplanting phases which need credibility. These stages present challenges at least equal to the initiation of cultures, and are more awesome because they mark the end of artificial control and a return to more traditional practices.

Recent publications concerning transplantation (2,3,6) and the factors influencing rooting in tree-fruit culture (5,9,10,11) give indications of diverse approaches.

Our approach is based upon survival and growth after transplation which relies on *in vitro* cultural history coupled with horticultural practices as follows.

RESULTS AND DISCUSSION

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Our approach is based upon survival and growth after transplation which relies on *in vitro* cultural history coupled with horticultural practices as follows.

The plant material that we have used includes 'M111', 'M7', 'M26' and 'M4' apple rootstocks (*Malus sylvestris* Mill.) and Mazzard 'F12/1' cherry rootstock (*Prunus avium* L.).

1. Laboratory Culture. Just as the condition of plants is important for more traditional propagation, so it is in micropropagation. The factors most likely to influence rooting and survival include the plant growth regulators, salt and sucrose availability, and time in the rooting medium.

(a.) *Growth regulators.* The cytokinin content of the last multiplication stage affects the subsequent rooting of excised shoots (Table 1). The table shows that for a given rooting response, shoots of 'Mazzard F12/1' required a lower auxin concentration in the rooting medium, when they came from cultures grown at the higher cytokinin concentration.

The auxin concentrations shown in Table 1 produced relatively broad peaks in the rooting response of shoots from either cytokinin source. Observations of rooting cultures showed that this occurred for all three major auxins when tested between 0 and 50 μM (0 to 9 mg/l *NAA*; 0 to 9 mg/l *IAA*; and 0 to 10 mg/l IBA).

Table 1. Rooting potential as affected by cytokinin content at the final multiplication stage. Results are the percentage of the propagules that were rooted at transplantation after 17 days on rooting medium. Mazzard 'F12/1'; 10 blocks with 15 shoots per block.

TO NAA (mg/l)	FROM BA (mg/l)	
	0.68	1.12
0.10	43%	69%
0.50	69	76
0.75	73	86
1.00	75	84
1.25	84	85
1.50	76	91

Taken in conjunction with the increasing quantity of roots per rooted shoot over the same range, our observations indicate that the higher auxin concentrations are superior. However, the quality of roots were altered to such an extent as to affect survival when transplanted. Increased auxin levels, particularly of NAA and IBA, caused the production of fused roots, as well as thickened roots associated with callus, which were prevalent on plantlets failing to survive. In consideration of survival, therefore, an auxin concentration that did not initially appear the best was finally selected (0.75 mg/l NAA), and the use of this concentration resulted in the need for 1.12 mg/l BA in the last cytokinin-containing medium for a good rooting response.

(b.) *Salt and sucrose availability*. Plant condition is further affected by nutrient and carbohydrate concentration during the *in vitro* rooting period. It is often assumed that optimum levels prepare plantlets for an autotrophic mode of life when transplanted. Several publications report the use of a diluted nutrient solution for rooting (1,4,7,9). Our observations (Table 2) agreed in principal with the above reports and revealed:

a. the requirement for sucrose in the rooting medium, irrespective of salt content.
b. the increase and then decrease of rooting potential with increasing salt levels, for each sucrose concentration.
c. the relative independence of sucrose concentration when using ¼ and ½ the concentration of MS nutrients (8).

However, we have noticed that survival was often better for cultures that were rooted on 21 and 28 grams of sucrose within the 92% range as shown in Table 2*.

Table 2. Rooting potential as affected by salt and sucrose content. Results show the number of propagules that were rooted out of a possible 25 (5 blocks of 5), recorded at transplantation. Mazzard 'F12/1'; 2.5 mg/l NAA.

Sucrose grams/l.	(MS) salts. Concentration Multiples						
	0	0.25	0.5	0 75	1.0	1.5	2.0
0	0	1	1	0	0	0	0
7	16	24*	20	11	7	2	0
14	20	25*	23*	18	17	6	1
21	21	23*	21*	22	22	14	4
28	12	23*	24*	21	18	11	4
35	16	23*	24*	24*	23*	11	5
42	17	24*	24*	21	21	16	2

(*represents over 92% rooting efficiency.)

(c.) *Time on rooting medium*. The time taken to produce desirable rooted shoots varies from 4 days on the rooting medium for 'F12/1' cherry rootstock to 10 days for 'M26' and 11 to 17 days for 'M111', 'M7' and 'M4' apple rootstocks. At these times roots are still quite short, 0.6 to 1.2 cm (¼-½ inch), and plantlets are easily transferred to soil for growing-on. Longer times than these have often reduced survival rates after transplantation.

The percentage rooting that we have achieved varies as follows:

'M7'	90 to 97%	'M4'	80 to 90%
'M26'	90 to 95%	'F12/1'	80 to 90%
'M111'	85 to 90%		

Although a figure over 90 percent is desirable, differences between one month's production and another do exist. We

have put over 156,000 shoots into *in vitro* rooting, a total for all the above cultivars, and we have achieved an average 85 percent rooting success.

2. Transplantation. Micropropagated plantlets for tree-fruits do not initially have the ability to withstand moisture loss from leaf surfaces, though this can be achieved by misting. Plantlets are routinely removed from their culture vessels by knocking out the agar and separating rooted plantlets, placing these in water until planting in two-inch-square (5 cm^2) containers — 36 in a flat of 11 × 21 inches (28 × 53 cm). Immediately after planting, flats are placed beneath frequent mist (Mistamatic leaf sensor with Flora Mist foggers) until they are ready to be moved to their final growing bed (usually 7 to 10 days).

The following factors influence success at this stage.

a. *Environment.* For the year-round production at Kelowna Nurseries Ltd., we have considered the use of a greenhouse and growth room (12,13,14). Although we have not found an answer to all our requirements, our greatest experience is in the use of the growth room. The environment of the 7000 square feet (650 m^2) growing area is controlled as follows:

i. lighting:

— high pressure sodium lamps (1000 W. Canadian G.E.)

— metal halide (1000 W. Canadian G.E.)

(1300 to 1500 foot candles, 16 hour photoperiod.)

ii. temperature:

— heating — gas-fired infra-red and heat output from lamps.

— cooling — greenhouse-type fan and cooling pads.
(25°C = 77°F)

Plantlets are placed in this environment from the moment they enter the mist bed until one month later. At that time they are about ⅛ inch (2 to 4 mm) in caliper. Mazzard 'F12/1' cherry rootstock usually grows to 5 to 6 inches (12 to 15 cm) high; 'M26', 5 to 7 inches (12 to 17 cm); 'M7', 'M4' and 'M111' 4 to 6 inches (10 to 15 cm).

b. *Potting mix.* We have had success using several of the more common mixes, though we have principally used a mix of peat, perlite, sand, at 3:4:1; v:v:v. This mix provides the support and drainage necessary for plant growth whilst reducing the conditions that sustain fungal growth.

c. *Irrigation.* Water supply can vary in salt content and should be considered when choosing the original location. When flats are moved from the mist beds they are suitably

moist, but close attention must be given to subsequent irrigation. Whilst plants are small, watering with a hand-wand is adequate, though taller plants are often unable to stand up in the water flow. This can lead to crooked growth if the plants are not righted. Automation of our system with Toro heads has reduced this problem.

d. *Fertilization*. Although plants have grown in mixes not adjusted for pH, we now adjust to near pH 6.0 with dolomite lime. Several mixes of granular fertilizer have been tested but their speed of release has caused burning. We now use a 14:14:14 Osmocote with a three to four month release formulation, plus added micronutrients. Superphosphate, iron chelate, magnesium, and calcium salts may be necessary to correct nutritional problems.

Using the growth room environment described, we have achieved varying degrees of transplantation successes:

'M7'	70 to 90%	'F12/1'	70 to 90%
'M26'	80 to 95%	'M4'	60 to 85%
'M111'	70 to 90%		

Perhaps the single greatest factor affecting these survival figures is disease, commonly damping-off fungi which become evident at removal from mist. Pasteurization with steam, or fumigation of the soilpile with Basamid (B.A.S.F., Ontario), followed by proper hygiene at transplantation and in the growing area should significantly reduce the problem. Dilute sprays or drenches of fungicide may control localized problems.

3. Post-Transplantation. From a controlled environment to an uncontrolled environment in one step is possible, though in our experience this has led to delay in top growth. We favour an intervening partially exposed environment into which plants are placed before full exposure. During the spring, the growth room can gradually be cooled off before transferring plants to a partially exposed environment which has minimal bottom heat. During the summer, plants can be moved to 50 percent shade. Following acclimatization, plants should be able to be transferred to full exposure, if conditions permit.

We have transplanted to field conditions without pre-conditioning in late April and May. Freshly planted material was subsequently hit by frosts and chilling winds and underwent a fall colouration and defoliation within a few days. Following a two month quiescent period most plants have shown good shoot growth and should be able to grow a further 30 to 60 cm (1½-2 feet) in the remaining two months of the growing season. Our total field planting is almost 30,000 from the cultivars mentioned above.

The losses that we have made would be similar for seed-

ling material as for micropropagated material, once the preliminary misting has passed. The condition of plantlets when they are transplanted can be greatly affected by alterations in kind or concentration of grown regulators, by the availability of salts and sucrose, and by the length of time on the rooting medium. We have found that this area may require month to month attention, and that newly isolated sources of a cultivar may require different conditions from existing stock. However, there is now little skepticism within our nursery that we can suitably adapt micropropagated material to the external environment on a commercially feasible scale.

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SMALL FRUIT CULTURE AFTER THE TEST TUBE

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There is an important transition period which tissue cultured plantlets must experience between the protected environment of the laboratory and the harsh world of the greenhouse. In fact, the ability to survive this transition is limiting the commercial use of tissue culture for some species. However, plants of some cultivars survive this crucial stage more easily than others.

Growers know that field-grown plants require good growing conditions: fertile, well-drained soil, proper watering, and nutrients. Tissue-cultured plants also require good growing conditions: controlled environment of heat, light, and chemical nutrients. Between these two very different growing conditions is a transition facility for preparing *in vitro*-propagated plants for growing on. The requirements for this facility differ according to the cultivar being grown.

This year we propagated 40,000 strawberry plants by tissue culture for growers who sell certified strawberry plants. We grew 'Hood,' 'Benton,' 'Olympus,' 'Totem,' 'Shuksan,' and 'Quinault' cultivars (2). We took the plants out of culture jars and put them directly into bedding plant containers in the greenhouse; our mortality was essentially zero. Caneberries, on the other hand, take considerably more care.

We programmed for field-ready strawberry plants on April 1. Strawberry meristems were started in culture in July. They multiplied in test tubes, then in mason pint jars, for four or five months, multiplying, in some cases, as much as six to one in ten days. Following the multiplication stage they were placed in rooting agar in pint jars for four to six weeks. We transferred the rooted plantlets from the jars into the greenhouse mostly between January 15 and February 15. The days were short, mostly cloudy and rainy, and cool to cold. Because of woody hillsides, we have less than five hours of direct sunlight on our greenhouses on February 1. The greenhouses are quonset style pipe houses (14′ by 90′) with inflated double-

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walled polyethylene covers that are tightly sealed; the humidity, therefore, is always very high. Heat is provided by circulating warm water in pipes in the floor. The floor is of ash, much like sand, from the local coal-fired steam plant. No supplemental light was provided. On sunny days the temperature in the greenhouse would go over 90°F; night air temperatures kept above freezing, but greenhouse floor temperatures usually held above 60°F. A small fan (4500 c.f.m.) moved greenhouse air.

We planted directly into six-packs using a very porous, fertilized, standard greenhouse mix with a pH close to that in culture, about 5.7. The trays of six-packs were set directly on the warm floor. We sprayed with Captan to discourage *Botrytis*. Normally we pot 30 plants from a one pint mason jar; however, with some cultivars the multiplication continues in the rooting medium such that we have taken as many as 100 Totem strawberry plantlets from a single jar. We can count on high survival only by those plants which have well developed roots, usually at least two roots an inch or longer, and which have a solid appearance to both stem and roots, as opposed to a succulent, watery appearance. We watered in the plantlets as soon as they were planted then, subsequently, hand watered as required, using a Peter's 20-20-20 fertilizer mix when we watered.

This year we also tissue-cultured several thousand Boysenberry, thornless Loganberry, and Marion blackberry (1,3). Direct transfer of these berries from jar to greenhouse was not possible without mortality rates of 20 to 50 percent, under the same conditions that caused no mortality to strawberries. Without sophisticated controls in our transition facility we achieved survival rates of 90 percent, or better, by putting the potted berries in diffuse light under a polyethylene tent for two weeks. No mist was applied; they were hand-watered as required. A well developed root system helped but did not eliminate the need for control of light and humidity in the rather long transition period. The Loganberries, Boysenberries, and Marion blackberries, qualitatively, progressively, in that order, appeared more rugged or better able to withstand sunlight or lower humidity, with Marions the most rugged. These berries also took longer to start aggressive growth than the strawberries.

Currently, we are tissue culturing various caneberries for a customer who will take them as rooted plantlets. We are weighing the merits of rooting *in vitro* as opposed to rooting in potting mix in closed, clear plastic shoe boxes in controlled, growth room conditions. So far, the potting mix appears to promote more roots sooner.

There is need for a series of experiments for caneberries to take place in a controlled environmental growth chamber, or similar device, to establish the optimum limits of light and humidity at various temperatures, just as experiments have been conducted to establish auxin-cytokinin ratios and nutrients for *in vitro* propagation.

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THE AFTERMATH OF THE TEST TUBE IN TISSUE CULTURE

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Tissue culture at Briggs Nursery has been around for twelve years or more, mainly as a research project and the hope of one man.

There was work done at that time, but until the chemicals and the media were developed, success was minimal. Finally, Dr. Wilbur Anderson, from the Northwest Washington Research and Extension Unit, Mt. Vernon, Washington, was able to start rhododendrons in tissue culture and make them multiply. Afterward, by manipulating chemicals and lights, more and more cultivars were added.

Three years ago our Production Department started to receive plants from the Tissue Culture Department. At first there were only small batches, but the explosion was waiting. In the spring of 1980 we were faced with thousands of tissue culture plantlets to root and grow on.

The first problem we had to face was how to root and grow the new plantlets. The plantlets coming from the test tube were very tender and completely different in character than plant materials normally worked with at Briggs Nursery. This presented new problems for the people in charge of this phase of production.

Soil media had to be developed both for rooting and growing of the new plantlets. The media had to be well drained,

There is need for a series of experiments for caneberries to take place in a controlled environmental growth chamber, or similar device, to establish the optimum limits of light and humidity at various temperatures, just as experiments have been conducted to establish auxin-cytokinin ratios and nutrients for *in vitro* propagation.

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Tissue culture at Briggs Nursery has been around for twelve years or more, mainly as a research project and the hope of one man.

There was work done at that time, but until the chemicals and the media were developed, success was minimal. Finally, Dr. Wilbur Anderson, from the Northwest Washington Research and Extension Unit, Mt. Vernon, Washington, was able to start rhododendrons in tissue culture and make them multiply. Afterward, by manipulating chemicals and lights, more and more cultivars were added.

Three years ago our Production Department started to receive plants from the Tissue Culture Department. At first there were only small batches, but the explosion was waiting. In the spring of 1980 we were faced with thousands of tissue culture plantlets to root and grow on.

The first problem we had to face was how to root and grow the new plantlets. The plantlets coming from the test tube were very tender and completely different in character than plant materials normally worked with at Briggs Nursery. This presented new problems for the people in charge of this phase of production.

Soil media had to be developed both for rooting and growing of the new plantlets. The media had to be well drained,

but the particle size had to be fine so the tender plantlets could be planted without damage. This is always hard for a medium to fulfill.

We also learned there was a large difference between summer and winter growing conditions, moreso with the tissue culture plantlets than other plants we work with.

The basic rooting and growing media are made up of the following: sawdust, peat moss, perlite, pumice, and vermiculite, plus fertilizers. We are still searching for the perfect medium for rooting and growing plantlets and, at the same time, transplant in the growing field without showing stress.

Disease was also a problem when we started to get plantlets from tissue culture. The first two years we thought the diseases would win. *Botrytis*, *Pythium*, *Rhizoctonia*, *Phytophthora* and powdery mildew seemed to be the main ones giving us problems.

Many of the fungicides used in the nursery industry showed some toxicity to the young plantlets. We feel this could be due to a lack of cuticle or wax on the leaves. As the plants mature and the leaves thicken, this problem seems to diminish. By using new fungicides and adjusting rates, we are preventing diseases from occurring.

Liverwort and mosses have also given problems in flats and boxes where we grow plantlets. The chemicals used in other parts of the nursery to control these damaged the young plantlets. The heavy metals, i.e. Cu, Zn, Fe, also injured plants so we still do not have the answer to this problem.

Plant size has been a concern of the people in production. The personnel in charge of liners want as many plantlets per square foot of growing space as possible. Crowding plantlets at the start causes die-out and disease problems. The growers want as large a plant as possible for better survival in containers and field.

We have found by experience that a small plant moved out into a field does not respond and grow nearly as well as a larger plant. A plant with a 3″ to 4″ root-ball and a 4″ to 6″ top grows well the first year. It is not affected by the summer heat, and the herbicides that are applied. If we use a small plant we lose that first year's growth.

In containers a much smaller plant can be used. We have had good response from plants with a 1½″ to 2″ root-ball and a 2″ top.

The plants coming from the tissue culture environment seem to show accelerated growth and, given the proper growing conditions, will make a saleable plant 6 to 12 months

before the same size rooted cutting. This is due, in part, because we grow the tissue culture plants at their maximum; lots of feed and more light. This also gives uniformity in size, which is a plus for our nursery and the purchasers of these plants.

In rhododendrons from tissue culture we do not have the growth and rest cycles that are formed in plants from rooted cuttings. The growth in these plants seems to be vertical and, unless they are pinched, the side buds stay dormant. A good example of this is the rhododendron, 'Vulcan'. It gives 12" to 15" growth in one growing season without side breaks. This is not the type of plant we want, so pinching of young plantlets becomes a high cost factor.

Chemical pinching would be a real help to tissue-grown plants. But, there is not any chemical that can do the job. Atrinal at high rates has not been of any help.

There has been a lot of concern in the nursery industry about genetic breakdown of tissue-culture grown plants, both in plant growth and winter-hardiness, plus flower truss. But after growing thousands of plants, both in containers and field, and seeing many of them bloom, we have not seen any signs of genetic variation or off type plants.

From experience, we have learned that if we use a good, healthy, single plantlet instead of a clump of plantlets when we come from the test tube, the plants that grow are normal. But, from clumps we sometimes end up with a mossy plant that never grows properly. It is easy to separate this type of plantlet as they grow in the liner stage. We have had a percentage of plants with leaf varigation, but it is not stable and disappears as the plant matures.

CONCLUSION

The benefits of tissue culture plants far out-weigh the problems in growing them. Tissue culture gives increased production by faster manipulation of new plants.

Uniformity of product is another advantage of tissue culture. The plants from the test tube seem to grow at a uniform rate, which is what a grower wants.

MODERATOR BRUCE BRIGGS: We are ready for questions.

VOICE: I heard sawdust mentioned by three of the speakers. I would like to know what type of sawdust, and is it treated in any way other than by sterilization?

STEVE WONG: Most of the sawdust we are using comes from a composted area. It has been through a compost, it is heated up to 140°F. Right now we are using cedar sawdust. We have used both fir and cedar — either one is good.

WILLIAM SMITH: At our operation, we use salt-free hemlock/fir sawdust. When we are direct rooting from the test tube into the propagating medium we sieve the sawdust.

GEORGE MATSON: Are any of you using artificial cuticles, so to speak? You mentioned that as a problem. Can you use anti-transpirants to spray young plants to give them some protection at the transplanting or transferal stage?

VOICE: Yes, we have recently tried using Wilf-Pruf as a bucket soak, also as a spray, but it is too early to tell whether there is any significant improvement over just the mist.

HAROLD TUKEY: Chrysanthemum propagators have been trying the anti-transpirants because initially the chrysanthemums don't have any cuticle — and they found no effect. However, two or three days in the sunlight and the cuticle comes on hard. So they have had no luck with the anti-transpirants — or anything else of this type.

ED LOSELY: I would like to direct a question to Steve Wong relative to the light intensity in your stage II tissue culture just prior to direct sticking from the culture medium. What light intensity do you use?

STEVE WONG: Five hundred foot candles. That is what we aim for. If we have the black plastic on then we have exact control over the light intensity. Without the black plastic and, if you are using sodium lamps as supplemental light then, of course, it is going to vary a bit. But we aim for 500 foot candles. With our sequence we attempt to go directly from the multiplication stage, as opposed to the other people here, directly into the greenhouse, by-passing the pre-rooting charcoal stage in the laboratory. We feel that by this method we can eliminate or reduce costs in the laboratory.

ED LOSELY: What light intensity do you use at the multiplication stage? That was the question.

STEVE WONG: Oh, I see. It is about 250 to 350 foot candles, I would say.

BRUCE BRIGGS: Anyone else want to comment on light? We go less than that ourselves. In fact, for some plants, as rhododendrons, 150 foot candles is enough. There is a difference among the different plants.

ROBERT NORTON: I might just comment on the type of radiation source, whether you are using high pressure sodium, or cool-white fluorescent, or whatever. I really don't think that

it makes any difference what type of light you use, as long as you are applying the proper amount of total radiant energy. We have had best results in terms of fluorescent lamps with regular cool-white, compared to Gro-Lux or other special plant growth lights. You don't need incandescent lamps. Just simple, cool-white fluorescent lamps are perfectly satisfactory. In terms of the comparison between high pressure sodium, metal halide, or any of the others of this type, the high pressure sodium is the most efficient. So, if you need greenhouse supplemental lighting, high pressure sodium is probably the best, with metal halide being second. So I think these three would be the primary light sources to use: cool-white fluorescent, high pressure sodium, and metal halide.

ANN KYTE: In our case, I would add that we had no supplemental lighting in the greenhouse for our berries. For the growing multiplication stage in the laboratory, our lighting runs from 100 to 300 foot candles.

DON DILLON: Question for Steve Wong. In your potting mix, do you incorporate any nutrients into those materials?

STEVE WONG: Yes, we include the usual elements like dolomite lime, gypsum, superphosphate, and Osmocote at 5 pounds per cubic yard, and we liquid feed for the first stage with a 10-52-10 starter solution for about three weeks.

BRUCE BRIGGS: Here again, caution must be used in a lot of these things; it depends upon your light, your water, your mix, and so on. What are you starting with? When you are talking about pounds to use, it depends upon a lot of things, so take a look before you get too far out on a limb; try it on a small scale before you burn your crop up.

RALPH SHUGERT: Bill, in getting the fall 1980 tissue-cultured rhododendron liners to the field, compared to the normally produced fall-planted rhododendron liners, which broke earlier in the spring, or was there any difference? That is, in the spring of 1981?

WILLIAM SMITH: The tissue-cultured rhododendrons broke quite a lot earlier. They really never stopped growing. During the winter they may rest a little bit, but the minute it warms up they start out. One of my slides showed regular cuttings on one side and tissue-cultured plants on the other; they were two different cultivars. One was 'Jean-Marie' and one was 'Crest'. But you could see the comparison in the field — both produced about the same sized plants.

KEITH TURNER: On your lighting studies, Bob, what kind of plant material are you working with — strawberries, foliage plants, or deciduous plants?

ROBERT NORTON: Strawberries, raspberries, and rhododendrons, primarily.

KEITH TURNER: If I could ask another question while I am on the subject. Speaking of high pressure sodium lamps, are you familiar with their wave length pattern?

ROBERT NORTON: Yes.

KEITH TURNER: I have studied them and, according to the graphs of photosynthesis in plants, their peak is in between the two peaks of the high pressure sodium. And I am wondering, if in fact, in terms of the energy that is put in and the light quantum that you get out, they are not that efficient, because the best spectrum for plants is not supplied by those lights.

ROBERT NORTON: I think we have been placing too much emphasis on the spectral qualities of lamps in the past. If you look at Marc Cathy's recent article in the Journal of the American Society for Horticultural Science you will see reference to this. Of course, this was expressed many years ago by the Dutch workers. I think there is a misimpression that light in wavelengths other than red and blue is inefficient for photosynthesis — this is not the case. What you are really talking about is the total energy — the total quantum energy from 400 to 700 nanometers that is effective for plant growth. It has been demonstrated time and time again in our facility and in other facilities with high pressure sodium and with low pressure sodium, which is absolutely monochromatic, as you know, that the total growth per micro-einstein of energy is really greater with some types of efficient lamps that have a very poor spectral output. The Sylvania people developed the Gro-Lux lamp, which had high radiant energy output in both red and blue and yet many, many tests have been conducted against cool-white, with cool-white being found to give superior plant growth, in most cases, than Gro-Lux lamps. So, if you manipulate the spectrum too much in a fluorescent lamp it costs money because it reduces the light output. So that is why I mention that high pressure sodium is probably the most efficient lamp to use for supplemental lighting.

RICHARD BUSH: My question is on tissue culture of Malling apple and Mazzard cherry rootstocks. What degree of virus testing has been done and what certification are you able to get?

DAVID DUNSTAN: The material that we place into culture is virus certified from the local plant quarantine station. All the techniques that we use in tissue culture are under sterile conditions — sterile manipulations. We get a plant quarantine certification at the end from the plant quarantine

officer provided he is assure of the cleanliness of all our facilities and all the techniques that we have used. He comes often to inspect our facilities and our growing on areas.

VEGETATIVE PROPAGATION TECHNIQUES — CURRENT IDEAS IN BRITAIN

A. BRUCE MacDONALD

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The last decade has seen many innovations in the production of hardy nursery stock within the British Isles, many of which have been directed to a number of aspects relating to plant propagation. The objective of this paper is to itemize some of the technical developments that have taken place within the last three years, in addition to those currently being used.

Before looking at some individual topics, it will first be helpful to summarize some of the current trends in British plant propagation:

(1) Nurseries specializing in individual crops, such as *Clematis*, are developing specialized growing systems — for example, liner production. This has been particularly noticeable with the formation of newer businesses and also in the rationalization that has occurred within some established companies.

(2) The production of crops if Britain that are traditionally imported from abroad, for example, rose rootstock and tree seedling rootstocks.

(3) Techniques to reduce fuel costs in propagation, which, in turn, have led in a number of instances to a simplification of plant propagation facilities.

(4) The use of polyethylene film for rooting cuttings in the winter as an alternative to mist propagation. Nurserymen have experienced problems with mist over the winter, in particular, due to excess water application leading to leaf drop on cuttings, increased fungal disease, and excess water in the rooting media.

(5) The interest by nurserymen in the growing of new plant introductions. This has been particularly evident in the plant lists of some of the more recent formulated nurseries.

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(5) The interest by nurserymen in the growing of new plant introductions. This has been particularly evident in the plant lists of some of the more recent formulated nurseries.

Blooms Nurseries of Bressingham, Norfolk, have introduced a number of new junipers from the United States, as well as producing phormiums from New Zealand. Also, Alan Thompson Nurseries at Windlesham, Surrey, are now offering a good range of the Darthuizer selection of shrubs from Holland. Hadlow College, in Kent, England, is collating and propagating up the different selections of *Kalmia latifolia* made by Richard Jaynes in Connecticut.

(6) The formation of a clonal selection scheme at Long Ashton Research Station, Bristol, for the major commercial lines grown by nurserymen.

(7) The emphasis on the correct siting and culture of stock plants.

(8) Tissue culture (micropropagation) has instigated a great deal of interest in the nursery trade, but it is not as well developed for ornamental woody plants as in North America. Its role has mainly been in research and for the growers of glasshouse crops.

(9) The importance placed on skills training in nurseries, which is assisted by a government-backed organization called the Agricultural Training Board. Also, educational establishments have provided more courses of a more specialized nature, catering to the different sectors of the horticultural industry, including the nursery stock grower.

(10) Mechanization and handling to streamline production systems, for example, greater emphasis to direct rooting and the importance of work organization. A recent project undertaken by the Ministry of Agriculture's Advisory Service (Extension Service) has been developed under the guidance of Brian Morgan in the preparation of softwood cuttings.

STOCK PLANTS

Siting and Planning. A number of production systems are dependent on the growing crop to provide the initial cutting material. The value of having a designated area in the nursery for stock plants is now fully appreciated by many nurserymen. The advantages of permanent stock plants have been well documented and include such practices as being able to "manipulate" stock plants by different pruning techniques to induce juvenility as an aid to rooting and also to provide a maximum number of well-graded cuttings from the minimum area. Careful selection and planning is necessary, otherwise time and space is wasted by overplanting with material that is easy to root, as they may be very prolific in producing large numbers of cuttings. At the other extreme, there may be the planting up of a low number of stock plants that do not fulfill

the requirements of the propagation program. The site of the stock plant area can be categorized as follows:

(1) Outdoor areas, ideally grown in the hedge system, where consideration has been given to shelter, soil improvements, and effective weed control prior to planting.

(2) Siting the stock plants under protection, for example, a structure clad by polyethylene or with a woven plastic material (shade cloth) providing between 40 and 60% shade. This system particularly interested me at Hadlow College in Kent where it was used for a wide range of woody plant material. We used it mainly for the high value deciduous shrubs, such as *Magnolia, Acer, Rhododendron, (azalea), Hamamelis, Fothergilla*, and *Corylopsis* for a number of reasons. It was found that cladding with woven plastic material was more advantageous than polyethylene. The great advantage of this system is that cutting material is available earlier in the season and one is able to collect it in the ideal condition over a longer period of time. The percentage rooting take is then improved and, in turn, one is able to improve the overwintering performance of the subsequent young plants by reducing losses.

Clonal Selections. In 1975 an important clonal selection scheme was initiated at Long Ashton Research Station, Bristol. This has received the full backing of the nursery trades associations in Britain (National Farmers Union/Horticultural Trades Association). Through grower meetings and the national press, nurserymen have been invited to submit material to the scheme for a list of plants being formulated by a committee. This committee is made up of nurserymen, research and extension workers, educationalists, botanic garden personnel, and plantsmen. The material submitted is examined by the committee during the growing year for such factors as trueness-to-name, habit, form, and plant health, together with ease of propagation. Plants selected from those submitted are bulked up and then released under a reference code, for example, LA 79 (Long Ashton 1979). Four plants that have now been released are *Cornus alba* 'Spaethii', *Daphne* 'Somerset', *Forsythia intermedia* 'Lynwood', and *Potentilla* 'Tangerine'. Considerable variation has been found in a number of plants assessed, for example, *Potentilla* 'Tangerine', *Cornus alba* 'Spaethii', *Virburnum farreri*, and *Philadelphus* 'Virginal'. However, on the other hand, little variation has been found in some plants and it has not warranted individual selection and subsquent bulking up, for example, *Hypericum* 'Hidecote'. For the future, the scheme plans to clonally assess some 100 different commercial lines over the next five years, including climbers, trees, shrubs, and conifers.

The Plant Introduction Scheme of the University of British Columbia Botanical Garden has negotiated to participate in the scheme and we shall be sending material this fall for their 1981-82 requirements. These include *Vitis coignetiae* and *Prunus laurocerasus* 'Otto Luyken'. In turn, it is planned that we shall receive the clonal selections from Britain and establish them in the Botanical Garden nursery. We then hope to include these selections in one of the scheme's objectives by collating and establishing improved and new clones of plants for distribution to the nursery trades within British Columbia.

An example of clonal assessment is seen by the work of David Whalley at the Glasshouse Crops Research Institute on a Leyland cypress, × *Cupressocyparis leylandii*. His studies have included assessments on rooting potential, growth rates, and field establishment of this important hedging plant. He showed that these are two clones (Clone 21 and Clone 121) that show definite improvement in rooting and growth rate compared with presently used clones (Clone 2 and Clone 11). Growth rates were evaluated and Clone 10 ('Naylors Blue') proved to be the slowest while Clone 122 was the fastest.

Pruning. Some major research directed towards the correct pruning of stock plants has been carried out at Efford Experimental Station by Margaret Scott. This work has been in progress for only a short period of time, but the results have shown a number of interesting observations; for example, spring and June pruning of *Virburnum* × *burkwoodii* are best for the production of high numbers of good quality cuttings for rooting in September/October. Records are being collected to provide information on the number of cuttings produced from a given number of stock plants as the years progress. We also carried out a number of pruning treatments in the stock plant area at Hadlow College and had some interesting results, particularly with *Garrya elliptica*, *Elaeagnus pungens* 'Maculata' and the dawn redwood, *Metasquoia glyptostroboides*.

PLANT PHYSIOLOGY

The Plant Propagation Department at East Malling Research Station, Kent, which has recently moved into new premises, is headed by Dr. Brian Howard. Examples of two lines of work that he and his colleagues are undertaking to increase knowledge on the internal mechanism of woody plants are:

(1) The preconditioning of shoots while still on the stock plants where etiolation has been induced, using black polyethylene structures, is being studied. These tents are placed over the hedges of stock plants prior to bud burst. This has been further developed by Margaret Scott for a wider range of

woody plants at Efford Experimental Station. This investigation will be particularly valuable to give one a further insight into the improvement of rooting of normally difficult-to-propagate plants.

(2) The influence of co-factors on the seasonal rooting of cuttings where current evidence suggests that the increase in bud activity in the spring does not directly influence the rooting of dormant woody cuttings.

Another example of research is plant physiology has been carried out by Dr. Keith Loach at the Glasshouse Crops Research Institute, Sussex. His work has been examining the problem in mist propagation that small water droplets have great difficulty in being directed to the underneath of the leaf lamina where the majority of stomata are sited. Thus, modifications in the environmental conditions to improve the situation would no doubt be beneficial to the plant propagator. He has indicated the value of providing a situation where cooler air is passed over and through the cuttings in a horizontal movement to reduce leaf temperatures. He has since recommended that this requires further examination as field research. He is also interested in environmental research to increase our knowledge of the interaction between carbohydrates, light, and the actual rooting process.

PLANT PROPAGATION FACILITIES — REDUCING FUEL COSTS

Some recommendations for reducing fuel costs have come from the work of Margaret Scott at Efford Experimental Horticultural Station in Hampshire. It can best be itemized under the following headings:

Polyethylene Film. The use of polyethylene film as an alternative to mist for winter rooting of cuttings was mentioned earlier in this paper. The reasons for this include problems related to excess water: a) producing saturation of the rooting compost, b) accentuating leaf drop, and c) increasing the incidence of fungal disease.

Expanded Polystyrene Sheets. Between 20 and 50% savings in fuel costs have been achieved by insulating the base, sides and ends of the propagation bed with expanded polystyrene sheets. The normal procedure is to wrap 2.5 cm thick sheets of polystyrene within polyethylene film. One trial in an unheated polyethylene structure to insulate a ground level bed with a base temperature of 18°C in March and April resulted in 30% saving in electricity consumption.

Duration of Basal Heat. Trials have been carried out to

provide basal heat at night time only, when off-peak electricity tariffs are available. Basal heat during the day is provided by natural solar radiation only. Subjects such as *Hebe* and *Choisya*, which are quick rooting, have shown little difference in the time taken to root; however, slower-rooting plants, such as *Camellia*, have required a further four weeks for rooting.

Electronic Temperature Controller. Generally rod thermostats are inefficient for two reasons. Firstly, they only record the basal temperature at one specific point within the propagation bed, and secondly, they can be quite varied in their response to a change in temperature. A system now being installed by some British nurserymen is an electronic temperature controller manufactured by Nobel Engineering, Worthing, Sussex. This is a system with 4 to 6 thermo-coupler sensors connected to one main controller. The required temperature is set on the main dial and the thermo-coupler sensors then provide an average reading over the bed at the depth at which the cutting is stuck. There is an easy readout system by which the average temperature of the bed can easily be seen. This equipment is very fast in recording a temperature drop, and also in bringing it up to the desired level. Inaccurate temperature control wastes energy and produces wide fluctuations in temperatures. Charles Tubesing, the Nursery Manager of the University of British Columbia Botanical Garden nursery, has two of these now installed and has found them very satisfactory so far.

Choice of Container for Rooting. The studies at Efford also included the assessment of the effectiveness of heat transfer to the rooting media using different types of containers. The results showed the importance of the container design and material in providing good contact between the rooting media container and the sand base beneath. For example, it was found that the temperature of an expanded polystyrene seed tray could only be raised with difficulty above 17.5°C, whereas 21°C was easily obtained using either a polypropylene seed tray or an expanded polystyrene cell unit tray.

Other Aspects. Work at Efford has evaluated the benefits of providing a thermal screen using a range of different materials. In fact, a total energy saving of 60% was achieved when beds were insulated with 2.5 cm expanded polystyrene sheets with the addition of an overhead thermal screen of aluminized polyester material.

The nurseryman has adapted these results for his own propagation requirements and facilities. For example, a recently established nursery at Broadhouse Farm, Droitwich, Worcestershire, has put the ideas into practice in their liner

production nursery. One of the leading nurseries in Britain, Notcutt's Nurseries, Woodbridge in Suffolk, has also adapted these results for their very ambitious new propagation unit, where basal heat from hot water is provided by panels that are joined end to end to cover the floor. These panels are covered by 5.0 cm thick polystyrene sheets wrapped in polyethylene, and capillary matting is then placed over the sheets. The cutting trays are laid on top of the matting itself. A mobile gantry system is installed over each of the propagation beds to make handling more efficient.

FIELD PROPAGATION

Layering. This reliable technique has been carefully reconsidered at a few nurseries, despite the large area of land it utilizes. An example is at Exbury Gardens Ltd. in Hampshire where the manager, Douglas Harris, has initiated new layer beds to produce a range of difficult-to-propagate rhododendrons, which are normally grafted or slow-to-produce, saleable plants from cuttings.

Due to the problem of specific replant disease *Thielaviopsis fasicola* and root gall *Agrobacterium* spp, combined with the introduction of the cherry rootstock, *Prunus* 'Colt', the traditional trench layering method for producing the 'F 12/1' selection of *Prunus avium* is quickly declining.

Rootstocks. The virtues of *Prunus* 'Colt', with its ability of being able to develop preformed root initials while still on the mother plant, have been well documented. Shade tree producers have shown interest in the more recent introduction by East Malling Research Station of *Prunus* 'Cob'. This is another selection from the *Prunus avium* and *Prunus pseudocerasus* hybrids developed by the Plant Breeding Department, which has greater vigour than *Prunus* 'Colt' and produces trees with good girth and straight stems.

Dr. Howard's department at East Malling is selecting clones of *Tilia* × *vulgaris* (Syn.: T. × *europaea*) and *Tilia cordata* for clonal propagation, based on rooting ability properties during the winter period. In addition, their compatibility characteristics are also being studied.

CHIP BUDDING

This old technique, used for many years in propagating grapes, and recently developed for fruit trees at East Malling Research Station by Dr. Howard, is now an established practice on commercial tree nurseries. Its advantages over shield or 'T' budding have been well documented in his publications. These advantages include the ability to bud over a longer

period of time to improve bud take, and so obtain a more even stand of trees with increased number of lateral shoots. More recently the technique has enabled tree growers to increase the number of subjects that may be field-budded, for example, *Gleditsia triacanthos* var. *Inermis* 'Sunburst', and *Betula alba* cultivars.

During a recent visit made by Dr. Howard to Vancouver, we discussed a new tie that East Malling and a commercial firm in Britain (Rapidex, Knutsford, Cheshire), have developed for chip budding. Initial trials suggest that the tie has sufficient strength to tie in firmly, and it also has the property of degrading within a period of 4 to 6 weeks from the time of budding. Polyethylene tape, the usual tie material, has to be removed. Thus, the major advantage of this new tie is that there is no need to remove it, thus saving on labour time.

The University of British Columbia Botanical Garden has commenced some joint training sessions with the BCNTA (British Columbia Nursery Trades Association), and one of the subjects dealt with has been chip budding. These courses have been held at nurseries in the Fraser Valley and some of the tree growers have been given these ties for assessment. It will be interesting to report back at a later date with the results.

CONCLUSIONS

The British Nursery Trades, like many other industries, have been suffering in the recession with high interest rates, high unemployment, and cutbacks in both private and public spending. The British nurseryman is resourceful and is now in a stronger position to adapt his growing techniques and market where necessary. From recent personal contacts, I am sure that the majority will come through this difficult period successfully.

MODERATOR GRAHAM HART: The next session is on the general subject of seedling production, with Jack Doty the first speaker:

SEEDLING PRODUCTION: *CEDRUS DEODARA*

JOHN C. DOTY

Viewcrest Nurseries, Inc.
Battle Ground, Washington 98604

Cedrus deodara and it's grafted cultivars, are well known for beauty and gracefulness. However, they can be a problem, especially at the seedling level.

Usually, every third year is an excellent seed crop, with a moderate to weak crop in the intervening years. Seed can be stored for up to three years if done properly. Most of our seed comes from Italy; but we do collect some locally when a good crop exists. Seedlings from local seed definitely are not as hardy.

Viable seed can usually be determined by a cut test. Greyish or off color radicals is an indication of bad seed. If this situation exists, a germination test is in order. They germinate quite readily on a wet paper towel on the windowsill.

Our first try at seedling growing over 20 years ago was to produce a two-year liner. At transplanting, mortality was high due to the poor root/top ratio and general sensitivity of the plant. It helps to prune branches and do little or no root pruning before transplanting.

The next approach to the problem was to try to produce a usable 1-year seedling. It is imperative to plant the seed as soon as frost danger is past. Seeds are broadcast, according to cut tests, general inspection of the seed, or a germination test, to produce a density of 30 to 40 seeds per square foot. We use a light sawdust mulch for uniform germination. Once conditions are right, germination will be fast. *Cedrus deodara* seeds *need no stratification, other than a two week chill period* which seems to speed germination.

Proper nutrients in the soil are important. We do not use slow-release nitrogen. A fast-release nitrogen is used so that we can control growth. Beds are fumigated with a combined mixture of 100 pounds of chloropicrin and 300 pounds of methyl bromide. We like to maintain a pH of 5.5.

Damping-off sometimes is a problem, which we control with routine fungicide sprays. We vary these from time to

time to minimize tolerance to the disease. *Fusarium* comes in the warmer months when the roots are down in the soil. Along with spraying, we try to keep the surface ½ inch of soil on the dry side and avoid plant stress.

When the seedlings are well established and summer temperatures are prevailing it is time for the big push. Now it is important to never stop growth. We constantly monitor soil moisture and have a routine foliar feeding schedule, where we now can control the nitrogen for later hardening-off. Water can be a problem in our area and we sometimes get rain in the early fall when we don't want it. So, we have to rely on other means to harden-off.

Our foliar feeding is continued into the fall with a mixture lacking nitrogen, to encourage bud set. Most of the nitrogen will have been leached out by irrigation and spring rains. Bear in mind that we try to extend our growing season to its fullest length and then use an accelerated program for hardening-off. Wrenching is another means by which we can further increase the dormancy factor. After the seedlings are beginning to go into dormancy, an undercutting blade is pulled through the beds, on or below the root tips, and at a slight angle. This disturbs the soil and sends the plants into further dormancy. Basically, what we are trying to do is to use all things at our disposal to slowly stress the seedlings to a dormant condition in preparation for lifting.

Lifting time is very important. We have found December 1, give or take two weeks to be the best for our area. I understand that there is no reliable test on conifers to determine dormancy. One needs to go back and monitor the temperature and conditions for the nursery. Even the record hot spell we had this year may have had a bearing on determining the optimum lifting time.

Keep in mind that the plants are not completely dormant at lifting time, but they are close, and will become dormant after storage. If we wait until after the first of the year, we are taking a chance on freeze damage.

Cedrus deodara seedlings definitely do not fall in the Zone 6 hardiness class, as does a mature plant. I can relate this to the big freeze we had some years back, when rhododendrons in the ground were killed, whereas the same cultivars that had been balled out earlier and subjected to the same conditions did not die. In other words they were shocked or stressed into dormancy.

It is important to minimize lifting to cooler time. We really do not want to stress the seedlings any more than we have to. Roots should be kept moist, but not overly wet. Tops are kept

dry at all times during processing, as well as while lifting. We like to pull the seedlings on a cloudy day; 20 minutes of exposure to the sun's rays is disastrous.

Storage brings up another problem. We used to root-wrap the seedlings in plastic. Latest indications are that a bare-root, loose pack, air circulated storage in polyethylene bags is the best, (and without too much moisture). *Botrytis* is our biggest enemy in storage. We used to dip the tops in fungicide but now we spray in the fields just prior to lifting. Storage temperatures are just above freezing. We have successfully stored *C. deodara* seedlings for three months by this method.

We feel it is very important that the customer know how to take care of the stock when he receives it — and to know when it is coming. Care instructions are enclosed for new customers, along with notification of the shipment.

A few months after shipping, we send a questionnaire to selected customers for comments. Returns are usually low, but they are effective. There always seems to be need for improvement.

Through the years, while working with *Cedrus deodara*, I think we have learned some basics which we can apply to our other seedlings, to a greater or lesser degree, depending upon the cultivar. They are:

1. Be in control of plant growth at all times.
2. Do not dig until ready.
3. Minimize shock at harvest time.
4. Instruct customers as to proper care after receiving the stock.
5. Give customers a chance to let you know if they have any problems.

DOUGLAS FIR CULTIVAR IMPROVEMENT PROGRAMS

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In British Columbia, where fifty cents in every dollar earned is said to come directly or indirectly from the forest industry, the raw materials for that industry, the trees on the hillsides, represent a truly enormous investment. Farmers and horticulturists have for centuries used both intensive management and genetic improvement to increase their yields, and foresters are now having to apply the same principles and

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techniques. Intensive management here means using all the tools that are available, which can include choice of the most suitable species, site preparation, control of spacing throughout the life of the crop, possibly fertilization, and use of the best available genetic material. Improvements in the latter will influence all the other techniques and while they must be seen as an integral part of intensive management, they may well be the most important one.

In B.C., about 10 million Douglas fir seedlings are planted each year on the coast and at any time there may be 20 million seedlings passing through the Ministry of Forests' Nurseries. As exploitation of the forests continues into the less accessible areas on the West Coast, species priorities will change. In 1980, for example, about 4.3 million cubic metres of Douglas fir were harvested on the coast while western hemlock at 9.5 million, represented the leading producer (1). However, predictions show that by 1995, 6 million Douglas fir seedlings will still be needed annually and, as the second growth stands established after the earliest logging are cut once more, the need for Douglas fir will increase again. A few percentage points of genetic improvement in product quality, volume production for a given site, or reduction in the time to reach a given size, can therefore have a great impact on the wood supply for the forest industry. These considerations have been used to justify investment in projects of cultivar enhancement within the species.

What is involved. In general terms, breed enhancement can be seen as the genetic manipulation of a chosen population through successive cycles where selection is followed by selective mating and the establishment of a new population in which further selections can be made. This is by no means the only option open to the breeder but it represents the most common and conservative approach. It can be applied to trees just as it has been to dairy cows or grain, but with such long-lived organisms there are differences which can help and hinder the process. Individual genotypes can be vegetatively propagated, maintained, and multiplied and, as many trees, including Douglas fir, are monoecious and produce large numbers of offspring; "litter-size" may be no problem and dam-sire relationships can provide greater flexibility of mating and testing designs.

Against this must be seen the problems of slow maturation giving long generation intervals and slow development periods which can amount to potentially poor juvenile-mature correlations. Scale and time are important considerations and no program can be designed and implemented overnight — history plays an important part. Techniques available later must be

incorporated and such changes can only be brought into a flexible program

All breeding and improvement programs must rely on the manipulation of the available genetic variation for the species and the environment of utilization The breeder has to decide which characteristics he would like to change, examine the economic impacts of such changes and examine the available traits and their inter-relationships. He can then work to move the population means for these characteristics in the desired direction. If the traits are strongly inherited and under simple genetic control, advance may be swift but for the more complex traits, slow but steady advances can be expected Disease resistance might be simply inherited, while growth-rate is more complex and may be harder to manipulate.

The Douglas Fir Program. Turning to the Douglas fir program, improvements in growth rate and form are the major goals, while disease resistance at present plays a smaller part on the coast. The root rots represent the most serious disease problem and genetic resistance to these has not yet been established Two levels of variation must be used. Douglas fir as a species extends from north of Fort St. James in Central B.C to Central Mexico, a range of over 30° of latitude, and even for a program restricted to the coastal form, raw material extends from Kemano to central California. With such a distribution, population variations can be expected. However, growth potential at any site for material from these parts of the range cannot easily be predicted. Estimates of inherent variation between populations can be looked at through isoenzyme analysis, but there is no safe substitute for field observation of performance over a number of years. These provenance tests, trials of population performance on a number of sites, should be established in advance of a breeding project, but even if the information appears later, it must be used to modify breeding strategies. Until it does become available, relatively conservative approaches to population variation are needed. In coastal Douglas fir, a major test was established in 1966 and this is now producing information For example, on a wide range of sites, material from western Washington and from the Johnstone Straits area on the north of Vancouver Island are presently outperforming local sources.

The breeding programs must then make use of the within-population variation at the individual tree level. Here, then, is an advantage in working with a native species and, as soon as reforestation by planting becomes a major enterprise, selection can start to bring about some genetic improvements. Following early studies of variation and of inbreeding, Dr. Alan Orr-Ewing started the plus tree selection program for coastal Doug-

las fir in 1957. He started to build up a collection of selected individuals which could be used for early seed production and for future breeding, testing, and reselection. At that time intensive phenotypic selection was chosen. Growth rate and form were the traits given most weight and, although the heritabilities were not known, an adequate relationship between phenotype and genotype was assumed.

Any tree breeding program must follow a similar series of steps. Trees must be selected in natural stands; these genotypes must be accumulated in a convenient location through vegetative propagation and, when cones and pollen appear, these individuals can be evaluated by progeny performance tests. The best individuals can be identified and new selections made. At best this is a slow process and problems can be relied upon to appear. In the Douglas fir program, problems of delayed graft incompatibility soon showed up and complicated the process. Early cone and pollen production was expected from grafted mature material, but the partial rejuvenation following grafting and the role of the environment had been underestimated and buds to produce the test generation were slow to appear. Rootstock research has done much to reduce the incompatibility problem (2,7) and cone stimulation techniques, both physical and biochemical, are also being developed to influence the latter problem (9).

For these reasons, the Douglas fir program between 1957-1966 consisted largely in the selection of trees from across the coastal range (using 100 percent visual cruising of good second-growth stands), collection of the material in the Forest Service Breeding Arboretum at Cowichan Lake and in the establishment of the first seed-producing orchards. A cooperative effort brought the forest companies and the University of British Columbia into the project. About 500 trees which were outstanding for form and volume growth were collected (3). Work on inbreeding and variation were continued as well as a major pioneering study by Dr. Orr-Ewing on wide inter-racial crossing (8), but it was not until the early 1970's that the present recurrent selection project could be started. As this project represents the present major effort in coastal Douglas fir cultivar enhancement in B.C., I will follow this approach.

By the early 1970's, reproductive buds were appearing on the grafts of the selected trees and a breeding program was designed to meet several specific objectives. The overall goal was to improve the form and growth rate of the planting stock for reforestation as quickly as possible but the program has to address more specific technical objectives. The most important of these is the production of pedigreed material for reselection following a conventional recurrent selection approach. With

the early lack of knowledge of heritabilities and the efficiency of field selection, provision of a more precise selection method to give rise to a second generation of material and increase gains, had to receive first priority. As a second objective, there was a need to study genetic relationships and values within the species and by controlling the mating patterns giving rise to the progenies, these two objectives could be met together. Provenance information was starting to appear but adaptability and, in particular, the flexibility of response of this material across the variable environment of coastal British Columbia, where the seed would be used, also needed to be looked at. The size and importance of genotype-by-environment interactions had to be examined and this meant the progenies should be tested widely. Some families can be expected to do well on a variety of sites, while others will have specific requirements and may only perform well on — say — the better growing sites. As a final objective some evaluation of the parent trees themselves was needed so that the first orchards could have the poor performers cut out, giving an intermediate level of gain.

With these specific objectives in mind, the decision was made to bring together a population of about 350 of the selected plus trees from coastal B.C. and from northern Washington in a rigid mating design. The disconnected, modified diallel design met these objectives (4). From that time, the main work of the coastal Douglas fir program has been devoted to making the crosses required by the design and planting and maintaining the progenies across the area where improved seed will eventually be used. This is time consuming, labour intensive and costly but there are now 77 test sites, mostly of about 3.5 ha, spread from Hope to Tahsis (5). As the seedlings grow and become established information will start to come in. Early indications can be useful but it will not be before the seedlings have been in the field for ten years that reliable information will make program decisions possible.

This project represents only one of a variety of options available to the breeder and, as it advances, its strengths and shortcomings become clearer. The strength lies in there now being over 200,000 seedlings of known parental origin scattered widely, whose relationships are covered through a balanced mating design and with an adequate, if not ideal, field test design. These seedlings will provide factual and precise information on which to make future breeding decisions. Some weaknesses lie in the inevitable restriction of the sample population and the way that population has been defined. More efficient designs could be used to meet smaller specific objectives — the single project approach is at best clumsy. It is,

however, fair to say that in 10 or 15 years time there should be some answers to the questions we now would like to ask and these should be reasonably reliable. At the same time there should have been some advance towards the goal of genetically improved seed for reforestation.

So far, the conservative approach has been looked at but, as this is a meeting of plant propagators. it would be shortsighted not to include a reference to the exciting possibilities for other approaches. There has been a session on tissue culture and, although we are still waiting for the techniques to be developed for Douglas fir, if and when mass propagation by tissue, cell, or organ culture become available, many new prospects are opened up These would not merely facilitate the more conventional approaches by perhaps by-passing graft incompatibility, but also would make new breeding strategies possible. It is important for the breeder to be aware of the state of these advances and be prepared both conceptually and in terms of material availability to take advantage of these developments.

In ten years time, quite different approaches to cultivar enhancement in forest trees may be possible but, in the mean time, the present project will produce information and steady improvement toward high yielding cultivars on which further work can be based.

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IMPROVING SEED GERMINATION IN *ABIES*

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Abstract. A procedure is described for drying stratified *Abies* seeds that allows stratified seeds to be safely stored and which promotes higher germination rates Seeds, dried to a moisture content of 35%, were stored for 12 months without losing the beneficial effect of stratification or without their viability being adversely affected After certain storage periods, germination of dried seeds was increased well above that in routinely stratified samples The use of this procedure in nurseries is discussed

Seeds of many north-temperate Coniferae plants germinate more rapidly, and sometimes more completely, following a cold-moist treatment period known as stratification (or pre-chilling) This treatment is designed to overcome germination blocks caused by internal seed dormancy mechanisms or poor germination conditions (7), the within-seeds processes that remove such blocks being collectively referred to as after-ripening (4). There are three main prerequisites for successful stratification· a) a moisture source to hydrate the seeds so that the necessary biochemical changes occur, b) near freezing temperatures that favor certain biochemical changes and morphological developments, but delay sprouting of individual seeds that have completed after-ripening, reduce microorganism activity, and prevent damage from respiratory overheating, and c) adequate aeration to allow respired carbon dioxide to escape and also to help minimize heat accumulation (4). To this should be added a fourth criterion, the correct period of treatment. This study concerned primarily the first and last of these factors.

In many forest tree nurseries, the method of stratification is usually some version of the so-called "naked stratification" technique described by Allen and Bientjes (1), in which seeds are soaked in water at room temperature. After hydrating for 1 to 2 days, excess water is drained off, and the seeds are placed in plastic bags and refrigerated at 1° to 5°C for periods of a few weeks to several months, depending on the species, before being sown. This treatment results in relatively high seed

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moisture levels (40% or more of fresh weight) and so differs from seed storage which, by definition, promotes seeds longevity, where moisture levels between 5% and 10% of fresh weight (as well as freezing or subfreezing temperatures) are required for most gymnosperm seeds (12). Whereas the role of moisture in seed storage and germination processes has been intensively studied and is well known, its effect in stratification is less well understood.

By design, stratification promotes germination. A few published reports have indicated that stratified seeds can be redried and stored at lower temperature (3,8,11), but the effect of the stratification treatment (germination stimulation) was lost, and dormancy reinduced, when moisture levels fell below 10%. Hellum (9) observed that repeated wetting and drying of *Picea glauca* (Moench) Voss seeds caused reductions in rate and amount of germination and in seedling dry weights. McLemore and Barnett (10) observed that dormancy was greatest in *Pinus taeda* L. seeds stored at 10% to 18% moisture, and was less at both higher and lower moisture contents, being least when seeds were stored above 20% moisture content.

Using a different approach, Danielson and Tanaka (5) found that stratified *Pinus ponderosa* Laws. seeds could be air-dried to a moisture content of approximately 26% and stored at 2°C for 9 months without losing the stratification effect. Stratified seeds of *Pseudotsuga menziesii* (Mirb.) Franco, air-dried to 37% moisture, could be stored only for 3 months, since germination occurred in the refrigerator during longer storage periods. In both species, stratified seeds that had not been air-dried germinated during the third month of storage because of their higher moisture levels (33% in *Pinus ponderosa*, 50% in *Pseudotsuga menziesii*). I was interested in determining if the seeds of other conifer species important in this region's reforestation programme could also be redried and stored after stratification. Research has concentrated on three *Abies* species — *A. amabilis* (Dougl.) Forbes, *A. grandis* (Dougl.) Lindl and *A. lasiocarpa* (Hook.) Nutt., although other tree species have also been investigated.

MATERIALS AND METHODS

Seeds of *Abies amabilis*, *A. grandis* and *A. lasiocarpa* were stratified, then redried to moisture levels of 35, 25 and 15% of fresh weight, and stored at 2°C for up to 12 months. A fourth moisture level, 45%, in undried stratified seeds, was also tested. The experimental procedure and seed sources have been described elsewhere (6).

Throughout this research, seeds were hydrated in distilled

water at room temperature for 2 days, drained, then refrigerated in plastic bags at 2°C for 4 weeks. This is similar to the stratification used for seedling production of true fir species in British Columbia nurseries Water uptake was regulated by the time of soaking, and actual moisture levels in the seeds during stratification varied between 40% and 60% fresh weight, according to seedlot.

A schematic procedure for drying stratified seeds is shown in Figure 1. Several standard-sized samples (usually 50 seeds, as used in the germination tests) are oven-dried at 105°C to constant weight (usually 24 h) to provide an average expression of the dry weight of a given number of seeds. This average expression is substituted in formula I (used to calculate moisture content percentage), which permits calculation of the fresh weight of a stratified, 50-seed sample at any given target moisture content (formula II = formula I transposed). In the laboratory, changes in fresh weight are monitored after the seeds have been uniformly exposed to the air in a thin layer spread on an absorbent surface. Repeated weighings, at progressively shorter intervals as the target fresh weight is approached, are made on at least 6 samples from random positions among the drying seeds. The same samples must be weighed each time. Provided all the seeds have been dried uniformly, when the average fresh weight of the monitor samples reaches the new fresh weight, all the seeds are rebagged, using fresh containers, and returned to the refrigerator in which they were stratified. Target moisture levels within ± 2.5% can be reached using this procedure

RESULTS AND DISCUSSION

The interactions between storage period and moisture level have been described by Edwards (6), who concluded that optimum germination in *A. grandis* occurred when seeds redried to 35% moisture content had been stored for 3 months (Figure 2). Four major effects were discerned:

a) Seeds dried to 35% germinated best for all storage periods, the differences at day 14 (upper set of bars) being statistically significant in almost all storage periods (Figure 2). These seeds stored well for 6 months, then germination began in the refrigerator Even after 12 months' storage, they germinated 75% to 80%, better than routinely stratified seeds that had been neither dried (45% moisture content) nor stored (0 weeks storage). Thus, seeds at 35% moisture content had retained the stratification effect throughout the longest period of storage.

b) In seeds dried to 35%, the difference between germination at day 14 (upper bars) and at day 28 (lower bars) de-

REDRYING PROCEDURE

- 8 - 10 SAMPLES OF 50 SEEDS EACH OVEN-DRIED TO CONSTANT WEIGHT
- CALCULATE AVERAGE DRY WEIGHT FOR A 50 - SEED SAMPLE
- USE AVERAGE DRY WEIGHT TO CALCULATE WHAT NEW FRESH WEIGHT MUST BE AT SPECIFIED MOISTURE CONTENT

i) SINCE M.C. % = $\frac{\text{FRESH WEIGHT (FW)} - \text{DRY WEIGHT (DW)}}{\text{FRESH WEIGHT (FW)}} \cdot 100$

ii) THEN NEW FW = $\frac{\text{AVERAGE DW X 100}}{\text{100 – SPECIFIED M.C.}}$

FOR EXAMPLE, SUPPOSE FW = 50 G AND DW = 40 G

$$\text{M.C. \%} = \frac{50 - 40}{50} \cdot 100 = \frac{10}{50} \cdot 100 = 20$$

WHAT MUST FW BE FOR M.C. % = 15 ?

$$\text{NEW FW} = \frac{40 \times 100}{100 - 15} = \frac{4000}{85} = 47.1 \text{ G}$$

$$\text{CHECK: M.C. \%} = \frac{FW - DW}{FW} \cdot 100 = \frac{47.1 - 40}{47.1} \cdot 100$$

$$= \frac{7.1}{47.1} \cdot 100 = 15.07\ \%$$

- AFTER STRATIFICATION, AIR-DRY SEEDS TO SPECIFIED M.C. % USING 5 - 6 50-SEED SAMPLES TO MONITOR DRYING
- RE-BAG SEEDS AND RETURN TO REFRIGERATOR (2^{o}C)
- STORE IN REFRIGERATOR FOR SPECIFIED PERIOD

Figure 1. An outline of the procedure used for drying stratified seeds to a known moisture level

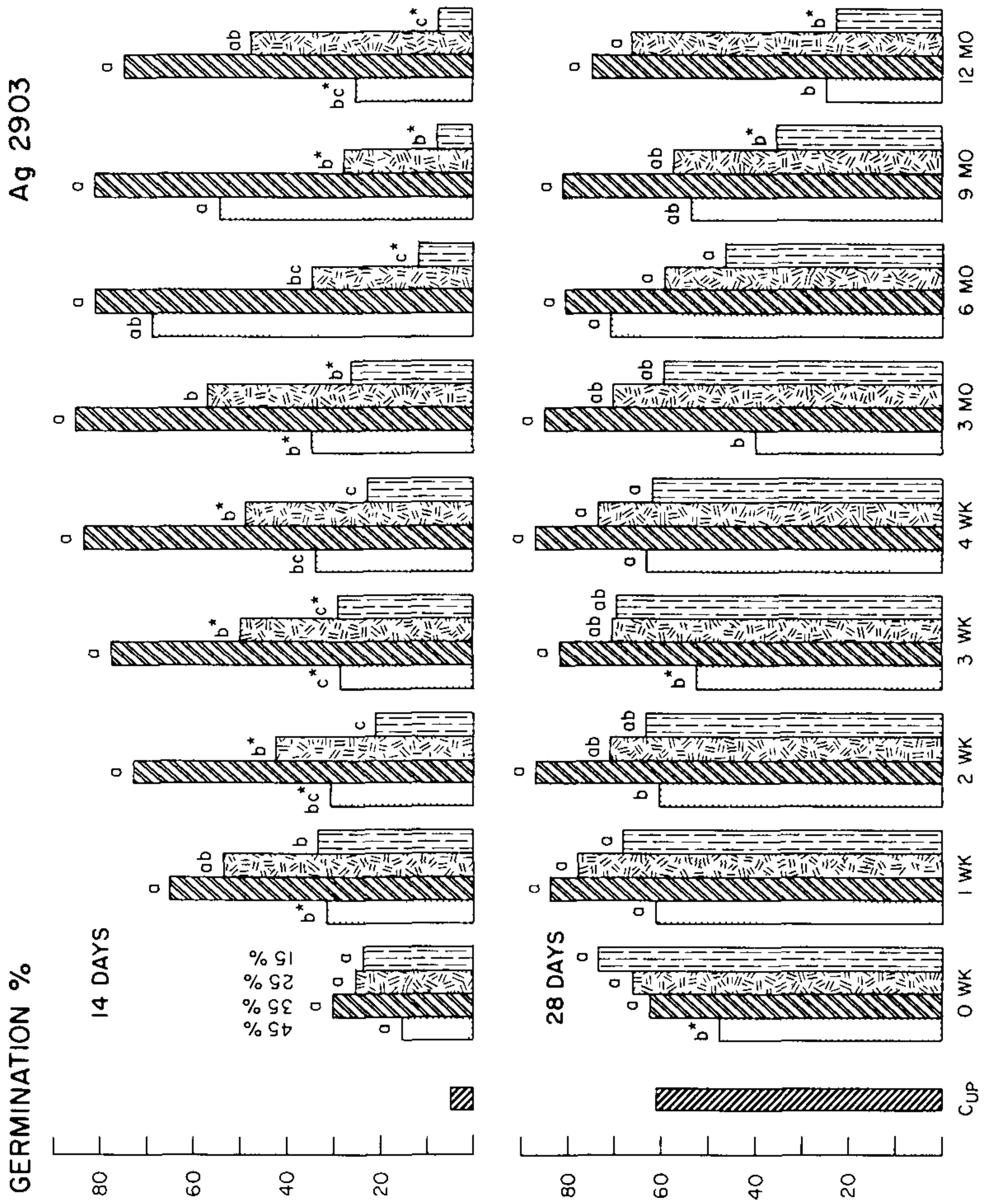

Figure 2. Effect of length of storage at 2°C and seed moisture content on germination rate (14 days), and on final germination percentage (28 days) of *Abies grandis* seeds that had been stratified for 4 weeks C_{UP} — unstratified sample Within each storage period, columns topped by the same letter represent germination means that were not significantly different (P = 0 05) An asterisk indicates P = 0 01

creased as storage period increased, until at 3 months' storage there was no difference. That is, all the germination that would occur had taken place within the first 2 weeks of the test (Figure 2). For some storage periods, germination was as complete as it would be by day 10

c) For seeds not dried (i.e., at 45% moisture content), germination fluctuated from one storage period to another, suggesting that moisture levels were also varying Variation between replications was also greatest at this moisture level. At 6 months' storage, non-dried seeds germinated relatively well, perhaps because these samples had lost some moisture.

d) Seeds at 15% moisture content germinated as well as or better than non-dried seeds through 3 months of storage, then their germinability decreased with longer storage periods (Figure 2). Tetrazolium staining showed that viability in ungerminated seeds at this moisture level remained high even after 12 months, so their apparent decline was likely due to the reimposition of dormancy. Ungerminated seeds at 45% moisture showed little staining activity after 12 months' storage, indicating that they were almost completely dead.

Redrying without additional storage immediately produced an increase in germination that persisted through the first 20 days of the germination test (Figure 3). Increases were larger the more the seeds had been dried, but the differences had almost disappeared by the end of the test. For seeds dried to 35% moisture and stored for 3 months, i) countable germinants (2) were obtained by day 5, at least 3 days earlier than without storage, ii) more than 80% had germinated by day 9, and iii) as already mentioned, germination was as complete as it would be by day 14, with 85% of the seeds sprouted (Figure 3).

An additional set of samples that had been newly stratified, but which had not been dried or stored, were germinated concurrently with seeds stored for 3 months Their final germination (approximately 65%) agreed closely with same treatment tested at the start of the experiment (Figure 3) In contrast, non-dried seeds stored for 3 months germinated less than 40%, demonstrating that storing seeds at high moisture level is detrimental to viability.

Seeds stored at 25% moisture germinated more slowly than those stored at 35%, reaching 70% at the end of the test (Figure 3). At 15% moisture, germination was rapid for the first few days, but fewer total germinants were produced than in the unstored control.

The greatest response to redrying and storage was ob-

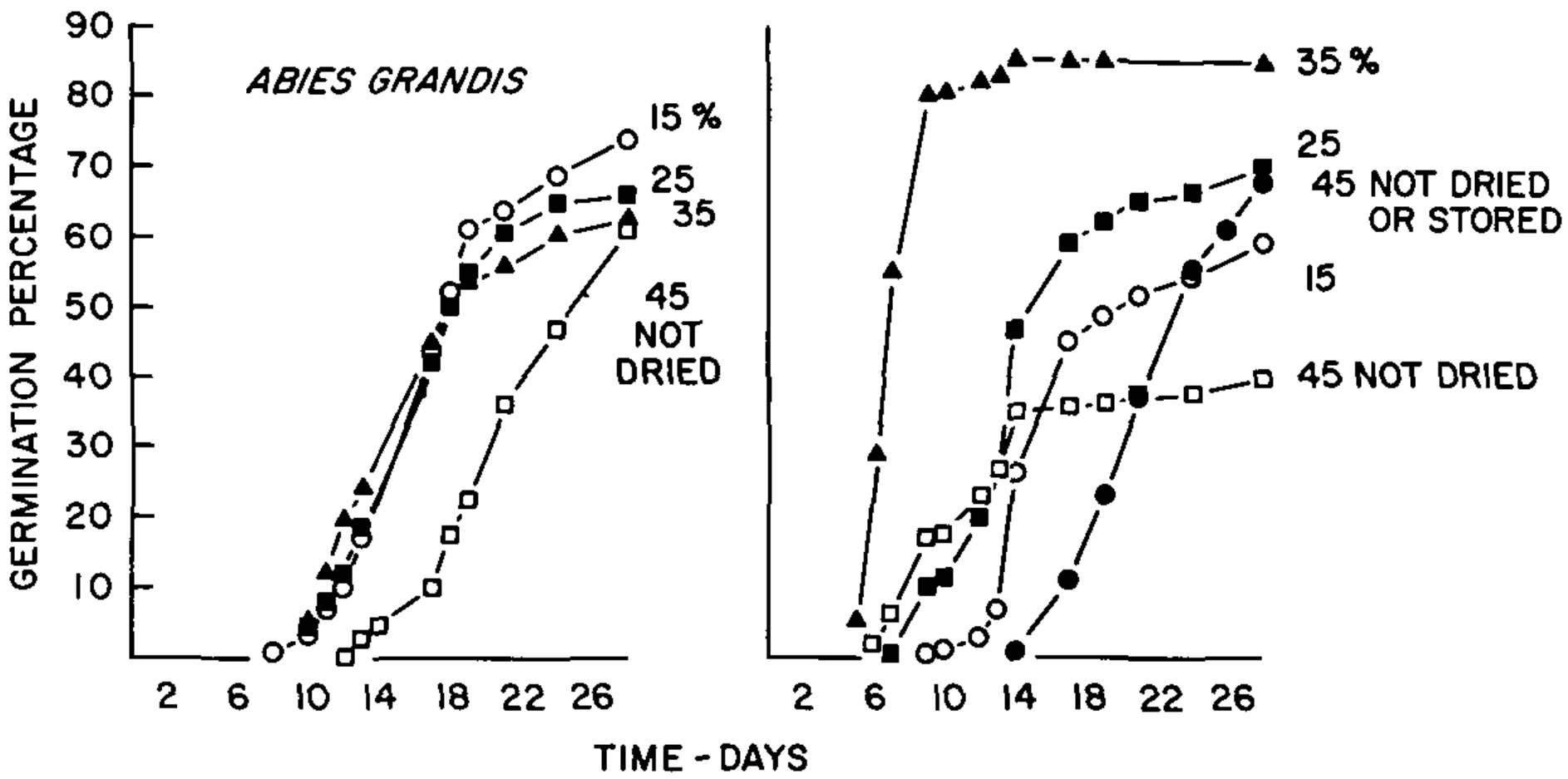

Figure 3. Cumulative germination during a 28-day test of stratified *Abies grandis* seeds following redrying to four moisture levels Seeds were tested immediately, without any storage (left) and retested after 12 weeks' storage at 2°C (right)

served in stratified *A. lasiocarpa* seeds that, until they had been stored for 3 months at 35% moisture, germinated less than 40% (Figure 4). With 3 months' storage, germination reached 70%, nearly 5 times that of a routinely stratified (no storage) sample, germination was as complete as it would be by the 14th day of the test. Optimum germination in this seedlot occurred following 6 months' storage at 35% moisture content. Seeds stored for 12 months at 35% and 25% moisture levels germinated over 60%, whereas non-dried seeds barely germinated when stored for 1 year.

All the results showed that not only is drying and storage of stratified seeds possible without losing the stratification effect, but that additional germination can also be obtained, especially in seeds dried to 35% moisture and stored for 3 months. To determine whether redrying stratified seeds to 35% moisture content followed by 3 months' storage would consistently improve germination of *Abies* seeds, this combination of treatments was applied to some 30 lots of *A. amabilis*[1]. Without fail, all seedlots responded by germinating faster and more completely than routinely stratified controls. Increases in final germination ranged from approximately 5% to over 45%[2]. To date, the treatment has been tested in the laboratory on

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[1] In collaboration with Dr C L Leadem, B C Ministry of Forests
[2] Edwards and Leadem, unpublished

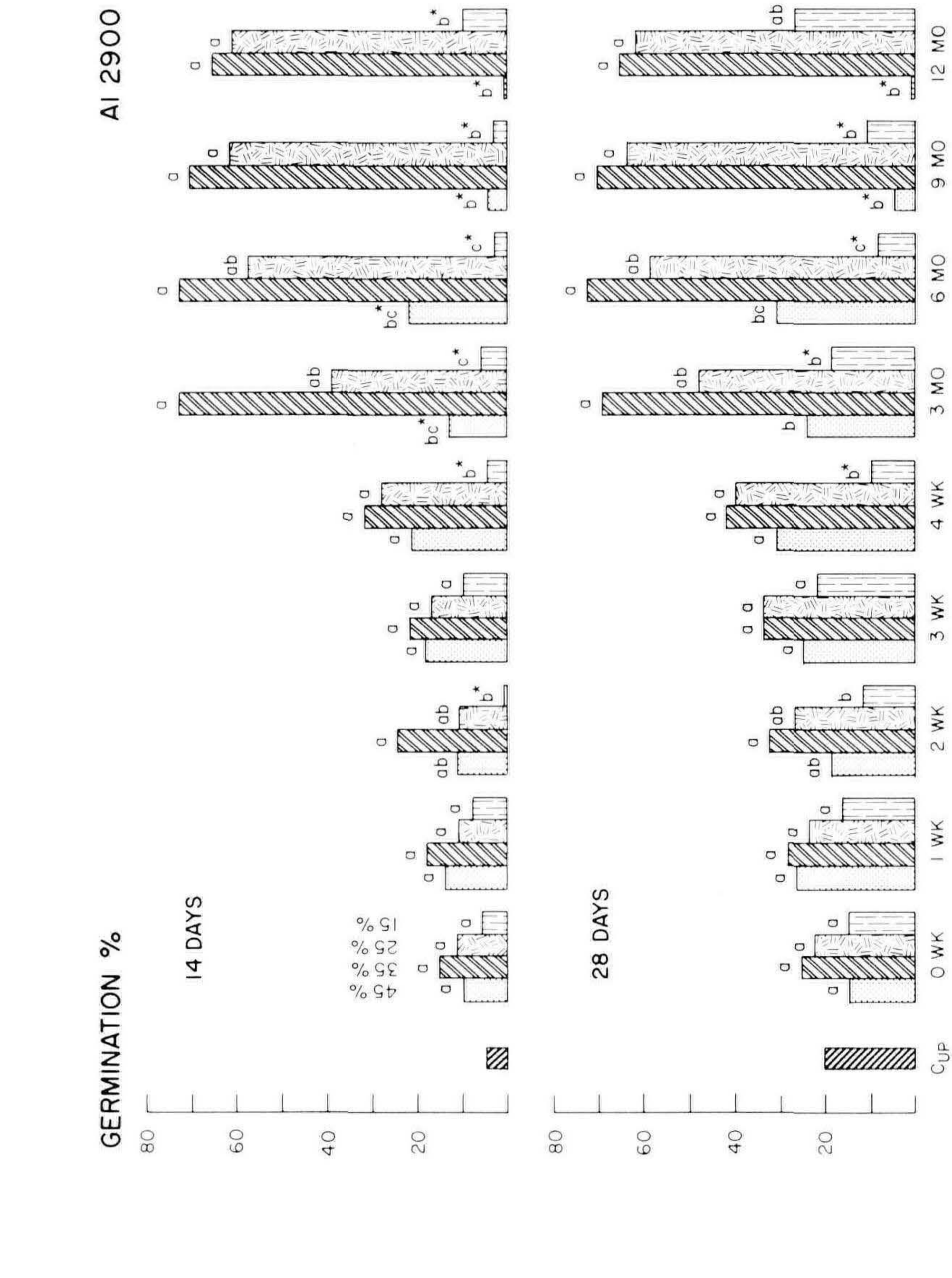

Figure 4. Effect of length of storage at 2°C, and of seed moisture content on germination rate (14 days) and final germination percentage (28 days) of *Abies lasiocarpa* seeds that had been stratified for 4 weeks. C_{UP} — unstratified sample. Within each storage period, columns topped by the same letter represent germination means that were not significantly different (P = 0.05). An asterisk indicates P = 0.01.

more than 50 lots of the three species native to British Columbia, as well as *A. procera* seeds, and germination has been increased in all instances. In local nursery trials, the treatment has not produced such consistent results, primarily because a new method of handling large quantities of seeds during the critical redrying step must be devised. Success, however, has been obtained elsewhere, notably with redried *A. procera* that germinated much better than routinely stratified seeds when sown under cold, wet conditions in the spring[3]. Seedling production was increased by 8 to 11% in two growing seasons.

When a suitable procedure for treating large quantities of seeds from numerous seedlots has been developed for nursery use, two practical implications need to be considered. First, stratification can begin well in advance of sowing date, and the seeds, after redrying, can be cold-stored for at least 6 months without losing the pretreatment effect or germinating in the refrigerator. Second, the sowing date becomes more flexible. Within the time limits identified, delays in sowing because of poor weather conditions, for example, can readily be tolerated. In effect, stratification could begin before sowing dates have been established.

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SEEDLING PRODUCTION IN THE EASTERN U.S.A.

RALPH SHUGERT
Zelenka Evergreen Nursery
Grand Haven, Michigan 49417

It is a distinct pleasure to share with you some seedling production techniques which I have observed, and indeed practiced, over the years. All of these observations will be geographically from Nebraska east to the Atlantic Ocean.

Assuming this is your first venture into the sexual propagation of plants, spend some time on researching the topic Every volume in the Proceedings of our Society gives us several articles on seed propagation. In Volume 29, there were two splendid articles, one by Tom Wood (3) (GB & I Region) and one by Hugh Steavenson (2) (Eastern Region), both presented at the Western Region meeting in 1979 at Sacramento, California.

One can go back to the first meeting of the Society in 1951, and read Dick Fillmore's (1) words on this topic After a review of IPPS papers, then purchase this book. "Seeds Of Woody Plants In The United States," Agriculture Handbook #450, Supt. of Documents, US Printing Office, Washington, DC 20402 (cost $13.60). This book covers seed data of 188 genera and is the true epitome of seeding procedure and information. After reading this book, you will be asking questions of your fellow propagators. At any of the IPPS Regional meetings, all program chairmen allow time for any questions — on any plant propagation topic. I also hasten to add, please remember the old adage that there are NO dumb questions! Sometimes the answers leave much to be desired, but never be embarrassed in asking questions. One final comment before we discuss some specific fundamentals — please keep records on all practices This information will be very valuable in future years. You can note, on this form, data pertaining to seed source, cost, amount sown, cutting test/percentage, density sown, seedling count, and size (as 1-0). You cannot have too

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much recorded data in your files; record tracking is very, very important.

In the time remaining, I would like to cover some basic prerequisites that should assist in producing fine quality seedlings, and they are as follows:

Seed Source. The important factor is to locate as many private collectors as possible Unfortunately, they are a vanishing breed of people, but there are a few remaining. You must know the source — geographic origin — of the seed you are sowing. For example, *Acer rubrum* ranges from the Canadian/U.S. border southward to Texas. Genetically, the seedlings produced from Florida mother-trees and those from Maine mother-trees are very similar, but they most certainly do not grow the same! You shall see the difference in the two seed lots by growth rate, time of fall color, winter hardiness, etc. I have often felt that the incompatibility problems with this species are seed-source related. For an acceptable source of seed, collect locally or use private collectors.

Seed Handling. Most seed you shall be sowing will benefit from fall seeding, with just a few exceptions. With most species, fall sowing allows the seed embryo to experience warm fall soil conditions, a cold winter, and germination in the spring. Unfortunately, we have seeds which offer a complexity of characteristics: seedcoat dormancy (impermeable seedcoat) as found in *Cercis, Gledistia, Robinia,* etc.; immature embryo dormancy, as found in *Cotoneaster, Tilia,* etc. The knowledge and understanding of stratification and scarification is very important to achieve economic seed bed stands. Included under the broad topic of seed handling is seed storage. The perfect conditions would be storage controls set at 34 to 36°F with 20 to 30 percent relative humidity. With proper storage conditions, you can have a back-up of one year's seed supply, which is very comforting during a seed crop failure year.

Seed Bed Preparation. Prior to the actual preparation of the seedbeds themselves is the very careful consideration of site location. Our industry has suffered countless lost dollars due to seedlings being completely destroyed due to "frost pocket" sites. The soil itself is of primary importance, and due to the intense culture of a high plant population per acre, utmost consideration has to be devoted to soil building and fertilization. I urge all of you starting, or perpetuating, a seedling production program to give much thought to organic's. This concept of green cover-crop plow-down and liberal manuring could well be the difference in harvesting your crop as a 1-0 or 2-0. The financial benefits of a 1-0 are quite obvious. The final step in bed preparation is to work the soil properly

and establish the proper grade to assure drainage. I caution you to spend some time with this function, and save money down the line. Seedlings do not grow well with "wet feet" — in fact, they well could, and do, perish.

Seed Bed Sowing. Your choice in sowing seed is basically two-fold; you can either drill or broadcast. Your decision (or the decision dictated to you) will be based entirely on soil type. In the lovely Platte River Valley of Nebraska, drilled seed is ideal Conversely, in the beautiful first row of hills adjacent to the Mississippi River, flood plain (in northeast Missouri) you broadcast because of soil crusting. With either condition, all seed beds should be mulch covered. The material used as mulch can run the gamut from bark-sawdust mulch, to sand, to oat straw. Use the material easily available in your area to be cost effective. Your seed bed density is extremely critical. To wit. If you are new to seed propagation, and your employer instructs you to produce *Pyrus calleryana* seedlings for understock *only*, your seed bed density is at a much different sowing rate that for a normal 1-0 seedling crop. Few propagators realize that proper seed bed population is mandatory to produce the plant size desired. The plant propagator must have direction from management to yield 25 seedlings per square foot, or 10 plants per square foot. Always remember that plants per square foot are determined by the seeding rate only — thinning of beds is not only expensive, but generally very impractical.

Seed Bed Maintenance. In my opinion, the most critical seed bed maintenance period is thirty days after germination. The one single thought on the seedling propagator's mind in April/May is the possibility of a late spring freeze. We are all a bit more knowledgeable now, and many seedling growers have installed solid-set irrigation systems which is an insurance policy for late freezes, and for irrigation during the growing season.

Other normal cultural seed bed practices would include fertilization and weed control. Your fertility program has to be predicated upon soil samples analysis. In this light, might I suggest that you retain a laboratory that specializes in nursery clients as opposed to the local grain elevator who will send your soil sample into a lab who will give you the information for growing 150 bu/acre corn! That certainly is not applicable to growing *Taxus cuspidata* (Syn.: *T. cuspidata* 'Capitata') seedlings! You have a valuable tool in controlling weeds by the proper usage of herbicides, but be careful! Hand weeding costs in seed beds can be horrendous — miscalculation of herbicide application can be failure! If you are inexperienced in the

herbicide product, please test prior to blanket application One traumatic experience you do not need, are seedlings killed by herbicides. A very safe product for grass control is Dacthal (75W) applied at the rate of 16 lbs/AIA every 30 days after the first "true" leaves are formed. Finally pest and disease control are best managed by a preventive program. After an insect, such as leaf hopper or spider mite, has infested your seed beds the damage is done Preventative spray is an excellent insurance policy.

The preceding words hopefully pointed out a few of the challenges of the sexual propagation of woody ornamentals. I can definitely assure you that the fruits of your labor shall be rewarding. Speaking, of course, for myself there is no greater exhilarating experience than evaluating germinating seedlings to herald in another season. Yes, you shall err, but don't make the same mistake twice — profit from the mistake!

Our nursery community has plenty of room for good, competent, seedling propagators. The personal satisfaction you receive in walking uniform vigorous-growing seed beds is truly unequaled. You will experience a tremendous feeling of personal satisfaction, and deep gratification in knowing you have done your job in a competent manner. Henry David Thoreau said it well with the words, "In this fresh evening, each blade and leaf looks as if it had been dipped in an icy liquid greenness. Let eyes that ache come here and look. . ." The challenge of seedling propagation is one of exhilaration. I trust that many of you shall have the opportunity to meet the challenge, and if it turns out to be sublime to know it by experience

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MODERATOR HART: Now, are there any questions for our panel on seedling production?

VOICE: Question for Chris Heaman. Do you do any testing or enhancement of the seed clones on your Douglas fir? Once having selected some of these do you do any testing with them — or anything else? What I am trying to get at is — it is orchardism in the wild. You are selecting only a few plantings. How about a bad disease attack? You may be in trouble then.

CHRIS HEAMAN: We hope to keep a broad enough base to look out for that. We don't want a narrow genetic base; we want to keep a broad base. Douglas fir has a lot of variation present We haven't had any major diseases so far, but we hope we have a broad enough genetic base to buffer us if we do suddenly get into disease problems. That is what we are concerned about all the time, keeping our genetic base large enough, although it is all right to have a narrow base in certain areas In the southeast U.S. they have planted entire plantations from a single seed origin. That's fine to invest in a small area, but you don't want to invest that way in a large area.

AL NEWCOMB: Ralph Shugert — What do you feel about grading seeds for size?

RALPH SHUGERT. My only experience in grading for size is when I was drilling through a Planet, Jr. Then size is very, very important. In my broadcasting of seeds — mostly ornamentals — seed size, as long as the cut test told me what density I want to sow, was immaterial. But I do know, getting back to the records, if you set the plate in a Planet, Jr., let's say 32 for *Prunus tomentosa*, then next year you have a guide to go buy, but you must check that plate because you might then need a plate 34 or 36. My experience has been, particularly in the *Prunus*, that seed size will vary every year.

JOHN HART. Question for Chris Heaman. I was involved for quite a while in a breeding program in Michigan. We found that there wasn't a real good juvenile-adult correlation because since you are growing in a container, competition is a lot different in this soil medium where the natural environment is lacking. What have you found along those lines?

CHRIS HEAMAN: We are certainly not too happy about using any juvenile assessments of our tree's performance. We are looking at field performance for growth; we are talking about getting 10 year's data in the field when the trees are about 10-to-15 feet high. We are not making assessments in the nursery.

JOHN HART. Do you also do nursery trials from seed to help avoid any kind of dominance effect? If two seedlings are grown in a greenhouse and one has already taken off, then when it is planted it is going to keep a certain increment above the other one and remain taller.

CHRIS HEAMAN: Well, this is why we are waiting to 15 years for assessments to get away from such effects. We do not have very good information yet on how long that sort of a nursery effect lasts. But it is certainly a thing we need to look

at, I agree We don't want to jump to conclusions on common effects, or nursery effects, or non-genetic effects.

VOICE: Question for George Edwards. Last year we had a number of seedlots of *Abies concolor* where any stratification would reduce the germination percentage quite a bit. Did you see such a variation in your studies from crop year to crop year?

GEORGE EDWARDS: Not with *Abies* although that kind of response has been reported in other species — in the East, particularly. In red pine and white spruce, I have noticed that stratification will — this is talking about collections from individual trees — behave this way If you have four individual trees, tree A one year may respond well to stratification — that is, you get better germination but the following year seeds from that tree may not respond. Other trees will reverse their status, but some trees continue to maintain a good yearly response to stratification. Dormancy, using the term dormancy very loosely, does vary from one crop year to another. In terms of *Abies concolor*, you are talking about stratification bringing down the germination percentage. We have noticed that in a number of our seed lots Stratification tends, as I mentioned earlier, to boost early germination. So the germination curve takes off in a hurry. But then it suddenly levels out — you don't get any further germination. So, a month or two months after you sow the seeds, you have actually fewer seedlings produced than from the unstratified seed I am not sure there is a single or a simple answer to that situation. It has been related to disease — it could be physiological, but we don't understand it.

MODERATOR DOUG CHRISTIE: I would now like to introduce the next panel, speaking on the general subject of container production.

WEED CONTROL IN NURSERY CONTAINERS

GEORGE F. RYAN
Washington State University
Western Washington Research and Extension Center
Puyallup, Washington 98371

Several herbicides are available for use in nursery containers. Each one differs from the others in the weed spectrum it controls, the way it behaves in the container growing medium, and its tolerance by nursery plants.

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One of the most useful of the chemicals now available is oxadiazon (Ronstar or Ornamental Herbicide I). It controls a broad spectrum of annual grass and broadleaf weeds, including bittercress (*Cardamine oligosperma*) which has been a hard weed to control either by hand or with chemicals. Oxadiazon is available only in granular formulations that should be applied when nursery stock foliage is dry to avoid leaf burn. The granules should be washed off thoroughly with irrigation before the foliage becomes wet with dew or light rain.

Control of annual grasses and some broadleaf weeds will be strengthened if oxadiazon is supplemented with napropamide (Devrinol) or oryzalin (Surflan). Common chickweed and mouseear chickweed, in particular, are not controlled by oxadiazon

Another weed that oxadiazon does not control is birdseye pearlwort (*Sagina procumbens*), which has become a serious problem in containers during the past few years. Birdseye pearlwort is a compact mat-forming plant with linear leaves and numerous small greenish blossoms. It is closely related and somewhat similar in appearance to some of the *Sagina* and *Arenaria* species that are sold as Irish moss for use in rock gardens. Inadvertent propagation and sale of the weed species as Irish moss should be carefully avoided.

Our trials in 1980 showed that oryzalin controlled all three weeds, mouseear chickweed, common chickweed and pearlwort Napropamide (10G) controlled mouseear chickweed and partially controlled common chickweed, but failed to control pearlwort Nurserymen have reported control of pearlwort with napropamide Our research on controlling this weed is continuing.

Both napropamide and oryzalin are tolerated by a wide range of woody ornamental plants in containers. They are particularly effective against annual grasses but also control a number of broadleaf weeds including pigweeds, lambsquarters and purslane. Oryzalin also controls oxalis, and napropamide partially controls common groundsel. Neither of these herbicides should be applied in combination with oxadiazon more often than once every 3 months.

A herbicide recently registered for use in dormant conifers is oxyfluorfen (Goal). It is especially useful because it controls common groundsel, preemergence or even after it is 3 to 4 inches tall. Goal should be used only on the conifers listed on the label, before growth starts in the spring or after the new growth hardens off.

Another herbicide for use on holly and juniper species in containers is the granular formulation of alachlor (Lasso II) It

controls annual grasses and some of the same broadleaf weeds that are controlled by oryzalin and napropamide. As with oxadiazon it should not be applied to wet foliage and the granules should be washed off within a short time after application

Other herbicides such as DCPA (Dacthal), diphenamid (Enide), and pronamide (Kerb), though not registered specifically for use in containers, are tolerated by a wide range of ornamentals. They control annual grasses and some kinds of broadleaf weeds, including the chickweeds, and may have potential for use in combination with oxadiazon

All of these herbicides are primarily for preemergence application to control weeds as they germinate or emerge from the soil. Oxyfluorfen does give some postemergence activity but its most efficient use is as a preemergence herbicide. Pronamide controls established perennial grasses and also controls grasses preemergence. Research continues on control of weeds after emergence, particularly on the pearlwort problem.

The use of herbicides should be combined with whatever hand weeding is necessary to control weeds which escape the treatments, and a general program of maintaining the nursery as free of weeds as possible will help to reduce contamination of the containers with weed seed

If a soil mix contains weed seed, fumigation or heat treatment will eliminate much of the weed problem initially. With an unfumigated mix containing weed seed, herbicides should be applied as soon as possible after transplanting and settling of the medium in the container. Even a container that starts out free of weed seeds will be contaminated by wind-blown seed within a few weeks, and herbicides should be applied in anticipation of the problem before germination and weed emergence starts.

USE OF OSMOCOTE IN CONTAINER GROWING

BEVERLEY R. GREENWELL[1]
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The base of a soil mix is very important in successful container growing The mix needs to have a high water holding capacity, with sufficient porosity to give rapid drainage

[1] Nursery Specialist, B C Ministry of Agriculture and Foods

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and aeration. It also needs to be retentive of nutrients and free of weeds, insects and diseases. Soil based mixes, in our climate, are generally poor

The weather in the southwest corner of British Columbia is very wet in fall, winter and spring but we can usually expect a long stretch of hot, dry, weather during the summer. With this weather pattern in mind — we must steer clear of any mixes containing soil; they are just too heavy to withstand our three seasons of monsoons Our mix MUST drain freely and the beds underneath the containers must also drain freely.

The mainstay of our mix is a sawdust:peat mixture in 3:1 proportions Some growers add about 10% sand. Hemlock or fir sawdust is generally used, as it is the most readily available and the least expensive of the common wood waste material. Bark or bark.peat mixes are beginning to be used, but are more expensive than sawdust. Either materials have been doing an equally good job in our trials.

More and more of the logs being used for lumber are being brought down to the coast for sawing, resulting in salty sawdust when cut. Growers must be careful to order sawdust produced from logs taken from inland sources. Many sawdust truck drivers have purchased their own salt meters to test their loads before delivery.

The sawdust:peat mixes do not hold nutrients well. This is one of its major drawbacks. Soluble fertilizers leach readily causing plant starvation during wet periods. A total liquid feeding program is not desirable nor recommended for our area. We have found that slow-release fertilizers, such as Osmocote, are mandatory for our container growing. Because we are using sawdust — a material no one else uses, trials are being carried out to establish the best rates and formulations of fertilizers to use in our mix.

Trials Results.

In 1979 we established plots of *Rhododendron*, *Thuja occidentalis* 'Smaragd', *Cornus* 'Elegantissma' (= *C. alba* 'Argenteo — marginata'?), and *Prunus cistena*, with Osmocote 18-6-12 at 8, 10 and 12 lbs; Osmocote 19-6-10 +Fe (Sierrablen) at 8, 10 and 12 lbs, and Osmocote 18-5-11 (14 mo) at 12, 14 and 18 lbs. per cu. yd. We also compared the use of our locally developed and used Saanichton Minor elements with Fritted Trace elements and Micromax. Of the 13 different treatments, Osmocote 18-6-12 at 10 lbs/yd^3 seemed to work the best in producing quality plants with good coloring and branching. From this trial we came to some conclusions:

1) none of the Osmocote formulations or rates provided

enough fertilizer to last an entire season without top-dressing.

2) Fertilizer is available to plants immediately at potting, making additional soluble fertilizer unnecessary or even undesirable in the mix.
3) Osmocote 18-6-12 (9 mo) at 8 lbs/yd, the standard rate at that time, was too low and did much better at 10 lbs, if careful watering was practiced.
4) Micromax did not significantly increase growth or quality of plants unless the Osmocote rate was also increased

In 1980 expanded trials increased rates of both Osmocote and minor elements. The color of *Rhododendron* (azalea), 'Mothers Day', was significantly increased with Osmocote 18-6-12 at 12 lbs/yd^3 and with the use of Micromax. *Thuja occidentalis*. 'Pyramidalis' and *T. occidentalis* 'Smaagd' color was better with all rates of 18-6-12 than with 17-7-12 (14 mo). Topdressing was required in all treatments

A trial using composted bark, where the suppliers were suggesting that no additional nutrients were required, showed that a complete addition was necessary. Growth in the bark mix was similar to sawdust and peat when all essential nutrients were added, that is lime, superphosphate, minor elements and Osmocote.

In topdressing trials, Osmocote 18-6-12 (9 mo) at 1 level tbsp/gal did a better job than 14-14-14 or 19-6-10 +Fe (Sierrablen). Also 18-5-11 (14 mo) at 1 hpg tbsp/gal did well as a topdressing.

In 1981 trials so far, all treatments are looking the same. We are trying the 17-7-10 (14 mo) this year, at some very high rates.

CONCLUSIONS

1 Osmocote 18-6-12 (9 mo) at 10-12 lbs/yd is good for most species. We have not had good results with 18-5-11 or 17-7-10 (14 mo), even at high rates.
2. Topdressing will be required in mid-summer after spring potting. The end of July seems to be the best time.
3 Winter feeding is suggested *after* the onset of dormancy Plants are always more hardy when they are growing with good nutritional status. (*Word of Warning*. Osmocote *does* release during winter in plastic shelter houses. A heavy watering to leach salt buildup during winter, once/month, will prevent salt damage.)

4. Micromax has worked especially well when used with Osmocote at high rates.

FOLIAR NUTRITION OF LANDSCAPE PLANTS

H.B. TUKEY, JR.

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Above-ground part plants — leaves, stems, branches and flowers — can absorb nutrients, pesticides and growth regulators from sprays. For almost seventy years, growers of commercial crops have used foliar sprays of nutrients to control minor element deficiencies in fruit plantings. Today, there is renewed interest in foliar nutrition due to increased cost of fertilizer, environmental concerns about nutrient applications to soil which may be carried into ground water supplies, and better knowledge of the plants that we grow. The main advantages of foliar nutrition, as compared to root applications, are (a) more rapid and (b) more efficient absorption of nutrients (3). To utilize these advantages, we must know the growth patterns of plants and when to apply nutrients for best effect

Several environmental factors affect foliar absorption. For example, an increase in temperature increases foliar uptake due, in part, to an effect on processes of penetration. In addition, there is a great influence of temperature on the structure of the plant which in turn greatly affects foliar absorption (4). The outermost layer of the cuticle on the leaves of most plants is composed of epicuticular waxes. These waxes, such as the bluish bloom on cabbage leaves, grapes, and apples, are exuded onto the surface of leaves in regular patterns. In tests where plants were grown at warm temperatures at relatively high light intensities, factors which favor foliar absorption, the epicuticular waxes were arranged in an upright fashion and did not cover the leaf surface completely, leaving small openings to the leaf surface below. In contrast, in plants grown at low temperatures and relatively low light intensities, the waxes were arranged as smaller or densely packed platelets which did not allow contact with the cell surface beneath. Thus, it would seem that the effect of light and temperature is indirect, affecting epicuticular waxes which, in turn, influences contact between the treating solution and the cell surfaces beneath.

The pH of the nutrient solution applied to plants also influences foliar uptake (3); pH affects the form of the nutrient and its ability to hold water which allows a longer time period

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The pH of the nutrient solution applied to plants also influences foliar uptake (3); pH affects the form of the nutrient and its ability to hold water which allows a longer time period

for absorption to take place For example, in the case of potassium phosphate, a common form of phosphorus to apply to foliage, at pH 3 to 6, monobasic phosphate ($H_2PO_4^-$) predominates which does not hold water well and is not easily absorbed. In contrast, at pH 7 and above, dibasic phosphate ($HPO_4^=$) predominates, which holds water and is easily absorbed. Thus, the effect of pH is an indirect one and, except at very low pH, such as 2 or 3, which causes severe injury to leaves, does not influence penetration itself.

As the relative humidity increases, foliar absorption also increases due in great part to improved retention of water, allowing nutrients to remain in solution. Although the cuticle is the primary barrier to penetration of foliar-applied substances, the thickness of the cuticle is not a good measure of the ability of a plant to absorb nutrients. Rather, it is the nature of substances in the cuticle and environmental factors which affect the development of the epicuticular waxes. Thus, the effect of most environmental factors such as pH, light, temperature, and relative humidity is indirect, affecting the plant and the substances in solution rather than the processes of absorption.

A great number of horticultural plants can absorb nutrients from foliar sprays with improved growth. For example, during propagation, herbaceous and softwood cuttings, which grow during propagation, absorb large amounts of foliar applied nutrients and make greater amounts of growth both during and after propagation than cuttings which have not received nutrients (5). In contrast, hardwood cuttings which do not grow during propagation may absorb nutrients, but there is little effect of the nutrients on growth Foliar applied nutrients to ground covers such as pacysandra and English ivy produced much heavier plants three months following propagation than plants that had received no nutrients or slow-release nutrients in the root medium (2). For continued growth, a combination of root-applied and foliar-applied nutrients produced the largest, heaviest plants. Similar results were obtained with other rapidly growing plants such as privet and some floriculture crops.

However, some plants do not respond favorably to foliar nutrition. Surprisingly, some species of juniper are injured by foliar applications (2). Despite the injury, nutrients were absorbed and, after treatment, plants recovered quickly and grew well. Azaleas are very sensitive to nutrition and require only small amounts of nutrients during growth. A diversity of azalea cultivars was badly injured by even small quantities of

nutrients in foliar sprays, which caused defoliation and greatly suppressed rooting (1).

Today, there is much research directed toward finding the pathway by which foliar-applied substances move through the cuticle into the leaves beneath. Use of specific strains and electronmicroscopy has demonstrated the presence of structures which extend from epidermal cells up into the cuticle. The nature of these strands has not been determined conclusively, but it has been suggested that they are pectinatious materials which could offer a pathway by which substances in solution could pass from the outer leaf surface into the interior of leaves.

These results demonstrate that horticultural plants can absorb nutrients from sprays to the foliage. Foliar nutrition is an effective method of getting nutrients into plants and offers another management technique for progressive producers of plants. Today, foliar nutrition has been or is being investigated for use with fruit and vegetable crops, forestry plantings, agronomic crops such as soybeans and corn, as well as nursery and floriculture crops Although all the nutrient requirements for plant growth can be met by nutrient sprays, it is common practice to combine foliar and root applications for best growth The effective use of foliar nutrition depends upon the plant and the production system It may be that for rapidly growing crops that are making primarily vegetative growth, root applications would offer the most convenient methods. However, in plants which are being grown intensively with good environmental control, and with improved knowledge of growth patterns, foliar applications could allow a better control of nutrition.

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MYCORRHIZAE IN RELATION TO CONTAINER PLANT PRODUCTION

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The associations of beneficial fungi with most plant roots are called mycorrhizae and have been described by me and others in past meetings of the International Plant Propagators' Society (2,3,5,6,7,9,10,11,13), and in extensive literature. There is, however, considerable need to better understand the nature of these symbiotic relationships in order to exploit their benefits in commercial nursery production. The microbiological aspects of container production offer special opportunities for exploration as well as some special challenges. My purpose in this presentation is to briefly discuss our current thinking in relation to the establishment and performance of these fascinating fungi. In other words, how and when should we inoculate container plants, and what must we do to ensure their survival and maximize their chances to enhance growth and survival of their host plants.

Mycorrhizae: form and function. In general, mycorrhizae are of two types: **endomycorrhizae** and **ectomycorrhizae** (8). An understanding of their key characteristics is essential to an understanding of the problems encountered in their application to nursery plants. Endomycorrhizae are largely of the so-called "VA mycorriza type," occur naturally on a wide range of herbaceous and woody nursery crops, and are obligate symbionts (cannot be grown in artificial culture) and therefore inoculum must be produced in the soil on living plant roots. Ectomycorrhizae, on the other hand, can be grown in culture, much like mushroom spawn, and occur on a more limited host range including the families Pinaceae, Fagaceae, and Betulaceae (i.e., pines, oaks, and birches). Members of the Ericaceae associate with fungi that probably can be cultured but, to date, largely have not been.

My reason for stating these characteristics is that these groups of fungi are quite different and their biology and response to environmental factors and the methods of handling them in our mycorrhization efforts may be very different. We have become painfully aware of this fact after several years of experiments, many of which have failed. But these failures have in fact become stimulants to in-depth thinking and discussions and eventually productive experiments. I would like to highlight these research processes shared so completely

with me by several graduate students. I acknowledge significant contributions to this team effort by James Graham, Jennifer Parke, Brenda Biermann, and John Kough.

Mycorrhization: colonization and performance. Mycorrhization involves two main phases. Phase one is the inoculation of receptive host roots with viable inoculum with high potential to colonize the roots. The second phase follows the inoculation and colonization phase (actually the parasitic phase) and could be termed the extra-matrical phase. This phase occurs outside the root in the soil rhizosphere and beyond. This extra-matrical hyphal network will serve to bear new spores, but also becomes the feeder system through which water and nutrients are acquired from the soil and transported back to the host (Figure 1). Without this hyphal system the symbiosis may not become mutualistic. In other words, the fungus benefits by having a place to live and acquire carbohydrates, but it remains a parasite that doesn't pay its own way because it fails to help the host plant acquire needed water and mineral nutrients.

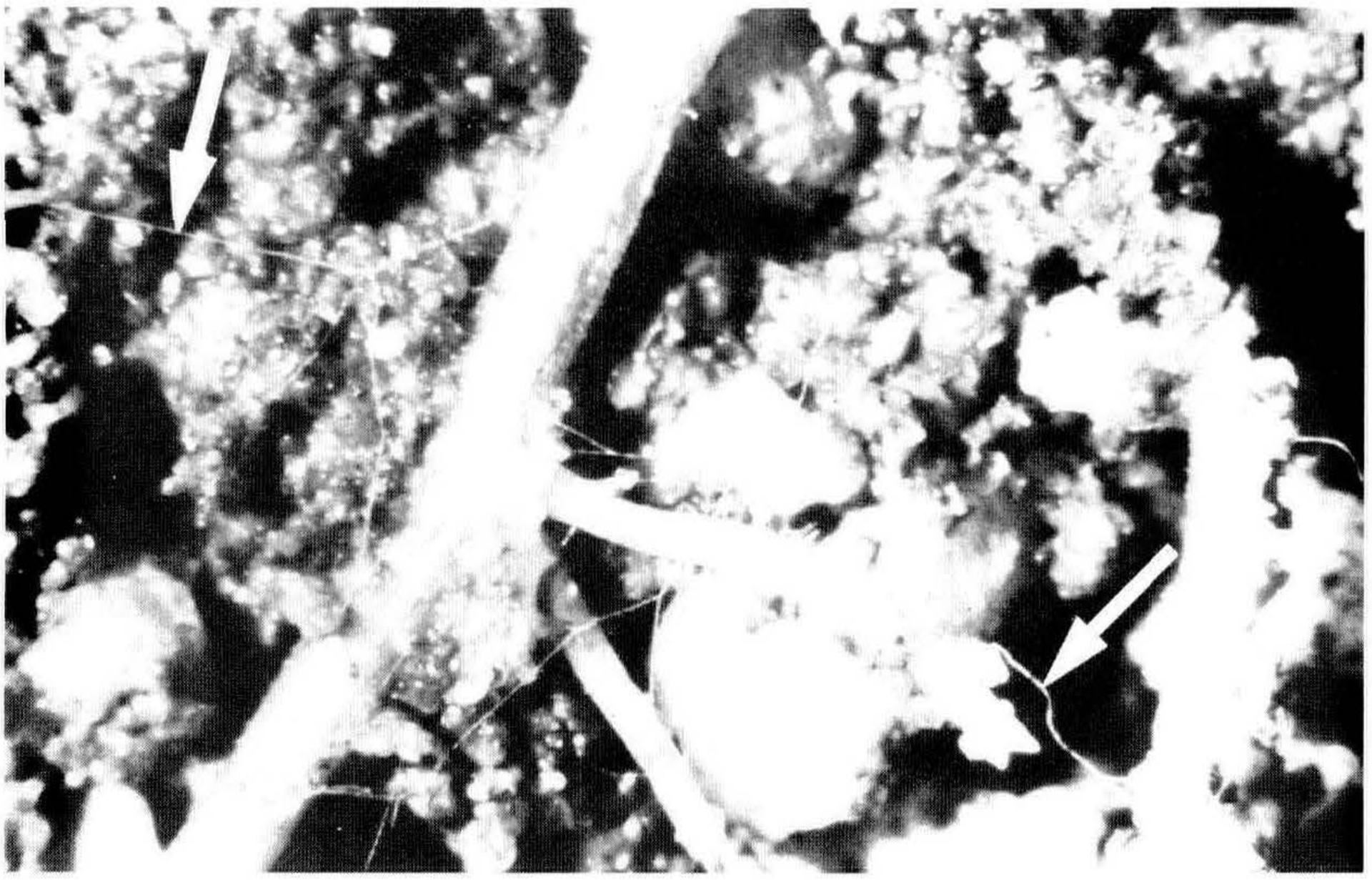

Figure 1. Extra-matrical hyphae (arrows) of *Glomus fasciculatus* extending from subterranean clover roots into the soil medium through which mineral nutrients are translocated from the soil to the root. (Photo courtesy of B. Biermann)

Until this last year, we assumed that if we observed the parasitic phase (colonization), as evidenced by morphological changes in the case of ectomycorrhizae, or by arbuscules or vesicules in the case of VA mycorrhizae, that the relationship was complete. We assumed that the extra-matrical hyphae had

been present but were removed during the straining procedure. But too often the plant seemed not to benefit by having "mycorrhizae." Why? The answer, we discovered, was that we frequently had complete root colonization, but apparently no extra-matrical hyphae to help the plant take up the phosphorus needed for growth.

The problem, then, was how to determine whether or not extra-matrical hyphae were present. The answer came to me one quiet lunch period as I perused a paper by Sutton and Sheppard (12) who had reported that VA mycorrhizal extra-matrical hyphae could aggregate sand-dune soil. Their focus was not on growth enhancement of the host plant, but their assay seemed to be just what we were looking for. The sticky extra-matrical hyphae actually bound sand grains together into aggregates. Thus, the more hyphae, the more sand grains were bound into aggregates. They shook off the non-aggregated sand grains through a screen that retained the aggregates which were then thoroughly washed off, dried and weighed The weight of sand grains was proportional to the extent of the extra-matrical hyphal network.

When I shared these thoughts with a former student, Dr. James Graham, a test system emerged that involved VA mycorrhizae on citrus and would test the hypothesis that the presence of extra-matrical hyphae was correlated with growth enhancement. It was known (J. Menge, unpublished results) that VA mycorrhizal fungus isolates from Florida for some reason failed to enhance growth of citrus grown in low P California soils, but native California isolates did enhance growth Dr. Graham ran the experiment in his California system and showed that Florida isolates colonized roots but failed to produce extensive extramatrical hyphae in California soils and correspondingly did not enhance growth, presumably due to the reduced hyphal network needed to acquire the P needed for growth (Figure 2) (4).

Thus we now have a new dimension to consider in our mycorrhiza research, but we also have the tool to measure it. These results serve to remind us that we cannot quantify mycorrhizae merely by counting morphological features, but must also attempt to determine whether the symbiosis is mutualistic, because there are soil factors which may prevent it from being so.

Soil factors that influence mycorrhizae. There are many factors in natural soil as well as environmental factors that undoubtedly influence the establishment and performance of mycorrhizae These are in addition to the host and fungus factors *per se*, although they may all be quite interdependent.

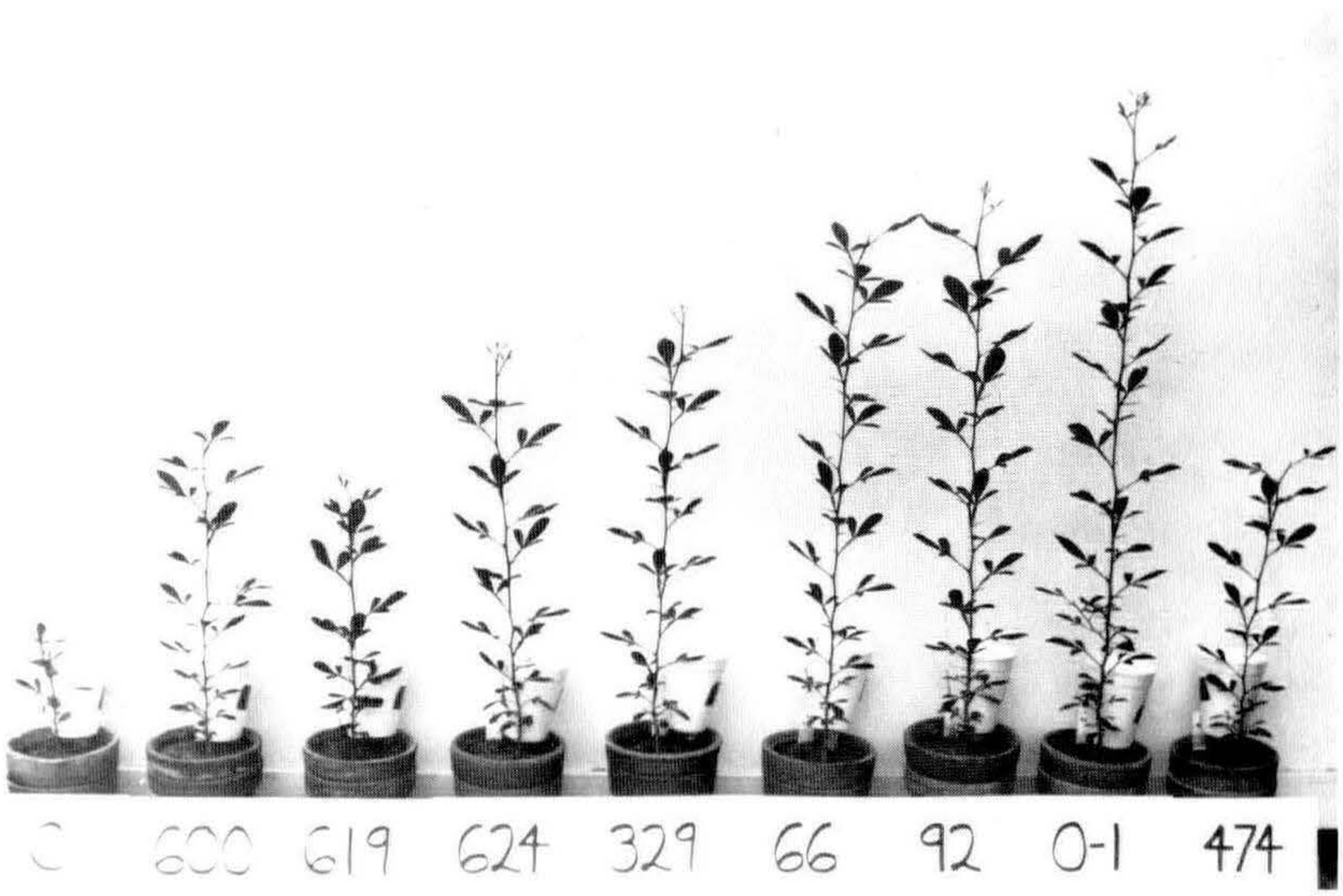

Figure 2. Growth response of Troyer citrange plants inoculated with different isolates of vesicular-arbuscular mycorrhizal *Glomus* spp. from Florida (isolates 600, 619, 624) and California (isolates 329, 66, 92, 0-1, 474) compared to the uninoculated control (C). (Photo courtesy of J.H. Graham).

For example, why did some isolates not form extra-matrical hyphae in one soil type while others did? We are currently testing a range of variables such as soil pH, organic matter content, pesticide content, nutrient levels, etc. Fortunately, in container nursery production, some of those variables can be controlled.

A series of experiments conducted by graduate student Brenda Biermann has focused on whether components of soilless container mixes influence the colonization and performance of mycorrhizae. She has found that VA mycorrhizae appear to be inhibited in soilless mixes containing peat, bark, vermiculite, and perlite. Further experiments suggest that these soilless mixes lack the P-fixing capacity that most soils have, so that too much P stays in solution and that inhibits establishment and performance of VA mycorrhizae. Adding some soil to the mix appears to nullify that inhibiting affect (1).

Helper Organisms: Another variable that we are especially interested in is the microbial complex in soil that is missing in container mixes or soils that have been pasteurized or sterilized by heat or gas. There is strong evidence to suggest that what we call "helper" organisms may be necessary in order for colonization to occur and for extra-matrical hyphae to form.

We are conducting tests to verify their importance and in the process isolate and identify them. Where would one find these organisms? We have hypothesized that if we can find a mycorrhizal association that is working, that we will also find organisms closely associated with the mycorrhiza and/or extra-matrical hyphae or rhizomorphs. If, by bioassay, we can find those that help mycorrhizae to form and function, then we should add them along with the fungi in the process of mycorrhization.

Thus we propose that there may be great benefit to "reconstituting" container mixes with organisms that we have chosen because of their ability to help plants grow. The most extreme need for reconstitution comes with tissue culture plants starting out in their "naked" state without the normal or natural complement of microbes in and on their roots. Our goal is to identify those organisms and learn how to add them to the system.

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MODERATOR CHRISTIE· I am sure we have many questions for this panel. We are ready for the first one:

STEVE WALKUM: Dr. Tukey, in your slides you showed increased growth with Osmocote plus a foliar spray, compared to Osmocote alone. Were you using the optimal level of Osmocote, or was it suboptimal?

HAROLD TUKEY: The amount — I have to look it up in the paper exactly — but it was a good level, I don't remember what optimal would be, but it was a production level of Osmocote The amount of time I don't know, though the picture was taken one month after we had stopped the foliar nutrition. We ran the foliar nutrition for three weeks, then a month without any foliar nutrition. During that whole time the plant was receiving Osmocote So it would be seven weeks after the beginning of treatment that the picture was taken. The Osmocote, in that experiment, didn't give us any additional breaks.

STEVE WALKUM. How would you apply the spray on a commercial basis, how often would you have to foliar spray to supply the major nutrients?

HAROLD TUKEY: We didn't try to compare foliar versus root nutrition. These were just experiments to show the materials could get in. I don't know exactly what the timing would be in experimental trials, but the three weeks of foliar nutrition was enough to give the plants about 11 weeks of nutrients without anything additional, before the Osmocote in the root medium began to provide nutrients. Rhododendron growers talk about applying nutrient sprays to the foliage about every four or five days during the growing season, for bedding plants, about once a week, ground covers about once a week, or once every two weeks through the season. But I think the timing depends entirely upon the situation, how fast the plants are growing, the temperatures, and all the rest of many factors.

JUDY GARLOCK: For the small nursery, do you think that foliar application of nutrients, along with the regular soil application is practical and, if it is, how would a small nursery obtain the information that it would need to start a program of foliar feeding?

HAROLD TUKEY: Practicability — I am afraid that is your job, to find out whether it works in your system or whether it doesn't. I can tell you how to get the nutrients in, I can tell you the plants will grow. Whether you make money at it, that depends entirely on your situation There are many materials on the market that are perfectly good for foliar application,

and the directions are good. All the big fertilizer companies provide such materials, and if you want to get going, just pick up some of those. I could mention lots of them but I won't here. The way to start is just to try it. That means a small sprayer of some kind to see if it works for you. The first batch is going to cost you way too much; you will not be able to make it profitable but you will see if it works. That is how people go at it. There is also published information available. People are using proportioners — growers, particularly in California, Ohio, and Texas, have been using proportioners and putting on nutrients through overhead irrigation systems. They think it goes in through the roots, but it is also absorbed through the leaves. Ed Wood has some experience on adding nutrients by overhead sprinklers to forest tree seedlings. You can get some information from him. Ralph Shugert says keep a control treatment. Absolutely! Test it, don't go over everything with foliar sprays.

JOE DAVIS: Harry Lagerstedt, have you considered rooting the stock at the same time as the scion graft with your filberts?

HARRY LAGERSTEDT: I have tried to graft two cuttings together, as is done with grapes and citrus, and I have totally failed there. The graft union dried out in every case. But from that I deduce that the root system in the moist sawdust is providing some moisture to the graft union, which an unrooted cutting does not do.

VOICE: Bev Greenwell, is there a problem in bringing in root rot by using alder sawdust?

BEV GREENWELL: There hasn't been — no. The main problem we have had with sawdust is that it breaks down too fast, but there hasn't been a root rot problem. Once the sawdust is broken down it is a lot tighter, and then there may be more root rot, because the sawdust will be too wet.

RALPH SHUGERT: Bob Linderman — a question to you. I am confused on mycorrhizae. I have it in my mind that with a container medium, the higher the organic content, the more possibility of mycorrhizae. The slides you showed disproved that. For example, with higher peat percentages in the medium — I would think I would have more mycorrhizae, but your data didn't show that. Comment please?

ROBERT LINDERMAN: What plants are you talking about?

RALPH SHUGERT: A wide range of woody ornamentals, virtually all the conifers — *Juniperus, Thuja*, etc.

ROBERT LINDERMAN: I can't comment on the conifers,

which might have had ectomycorrhizae, because our experiments were related to VA mycorrhizae. As long as there is some soil, some clay to tie up part of the nutrients, then you tend not to have a nutrient inhibition of mycorrhizae.

The soilless mixes tend not to bind phosphorus. Phosphorus is known to inhibit both ecto and VA mycorrhizae. You have to bind part of what you are supplying or, if you water it often enough, you are going to send part of it through and not have an inhibition. But if the phosphorus remains there in solution, then it becomes inhibitory to mycorrhizae. That won't happen in all cases, but it could because the phosphorus is very available. It is not bound by most of the organic amendments that you are talking about. Peat moss or bark tend not to bind the fertilizer, they keep it in solution, therefore, if you have a lot of rain it is going to wash through and you are going to have to fertilize more often. But if you keep it in solution, it is going to inhibit mycorrhizae. That seems to be the effect. If you add some soil or clay, which have a high fixing capacity, then the phosphorus is chemically bound to those particles, and you tend to have less phosphorus in solution, therefore less inhibition. Does everybody understand that? I had to go over this very fast, but there is a phosphorus inhibition of most mycorrhizae, so that if you have phosphorus in solution and available, it will tend to inhibit the mycorrhizae. You can have more phosphorus available in soilless mixes than in a mix that has soil added to it. Even pasteurized or sterilized soil, or some other clay particles that have a greater fixing capacity, will nullify that effect.

HAROLD TUKEY: I was too quick to make fun of my friend from Washington. You might not expect to necessarily find an advantage with foliar nutrition, if you are doing a good job with root nutrition. Foliar application doesn't offer anything magic. If you get different materials into the leaves that are not going in through the roots, then you will get an effect. If you are doing a good job through root nutrition, you can put all you want onto the foliage, but you probably are not going to get much change.

JIM SAHLSTROM: I would like to ask Dr. Ryan a question. We use Devrinol about three times a year in our nursery through the sprinkler system. Once in a while I have a feeling we may be getting it on our bedding plants. How much can we put on our bedding plants without damage to them? And also perennials, I would like to use it on that.

GEORGE RYAN: I can't really answer that. I have had no experience with it on bedding plants or perennials. There is some work being done on that at various places across the

country, but I can't answer the question. I would only say to contact the Stauffer representative and see what they say about it.

GEORGE MATSON: What is the optimal time or method for inoculating plants with mycorrhizae — in the seed flats, or in containers, or do you just mix it in your soil?

ROBERT LINDERMAN: My general attitude has been to inoculate at the earliest possible time. That is why we have looked at tissue culture — or at time of seeding. There is a problem with longevity of inoculum because of the form one has to use. So, in Georgia, Don Marks can inoculate ectomycorrhizae pine trees, he can inoculate them at time of seeding, and the inoculum stays alive and well until there is a root to receive it. In the Pacific Northwest if we use the same technique, inoculate at the time of seeding, the inoculum is worn out, or the inoculum potential is way down by the time there is a root to be infected. So, that is really the rule of thumb. If you can get the inoculum together with a receptive root in a minimal amount of time, that is the best. So, if you are sticking a cutting, and you don't have roots yet, there is a chance that the inoculum wouldn't be any good by the time you did get roots two months later. So in that case, I would rather be adding the inoculum after you already have a root ready to be infected. If you are talking about tissue culture we would like to have the mycorrhizae right there as soon as roots form; that is why, in our experiments, we are taking cuttings right out of phase 2 tissue culture, rooting them directly in a vermiculite medium, and, as soon as they root, get the inoculum there — that is the best situation. There are logistics problems for tissue culture people to get those two things together at the right time. That is the reason that we are doing research on it.

STUART FRASER: Question for Dr. Tukey. Is there any relation on the effectiveness of foliar feeding to leaf surface, any work being done on conifers, or one particular interest of mine — *Calluna*?

HAROLD TUKEY: I can't speak specifically — conifers do show foliar absorption, but there is some injury. We have noticed, quite surprisingly, that some of the junipers are injured relatively easily by foliar nutrition — at rates that the deciduous materials can handle very well. You always think of good old junipers being rather tough, but as far as the foliage they apparently are not. They absorb nutrients nicely, and the injury that appears is peripheral but new growth develops easily. But I don't know the reasons for the injury. It isn't just the thickness of the cuticle, because the cuticle in some coni-

fers is about the same as in other plants, so there is no relationship there. It has to do with the cuticle make-up and we haven't looked at that. I am sure that there is a relationship, but I don't know what it is.

VOICE: Question for Bev Greenwell. Regarding container-grown azaleas in the Pacific Northwest, do you think 10 lbs is the optimum rate of 18-6-12 Osmocote?

BEV GREENWELL: We had good results at 10 pounds and even as high as 12 pounds, but that is with very careful watering. One should monitor their own salt content if they are going to those rates. What you are doing is hovering at the very peak between optimum growth and toxicity. And if you sneak over into the toxicity range, you lose any advantage of going to the high rate.

VOICE: How about just 8 pounds to be safe?

BEV GREENWELL: OK — you are going to be safe, but then you are getting down to where you have fairly good looking plant material, growing at a reasonable rate, but you are actually getting hidden hunger symptoms — where you aren't getting optimum growth, but they look OK. You are safe but it might take you an extra year to grow the plant.

WESTERN REGION 1981 AWARD RECIPIENT*

PRESENTED BY BRUCE USREY

The individual we honor today for the Western Region Award of Merit has achievements so extensive that it is hard to choose where to start. His achievements cover more than a quarter of a century. One marvels that an individual could be involved in so many projects to benefit his industry and fellow man.

He has always been alert to new processes and procedures. Always among the first to experiment with new equipment and new supplies in an effort to produce a better plant. The propagation of plants by faster, more efficient methods is always a challenge. He has found a special challenge in tissue culture and is commercially producing many hundreds of thousands of plants by this method, including conifers, berry vines, apple trees, *Kalmia*, a long list of *Rhododendron* cultivars, and many other plants.

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* Presented at the Western Region 1981 banquet.

fers is about the same as in other plants, so there is no relationship there. It has to do with the cuticle make-up and we haven't looked at that. I am sure that there is a relationship, but I don't know what it is.

VOICE: Question for Bev Greenwell. Regarding container-grown azaleas in the Pacific Northwest, do you think 10 lbs is the optimum rate of 18-6-12 Osmocote?

BEV GREENWELL: We had good results at 10 pounds and even as high as 12 pounds, but that is with very careful watering. One should monitor their own salt content if they are going to those rates. What you are doing is hovering at the very peak between optimum growth and toxicity. And if you sneak over into the toxicity range, you lose any advantage of going to the high rate.

VOICE: How about just 8 pounds to be safe?

BEV GREENWELL: OK — you are going to be safe, but then you are getting down to where you have fairly good looking plant material, growing at a reasonable rate, but you are actually getting hidden hunger symptoms — where you aren't getting optimum growth, but they look OK. You are safe but it might take you an extra year to grow the plant.

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He is past president of the International Plant Propagators Society, past president of the Western Region, IPPS, a supporter of the Western Washington Horticultural Society, a past president of Rainier Chapter, Washington State Nurserymens' Association, and a member of the Board of Directors, WSNA. He has been chairman of the Legislative Committee, and chairman of the Highway Committee, WSNA; chairman of the Grades and Standards Committee of the American Association of Nurserymen, a member of the American Rhododendron Society, and he is on the Board of Directors of The Rhododendron Species Foundation. He was named citizen of the year of his home town. He is an avid football fan and at times a pretty fair salmon fisherman. His name is Bruce Briggs.

MODERATOR LARRY CARVILLE: We will now have five presentations dealing with the general topic of "Plant Growth Regulators". David Lane of the Summerland Research Station at Summerland, British Columbia, will give the first paper:

PLANT MANIPULATION *IN VITRO* WITH HORMONES

W. DAVID LANE

Research Branch, Agriculture Canada
Summerland Research Station
Summerland, British Columbia, V0H 1Z0 Canada

Abstract. The experiments described in this paper illustrate some of the responses of shoot cultures to treatment with growth regulators and the manipulations made possible through their use. First examined are the growth regulator requirements of shoot cultures. Cytokinin, in particular, is required by most cultures but, in exceptional circumstances, may not have to be supplied in the medium. The optimum growth regulator concentration required for shoot or root growth varies considerably between species and cultivar; growth regulators supplied in the medium can interact with those produced by the cultures and result in dramatically different responses. Varient requirements probably caused by this effect influence rooting more than shoot growth, particularly in the cultivar M.9. Its roots initially develop into callus rather than roots when continually exposed to a normal concentration of auxin in the medium. Shoot cultivars can be manipulated by exploiting differences in their tolerances to growth regulator concentrations higher or lower than their optimum. This should make it possible to develop procedures for preventing back mutation of spur-type strains to standard growth habit and, used in reverse, may be useful for isolating and identifying new spur-type strains arising as induced mutations in shoot cultures.

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INTRODUCTION

It is commonly known by tissue culture specialists that the plant growth regulators — i.e. plant hormones — are fundamentally important in determining the growth characteristics of shoot cultures *in vitro*. Usually, cultures die if one or more are not included in the medium (1). Plant growth regulators also influence the number and length of shoots (2) and root number, size and length (3). Also, they influence callogenesis and rate of callus growth (4) and are thought to have secondary effects on such things as rooting success and the ease with which plants can be transplanted because of carryover effects from the shoot proliferation medium.

This paper presents results from three sets of experiments. In the first, the influence of cytokinin, auxin and gibberellic acid alone, and in combination, on flax shoot cultures is examined and information is presented bearing on the growth regulator requirements of shoot cultures. In the second section, a comparative examination is made of the response by five apple cultivars to a range of cytokinin and auxin concentrations by measuring their shoot growth and rooting. The variation in response among the cultivars is discussed. Finally, an experiment is reported in which three strains of the apple cultivar McIntosh, with standard, spur-type and dwarf growth habit, were examined for tolerance to cytokinin concentrations below and above their normal optimum; and the implications for prevention of mutations in shoot cultivars are discussed.

MATERIALS AND METHODS

Standard techniques described previously (5) (6) were used to initiate and maintain mother cultivars. Briefly, explants were obtained from germinated seed (flax) or from field trees growing at the Summerland Research Station. They were surface sterilized and incubated in Murashige and Skoog nutrient medium (7) containing 5μM (apple) or 0.1μM (flax) benzyladenine. Incumbation was in a growth chamber adjusted for day/night: cycle 16:8 hours, with temperatures of 22° and 28°C.

RESULTS AND DISCUSSION

Shoot Culture Requirements for Growth Regulators

Although plant species respond differently and differences among cultivars are common (8), particularly in the optimum concentrations they require, responses of a generalized nature form a fairly consistent pattern and are useful for defining most shoot culture requirements. These growth requirements

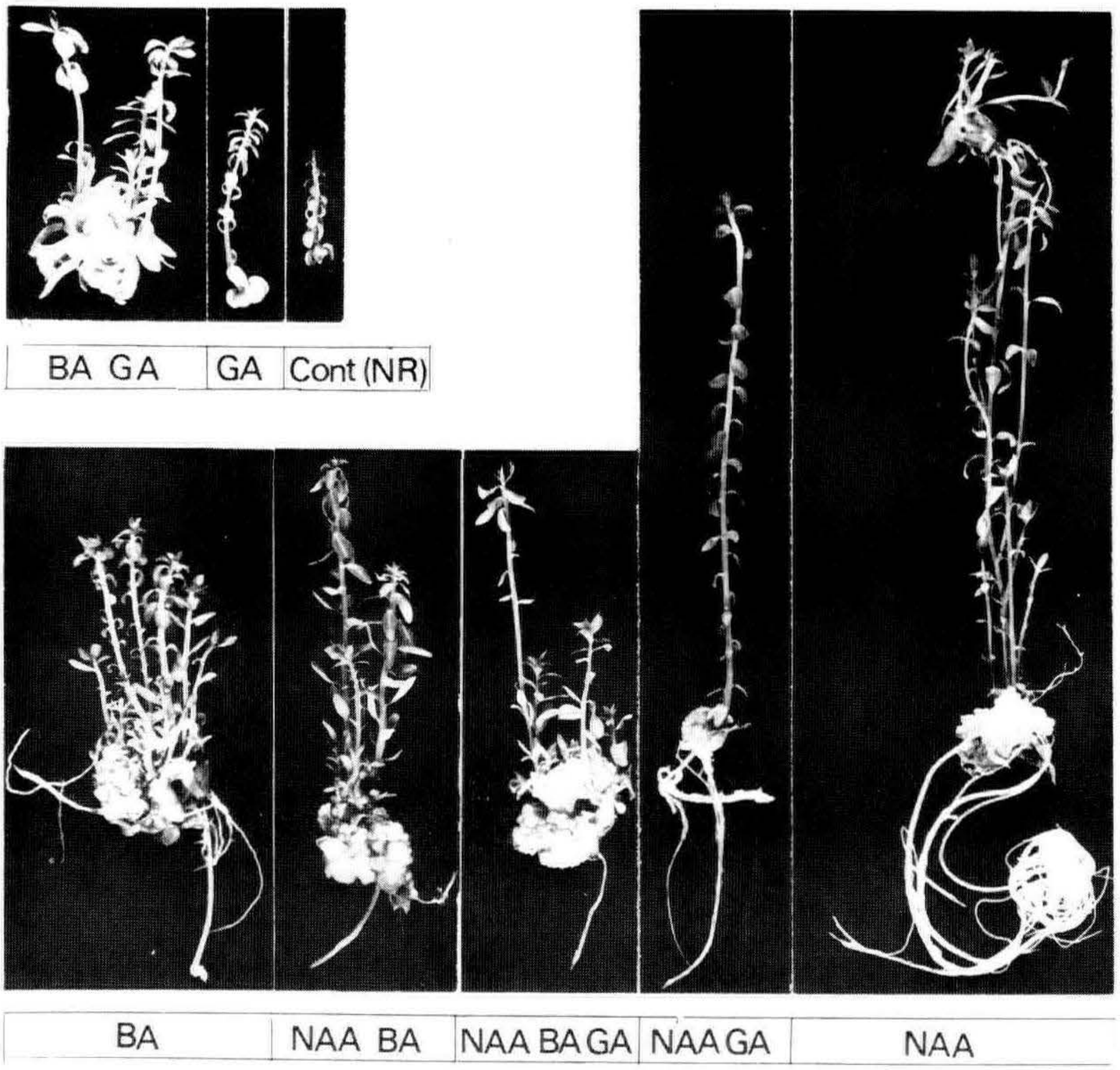

Figure 1. The influence of BA, NAA and GA alone and in combination and the no regulator control on the morphogenic development of flax meristem-tips. Concentrations: BA, 0.1 μm; NAA, 0.05 μM; GA, 5 μM.

are not consistent enough to be considered rules, though, as exceptions are known.

Exceptional responses usually result from what is assumed to be the presence of growth regulators produced by the cultures themselves which interact with those supplied in the medium.

The effect of growth regulators on flax shoot cultures, summarized in Figure 1, shows the effects of individual and combined growth regulator treatments. Cytokinin (benzyladenine, BA) considered to be mainly synthesized by root tissue, was required by those flax shoot cultures which were devoid of roots. The control treatment with no BA died. Once the cytokinin requirement was met, study of the interaction of BA

with other growth regulators was possible. GA had no effect on shoot number, or it was inhibitory when combined with the treatments of BA alone, with the auxin, naphthaleneacetic acid (NAA) alone, or with BA plus NAA, depending on the concentration used. Addition of NAA often resulted in a reduced number of shoots, but those which did grow were longer. This effect could be used to advantage to give cultures with shoots which were less crowded and more easily manipulated *in vitro* than those with higher shoot number. In the flax shoot cultures, NAA alone resulted in root formation and gave rise to complete plants which grew similarly to germinated seedlings. Exogenously supplied cytokinin was no longer required in this situation, probably because cytokinin synthesis in the root supplies the requirement. Table 1 summarizes the results of these experiments and gives the calculated yield of shoots based on the frequency with which shoots became established and the average shoot production of those which did. The results indicate that in this system both NAA and GA have either neutral or, more often, inhibitory effects on shoot production.

Table 1. The influence of growth regulators on percent frequency of meristem-tip cultures forming multiple shoots; average number of shoots per proliferating culture; yield of shoots per 100 cultures; and average dry weight of cultures.

	Shoot Proliferation			
Growth Regulator	Frequency	Ave. No.	Yield	Dry wt.
BA *	93	5.7	530	57
BA NAA	79	4.6	363	53
BA NAA GA_3	80	3.3	264	48
BA GA_3	60	3.7	222	34
NAA	47	3.2	150	80
NO REGULATOR	33	2.8	92	29
NAA GA_3	13	3.9	51	29
GA_3	7	1	7	10

* Concentrations: BA, 0.1μM; NAA, 0.5μM; GA_3, 5μM. Previously published in reference 1.

Variation Among Clones in Response to Growth Regulators

Consistent requirements for growth regulators, such as cytokinin, applicable to most species commonly grown as shoot cultures *in vitro* are more universal than the specific growth regulator concentrations which give optimum growth (shoot number). In fact it is common for cultivars of a species to respond with different optimum concentrations of cytokinin for shoot proliferation and of auxin for root initiation, although, these differences are often small. The results of an experiment comparing the cytokinin requirements of four apple cultivars (three rootstock and one scion) for optimum shoot

production is presented in Table 2. Shoot production at the optimum BA concentration varied with the cultivar; the most prolific shoot producer, M.27, gave 249 percent more shoots than the least productive. The optimum BA concentration also differed, with M.26 and Macspur having an optimum of 5μM, and M.27 and M.111 producing best at 10μM. These figures would be modified downward somewhat if the most appropriate rate of shoot production for propagation, rather than for the maximum was recorded. The results demonstrate, however, that cultivar differences do occur even in closely related cultivars. There are several possible reasons why the cultivars responded differently. The effective levels of growth regulators produced by the cultures themselves could very well be different and, therefore, could influence the optimum concentration required in the medium. If the cultures are partially self sufficient, not as much added growth regulator would be required. Optimum concentrations could also be influenced by other characteristics of the cultures, such as the rate at which the growth regulator is taken up, the efficiency with which the culture transports it, or the speed with which it is broken down metabolically.

Table 2. Average number of shoots per culture of apple shoot cultures grown at 1.0, 5.0 and 10 μM BA.

	BA μM		
	1.0	5.0	10.0
M.27	1.22	6.16	7.54
M.9	0.50	3.03	3.91
M.26	0.50	3.41	2.72
Macspur	1.47	4.56	3.10

Standard error = 0.37

Rooting responses of apple were much more variable than shoot growth. Table 3 shows that the reaction of M.9 is quite different from the other rootstock cultivars tested here and that acute exposure to NAA, rather than chronic, is required (Table 4). It was observed that M.9 formed callus much more readily than the others when exposed to auxin, perhaps because its shoot cultures either respond to lower concentrations or had higher internal levels. As the root initials formed they developed into callus rather than roots. Acute exposure to NAA gave good root initiation but reduced callus growth because callus requires continuous supplies of auxin for its growth. Root initiation also requires auxin but initiation occurs within a few days. Once initials are formed root extension, which does not require auxin, can proceed unhindered.

Table 3. Percent rooting of four apple cultivars at a range of NAA concentrations.

	NAA μM					
Cultivar	0.1	0 33	1.0	3.3	10	33
M.27	10%	35%	85%	26%	15%	0%
M.26	5	16	85	30	15	0
M.111	20	20	58	84	7	5
MACSPUR	0	34	58	31	43	0
M.9	0	0	0	0	0	0

Table 4. Percent rooting of M 9, acute versus chronic exposure to NAA.

NAA Treatment							
Acute, mM NAA		Chronic, μM NAA					
0 54	1.61	0.1	0.33	1.0	3.3	10	33
45 (7.8)*	52 5 (7 9)	0	0	0	0	0	0

Standard error of percent rooting

Tolerance to BA Concentrations Higher and Lower than Optimum

In addition to having requirements for growth regulators as well as optimum concentrations, shoot cultures respond, and can be manipulated, by their response to BA supplied at below or above the optimum concentration. We compared the response of three strains of 'McIntosh' apple, with either standard, spur-type or dwarf growth habit, to a range of BA concentrations. Although the optimum level for all three strains was the same, there were striking differences in tolerance to high concentrations (Figures 2 and 3). The strains with standard growth habit ('Summerland Red McIntosh') could tolerate only a slightly higher level than the optimum, the spur-type ('Macspur') considerably higher, and the dwarf 'McIntosh Wijcik' a very high level without showing phytotoxicity or dying. It is apparent that the more extreme the growth habit the greater is the tolerance to supra-optimal BA concentration. At less than optimum concentrations, the response was reversed; the standard grew more vigorously than the spur type or dwarf. These experiments show, therefore, that by manipulating the growth regulator concentration, growth of one form can be encouraged while other forms are inhibited. A selective medium such as this could have valuable practical uses. In many tissue culture propagation laboratories a concern is mutation of spur-type forms, which arose as natural mutations in the field, to the standard growth habit types from which they originated. This is reenforced by the notion that spur-type growth habit is a chimeral characteristic. The selective medium could be used to advantage to encouraging faster growth of the desirable form by choosing an appropriate concentration of

BA. Any mutated sectors which should arise would soon become diluted because of their slower growth — and the faster growing, desirable form, would predominate. Using this mechanism, accumulation of mutated tissues could be prevented.

A second use is for selection and breeding. Using the differences in tolerances identified in these experiments it may be possible to encourage growth of mutated cells and develop this into a new technique for obtaining new mutants with spur-type or dwarf growth habit from standard growth habit form.

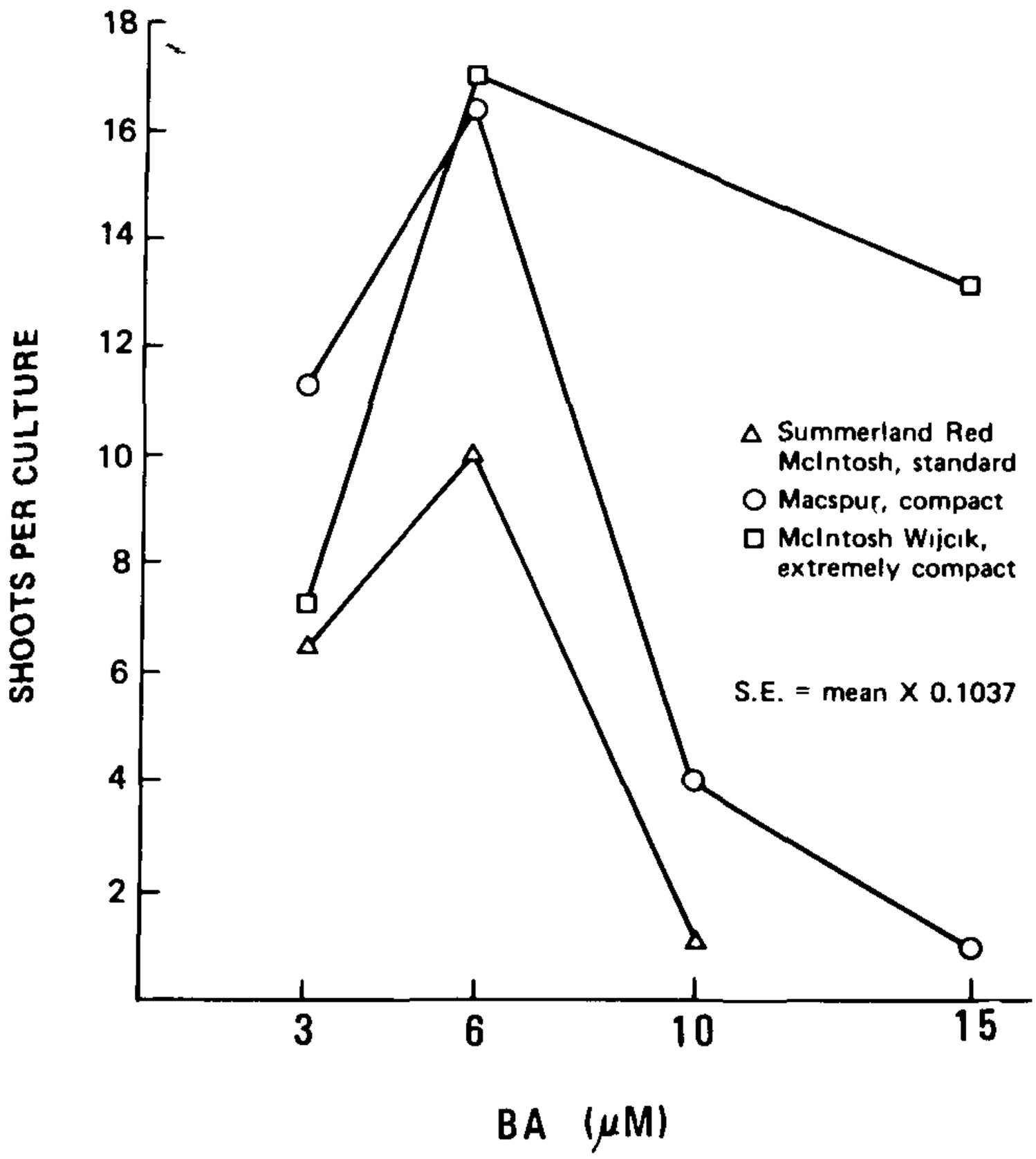

Figure 2. Number of shoots produced by meristem-tip cultures after 42 days growth by the three strains of apple with standard, compact or extremely compact growth habit as influenced by BA concentration.

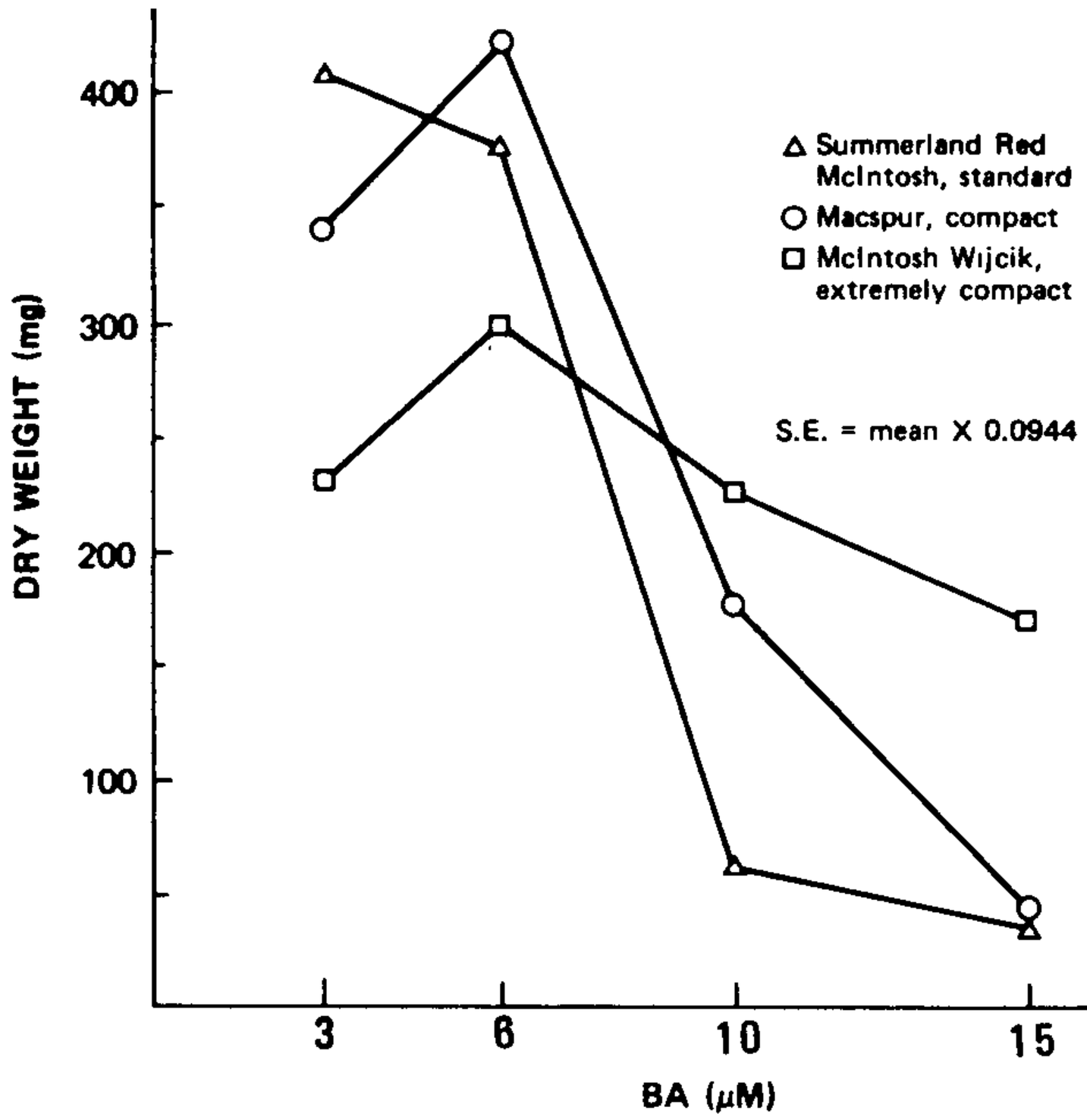

Figure 3. Dry weight of meristem-tip cultures after 42 days growth of the three strains of apple with standard, compact or extremely compact growth habit as influenced by BA concentration.

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A COMPARISON OF SEVERAL HORMONE FORMULATIONS FOR ROOTING CUTTINGS

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Abstract. Three rooting hormone products: liquids, Dip n' Grow, and Wood's Rooting Compound, and the powder, Hormex No. 8, were compared for rooting efficacy on eight species during December. Results varied by species, but in more cases, a heavier root system was produced by the liquid products. The solvent system was changed on Dip n' Grow by the manufacturer and a new trial was conducted in May with two species using the new formulation There were no significant differences with *Forsythia* × *intermedia* 'Spring Glory', but Wood's Rooting Compound appeared to be more effective at lower concentrations with *Virburnum* × *burkwoodii*.

There have been many reports over the years in I.P.P.S. publications on the use of Dip n' Grow and Speedy Dip No. 2, an earlier name for the same formulation. Dip n' Grow was a liquid formulation containing 20 percent dimethyl sulfoxide as part of the solvents but was never registered with the E.P.A. for sales throughout the U.S. It was offered for sale in the states of Oregon and Washington under State 24 c registrations. In 1980 a new product, Wood's Rooting Compound, which contained approximately the same amounts of indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) with 20 percent dimethyl formamide as part of the solvents, received an E.P.A. label for national sales.

The formulation of Dip n' Grow was changed during 1981 and now has an E.P.A. label for sale in all states. The label on the new formulation does not show DMSO, Dichlone, or boron, which were in the original product.

MATERIALS AND METHODS

Winter Trial. Three hormone products and an untreated control were used to promote rooting of eight species in trials started during December 1980. Dip n' Grow was composed of dimethyl sulfoxide (DMSO) 20%, IBA 1.0%, NAA 0.5%, Dichlone (2,3-dichloro-1-4 naphthoquinone) 0.1%, and boric acid 0.017%, and 78.38% inert ingredients. Hormex No. 8 contains 0.8% IBA in talc. Wood's Rooting Compound contains IBA 1.03%, NAA 0.51%, ethanol DS 3A 78.546%, and dimethyl formamide 20.0%.

Test plants and the number of 10 cutting replications used were: *Buxus sempervirens* 'Suffruticosa' (6), *Euonymus fortunei* 'Gracilis' (Syn. variegata) (6), *Juniperus horizontalis* 'Wiltonii' (6), *Ligustrum japonicum* (10), and *Viburnum davidii* (10). All treatments were randomized in 3 inch deep perlite filled flats

which were maintained at 72°F by electric cables. Mist frequency was determined by a Mist-A-Matic control.

Summer Trial. The formulation of Dip n' Grow was changed during 1981 and it has received a national E.P.A. label. The IBA and NAA levels remain the same but DMSO, Dichlone, and boron are no longer listed as contents. Softwood cuttings of *Forsythia* × *intermedia* 'Spring Glory' and *Viburnum* × *burkwoodii* were treated on May 14 and May 13 respectively with the new formulation at 1 in 10, 20, and 40 dilutions, the old formulation at 1 in 20, Wood's Rooting Compound at 1 in 10, 20, and 40 dilutions, Hormodin No. 2 (0.3 percent IBA in talc), and an untreated control.

The cuttings were lifted and evaluated when the majority of cuttings of a species had root systems large enough to insure survival. Evaluation was on the basis of heavy, medium, and light rooting with standards that varied somewhat with the type of root systems produced by the species. Results are presented both as total percentage rooting and by a rooting value system. A value of 3 was assigned to a heavily, 2 to a medium, and 1 to a lightly rooted cutting. The total of the number of cuttings in a category was multiplied by the assigned value and the sum for a replication was used for statistical analysis.

RESULTS

In the winter trial. rooting values indicated that *Buxus sempervirens* 'Suffruticosa', *Ligustrum japonicum*, and *Pinus* mugo were not benefited by the application of a rooting hormone. It is likely that the 1 in 5 dilution of the liquid hormone products was too strong for these species.

Euonymus fortunei 'Gracilis', *Juniperus horizontalis* 'Wiltonii', *Photinia* × *fraseri*, *Thuja occidentalis* 'Fastigiata' and *Viburnum davidii* did respond to one or more of the hormone treatments. Generally, rooting values were higher with either of the liquid products than with the powder formulation. Rooting results with *Photinia* were not statistically significant because of variations among replications but did show a response to hormones.

In the summer trial, some drying of the *Forsythia* cuttings occurred, causing variations among replications. Differences in rooting during the 19 days of this trial were not great with the exception of the Dip n' Grow, 1 in 20 dilution, which were unexplainably depressed.

There were significant differences among treatments with *Viburnum* × *burkwoodii*. Only the highest concentration of the new formulation of Dip n' Grow was superior to the con-

trol while all dilutions of Wood's Rooting Compound were superior. The 1 in 20 dilution of the old formulation was also effective. Again the rooting results of the 1 in 20 dilution of the new formulation on *V.* × *burkwoodii* appear to be out of line.

More trials will be necessary to determine whether the dilutions of Dip n' Grow mentioned in numerous reports in IPPS publications can be used without modification with the new formulation. Wood's Rooting Compound appears to be effective at very dilute rates and this should be considered when trying this product.

Table 1. Effect of three hormone products on rooting cuttings of eight ornamental species.

Species, Rooting Period, and Number of Replications( )	Treatment	Percent of Cuttings Rooted	Average Rooting Value*	
Buxus sempervirens 'Suffruticosa'	Control	81.7%	14 0	N.S.**
12/3/80 - 2/12/81 (6)	***Dip N'Grow 1 in 5	78.3	15 2	N S.
	Hormex 8	73 3	10 8	N.S
	Woods R C 1 in 5	80 0	13 3	N S
Euonymus fortunei 'Gracilis'	Control	63.3	7 7 a	
12/3/80 - 4/27/81 (6)	Dip N'Grow 1 in 5	100.0	18 5 b	
	Hormex	90.0	14 5 b	
	Woods R.C. 1 in 5	96 9	19.5 b	
Juniperus horizontalis 'Wiltonii'	Control	82 5	17.8 a	
12/9/80 - 4/27/81 (6)	Dip N'Grow 1 in 5	86.3	20.2 b	
	Hormex 8	66.3	13 7 a	
	Woods R C. 1 in 5	66.3	15 8 a	
Ligustrum japonicum	Control	90 8	20.6 b	
12/4/80 - 2/11/81 (10)	Dip N'Grow 1 in 5	87.5	16 7 a	
	Hormex 8	85.8	19 7 a	
	Woods R.C 1 in 5	87 5	17.5 a	
Photinia × *fraseri*	Control	0	0	
12/4/80 - 3/30/81 (4)	Dip N'Grow 1 in 5	35 0	4 8	N S.
	Hormex 8	20.0	2.5	N.S.
	Woods R.C. 1 in 5	60.0	12 3	N S
Pinus mugo	Control	45.0	8 3	N.S
12/9/80 - 6/2/81 (4)	Dip N'Grow 1 in 5	40.0	7 5	N.S.
	Hormex 8	37.5	7 5	N S
	Woods R.C. 1 in 5	42 5	9.5	N.S.
Thuja occidentalis 'Fastigiata'	Control	52.0	5.8 a	
12/9/80 - 2/9/81 (10)	Dip N'Grow 1 in 5	84.0	16 0 b	
	Hormex 8	67.0	7 6 a	
	Woods R.C 1 in 5	79.0	13 3 b	
Viburnum davidii	Control	77 0	10.9 a	
12/3/80 - 1/29/81 (10)	Dip N'Grow 1 in 5	92 0	23.2 c	
	Hormex 8	93.0	16.0 b	
	Woods R.C 1 in 5	90 0	22.8 c	

* See text for explanation of rating scales

** Means followed by the same letters are not significantly different at 5% level of the Duncans Multiple Range Test.

*** Old formulation

Table 2. Effect of several hormone products on the rooting of softwood cuttings of two species.

Species, Rooting Period, and Number of Replications( )	Treatment	Percent of Cuttings Rooted	Average Rooting Value*	
Forsythia × *intermedia* 'Spring Glory'	Control	90.0%	19.0	N S **
5/14/81 - 6/1/81 (4)	Dip N'Grow 1 in 10	97.5	20 5	N.S.
	Dip N'Grow 1 in 20	80.0	16 3	N.S.
	Dip N'Grow 1 in 40	97 5	24 0	N.S.
	Dip N'Grow 1 in 20 Old formulation	97 5	20 5	N.S
	Woods R.C 1 in 10	97.5	22.5	N.S.
	Woods R.C 1 in 20	97.5	23 0	N.S.
	Woods R.C. 1 in 40	92.5	22.5	N S
	Hormodin 2	100.0	24 8	N.S.
Viburnum × *burkwoodii*	Control	82.5	14.0 a	
5/13/81 - 6/16/81 (4)	Dip N'Grow 1 in 10	97 5	28.3 b	
	Dip N'Grow 1 in 20	75.0	16 3 a	
	Dip N'Grow 1 in 40	90.0	15.5 a	
	Dip N'Grow 1 in 20 Old formulation	97.5	26.3 b	
	Woods R C 1 in 10	97.5	27.0 b	
	Woods R.C. 1 in 20	100 0	26 0 b	
	Woods R C 1 in 40	100.0	24.0 b	
	Hormodin 2	90 0	17 3 a	

* See text for explanation of rating scales.

** Means followed by the same letters are not significantly different at 5% level of the Duncans Multiple Range Test.

PROPAGATION OF ALASKA YELLOW CEDAR (*CHAMAECYPARIS NOOTKATENSIS* [D. DON] SPACH.) BY ROOTED CUTTINGS FOR PRODUCTION PLANTING

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Abstract. Rooted cuttings of yellow cedar from young material reached a plantable size in one growing season Two and four years after planting on typical sites, survival and height growth of the cuttings compared favorably to those of the seedlings. A hedging orchard was established from seed of selected parent trees in order to produce juvenile material for the large scale production of rooted cuttings and, in 1981, the first production of rooted cuttings for reforestation was begun

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Table 2. Effect of several hormone products on the rooting of softwood cuttings of two species.

Species, Rooting Period, and Number of Replications( )	Treatment	Percent of Cuttings Rooted	Average Rooting Value*	
Forsythia × *intermedia* 'Spring Glory'	Control	90.0%	19.0	N S **
5/14/81 - 6/1/81 (4)	Dip N'Grow 1 in 10	97.5	20 5	N.S.
	Dip N'Grow 1 in 20	80.0	16 3	N.S.
	Dip N'Grow 1 in 40	97 5	24 0	N.S.
	Dip N'Grow 1 in 20 Old formulation	97 5	20 5	N.S
	Woods R.C 1 in 10	97.5	22.5	N.S.
	Woods R.C 1 in 20	97.5	23 0	N.S.
	Woods R.C. 1 in 40	92.5	22.5	N S
	Hormodin 2	100.0	24 8	N.S.
Viburnum × *burkwoodii*	Control	82.5	14.0 a	
5/13/81 - 6/16/81 (4)	Dip N'Grow 1 in 10	97 5	28.3 b	
	Dip N'Grow 1 in 20	75.0	16 3 a	
	Dip N'Grow 1 in 40	90.0	15.5 a	
	Dip N'Grow 1 in 20 Old formulation	97.5	26.3 b	
	Woods R C 1 in 10	97.5	27.0 b	
	Woods R.C. 1 in 20	100 0	26 0 b	
	Woods R C 1 in 40	100.0	24.0 b	
	Hormodin 2	90 0	17 3 a	

* See text for explanation of rating scales.

** Means followed by the same letters are not significantly different at 5% level of the Duncans Multiple Range Test.

PROPAGATION OF ALASKA YELLOW CEDAR (*CHAMAECYPARIS NOOTKATENSIS* [D. DON] SPACH.) BY ROOTED CUTTINGS FOR PRODUCTION PLANTING

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Abstract. Rooted cuttings of yellow cedar from young material reached a plantable size in one growing season Two and four years after planting on typical sites, survival and height growth of the cuttings compared favorably to those of the seedlings. A hedging orchard was established from seed of selected parent trees in order to produce juvenile material for the large scale production of rooted cuttings and, in 1981, the first production of rooted cuttings for reforestation was begun

An increase in high-elevation logging activities in the Coastal Forest Regions of British Columbia has focused attention on the use of "minor" species for reforestation. Yellow cedar is an important and valuable component of certain ecosystems at these high elevations. Unfortunately, the seedling requirement for the reforestation of this species cannot be met by the nurseries because of the shortage of cones and poor

seed germination. Therefore, the alternative method of producing planting stock of yellow cedar by means of rooted cuttings has been explored.

Rooted cuttings can be produced quite successfully in many conifer trees, providing that the cuttings are taken from juvenile material. In Japan, *Cryptomeria* cuttings have been used extensively in reforestation for centuries. In West Germany, a million Norway spruce rooted cuttings are produced annually from selected trees for reforestation (5). In Ontario, Canada, a program using rooted cuttings from young white spruce ortets is under way both for tree improvement and reforestation (7). In many species, however, there is a decrease in growth rate and orthotropic growth form in the cuttings as a result of increased age of the parent trees, e.g. in *Pinus radiata* (8). On the other hand, it is recognized that juvenility can be retained by "hedging" forest trees to provide a source of juvenile material for cuttings (6).

For yellow cedar, Bloome and Van Hulle (1) and Van Elk (3) in different studies of ornamentals, had little success in rooting cuttings from old trees. Similar results were obtained by Karlsson (4) when rooting old material, but when taking cuttings from 3 to 10 year old trees and setting the cuttings in coarse, well-aerated material, and applying hormones as recommended by Brix (2), rooting was successful and plantable stock was produced in one growing season.

Growth comparison between rooted cuttings and seedlings of yellow cedar

Even though rooting of cuttings from young yellow cedar trees can be accomplished easily, the material would not be considered seriously in a reforestation program without some knowledge of how the cuttings' growth performance compare to that of seedlings.

To gain information on those features, two experimental plantations were established on sites suited to reforestation by yellow cedar.

The first plantation is located at 1000 m elevation in the Mission area (Lat. 49° 10′ Long. 122° 20′) and was planted in row-plots of five trees in the fall of 1976.

The following plant categories were included:

a) Seedlings	Provenance: Mission
b) Rooted cuttings taken from 1 year old seedlings	Provenance: Mission
c) Rooted cuttings taken from 3 year old seedlings	Provenance: Mission
d) Rooted cuttings taken from 7 year old seedlings	Provenance: Kelsey Bay — Lat. 50° 22′ Long. 126° 02′

The results after four years on site appear in Table 1.

Table 1. Survival and total height by year since planting at Mission.

Type of plant	No. planted	Survival percentage 1980	Average height cm				
			Age 1	2	3	4	5
			Time of planting	1977	1978	1979	1980
a) Seedlings	75	98.7	34.7	42.0	61.8	95.3	129.5
b) Cuttings, ortet 1 yr.	75	98.7	44.4	58.0	79.6	107.9	142.0
c) Cuttings, ortet 3 yr.	75	100	36.2	50.4	70.9	100.9	129.7
d) Cuttings, ortet 7 yr.	60	100	34.8	47.2	65.1	95.6	129.3

The second plantation was established in the fall of 1978 on Mt. Ephinstone at 1000 m elevation (Lat. 49° 28′ Long. 123° 33′). Both the seedlings and the cuttings originated from cones collected from 10 selected trees in the Mt. Ephinstone area. At time of planting, seedlings in this test were two years of age and the cuttings, which were taken from 2-year old ortets, were one growing season old. Each family is represented by 50 seedlings and 50 cuttings and planted in replicated row-plots of 10 trees. This plantation has been browsed heavily by deer, but both types of plants have been hit equally. Survival and height growth were recorded after two growing seasons in the field and provided the following data:

Table 2. Survival and total height after two years at Mt. Ephinstone.

Family No.	Survival Percentage		Average height, cm Seedlings		Cuttings	
	Seedlings	Cuttings	Time of planting	2 yrs in field	Time of planting	2 yrs in field
23	98	92	37.4	56.7	37.6	58.4
29	90	92	37.1	58.4	41.8	60.7
30	98	94	35.8	52.8	37.0	61.5
31	88	86	35.0	56.1	41.8	69.9
33	92	96	32.5	56.3	38.6	59.4
34	98	98	41.8	52.7	43.1	61.7
35	90	100	43 0	49.2	35.3	54.5
39	98	100	39.3	58.2	43.8	62.4
40	98	94	43.2	57.8	34.0	56.6
42	90	98	36.7	58.3	33.3	53.1
Mean	94	95	38.2	55.7	38.6	59.8

The most noticeable feature of these plantations is the high survival rate for both seedlings and cuttings. Ortet age did not affect survival (Table 1). The poorest family at Mt. Ephinstone, number 31, was not significantly poorer than the best (Table 2).

Cutting height growth was not affected by ortet age although cuttings from 1-year-old seedlings grew about 10 per-

cent taller. This difference is due to a height advantage these cuttings had at a time of planting (Table 1). No correlation was found between mean height of seedlings and cuttings from the same family (Table 2). At the end of the second growing season in the field, most cuttings had obtained orthotropic growth form and there was no obvious difference between the seedlings and the rooted cuttings.

Judging by these early results, the use of rooted cuttings can be considered as an alternative in a reforestation program when seedling planting stock is in short supply.

Establishment of hedging orchard and rooting cuttings for reforestation

The successful results from the rooting of yellow cedar cuttings in 1974 led to the decision to establish a hedging orchard to provide material for the future production of rooted cuttings for reforestation. The selection of parent trees of good phenotype and the collection of cones from these trees were carried out by staff from the Vancouver Forest Region between 1975-78. The seedlings from these selected trees were grown in the nursery, and in 1978-79 the hedging orchard was established at Cowichan Lake Research Station. The seedlings were planted in rows 3.75 m apart with 90 cm between the seedlings. Each row of 50 seedlings represents one family of half sibs. The total orchard is 0.8 ha. With the wide spacing between the rows it is possible to rogue out a family if necessary and replant a more suitable one without having to consider competition from neighboring rows. Two years following the planting of the hedge rows, the seedlings had reached their productive size. It is estimated that 4 to 5 years after establishment this orchard should yield enough material to produce 250,000 cuttings yearly.

In 1979 and 1980 some testing of growing regimes was conducted to evaluate different approaches to a large scale production of rooted cuttings. Different container types were tested, and the Spencer-Lemaire containers were found to be superior, yielding 80 percent plantable stock. Because this container opens up to release the plants, planting can take place directly from the containers without unnecessary disturbance to the delicate root systems of the cuttings. There is also a financial saving in using the Spencer-Lemaire containers as compared to other container types where the cuttings must be re-potted before field planting.

Based on these results, the Silviculture section of the Vancouver Region requested 50,000 plantable rooted cuttings for their 1981 fall planting program. To meet this request, 75,000 cuttings were clipped from the hedging orchard in January of

this year, set in Spencer-Lemaire containers, and placed in greenhouses. The resulting stock will be planted under production conditions in October, 1981.

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NEW HORIZONS IN ROOTING HORMONES

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My first remembrance of using a liquid rooting hormone goes back to 1951 when I tried a 24 hour soak of English holly in ethanol and IBA. After reading in Hartmann and Kester's text (1) on plant propagation the advantages of liquid hormones I decided this was the way to go. Since that time I have been involved with improving my abilities in rooting cuttings as a commercial wholesale grower. My first tests with ethanol as a solvent showed that with certain water sources as a diluent, a precipitate would form. From there I went to additional solvents to prevent this. After trying many, I found improved rooting was because of better penetration of the hormone through the plant tissue, I determined to find the best additional solvent for penetration.

To me, the reasons for using a liquid hormone are many. Firstly, you can select the concentration best for the species or cultivars you grow. The best concentration for any given plant is varied because of climate, fertility, water, age of plant, hardness of cutting, and time of year. The way you can deter-

this year, set in Spencer-Lemaire containers, and placed in greenhouses. The resulting stock will be planted under production conditions in October, 1981.

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mine the best concentration for your method of growing is by a series of bracketing three concentrations on a small number of cuttings. Another advantage is you can stock one hormone with an infinite number of concentrations possible, instead of stocking many powders with different concentrations, and still maybe not having the best concentration for your conditions. Also with a liquid hormone, you get better penetration of tissue and tend to form roots as deeply as you dip the cutting instead of getting roots mostly on the wounded basal end. The less concentrated forms require longer periods of soaks and are not as economically feasible. In addition, many times with a powder, if the cutting is too wet excessive amounts of powder adhere to the cutting and, if too dry, too little is retained. With a liquid dip all are evenly treated. With these things in mind I proceeded to formulate a liquid hormone.

As with the development of any new item, a multistage effort was started. First, as is usual, a literature search was done. Maybe the only difference with our search was the inclusion of medical literature. More effort has been given to animal tissue penetration than plants and, hopefully, something different would turn up. Concentration was given mostly to the dipolar aprotic solvents. Those that were chosen were sulfolane, dimethyl acetamide, dimethyl formamide, dimethyl sulfoxide, and acetone. Dioxane was also tried but rejected because of plant toxicity. The reason for choosing this group was that they were exceptionally useful in crossing through living tissue without undue toxicity.

Another group was chosen for the following characteristics: evidence of penetration, tissue tolerance, compatibility, and tissue preservative qualities. These were mannitol, sorbital, glycerine, and propylene glycol. Also included were magnesium sulfate and magnesium chloride for their properties of altering or improving crossing of materials through membranes.

The next step was a tissue penetration test of the materials, using Rhodamine B and Malachite green. Incidentally, Rhodamine B was the most effective for this purpose.

These materials were then incorporated with ethanol. Ethanol has many properties that make it the logical primary solvent. Besides it's highly solvent properties and price, it's high volatility allows the concentration of the auxin-like materials for absorption. These solvents were then used with indole-3-butyric acid and 1-naphthaleneacetic acid.

The last and final phase was the determination of whether or not they would aid in the rooting of plants. Twenty different kinds of plants were used in a blind study to determine

their rooting ability. An additional ten kinds of plants were then tested on the most promising formulations. Many of the easier rooting plants were almost equal in their response as would be expected. The most promising solvent in our tests proved to be dimethyl formamide. I will admit my evaluations were based on how quickly they rooted and with thirty years experience, which ones I would rather have to plant on. I would like to thank the Environmental Protection Agency for the way they worked with me in the approval of this formulation.

Now to address the title of this paper, research has commenced on several different projects. One a hydrophilic dip containing a fungistat and a rooting hormone for those bareroot trees that are hard to establish after storage. Another is a pressurized spray can containing a callusing agent, a fungistat, and with enough mechanical strength to hold a field bud in place without desiccation and allow the resultant growth to be unimpeded. Work is progressing on the rooting of plants in polyethylene in storage instead of in conventional media. Hopefully one or more will work out.

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GENETIC STABILITY OF HORTICULTURAL PLANTS PROPAGATED BY TISSUE CULTURE

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The term tissue culture, as popularly used, covers a multitude of cell, tissue, and organ culture techniques. The aspect of most interest to plant propagators is micropropagation, the rapid asexual multiplication *in vitro* of a desired plant. Most commonly, the explant used in micropropagation is a meristem-tip, shoot-tip, or bud that is induced to grow and then proliferate in culture. The basis of this procedure is the stimulation of new shoots *in vitro* by treatment with an appropriate plant growth hormone. A cytokinin in the culture medium stimulates growth of axillary and/or adventitious buds. The resulting shoots can then be rooted by transferring them to a medium free of cytokinin and containing an appropriate auxin

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concentration, or by rooting them directly in the greenhouse using more or less standard procedures. Micropropagation can also include the production of somatic embryos in culture, a process which is also under hormonal control. Propagation by somatic embryogenesis is not yet typical of commercial applications.

Questions concerning the genetic stability of plants produced by tissue culture often arise. Will these plants look like and grow like the source plant from which the cultures were initially established? The answer to the question depends upon a number of factors including the type of plant in culture and its inherent stability, the culture techniques being used, the growth regulators and other chemicals employed in the media, and the cells, tissues, or organs being cultured.

Generally, plants regenerated from axillary shoots are considered most likely to be phenotypically identical to the parent plant (2,5), while plants derived from adventitious shoots or somatic embryos are considered to be more likely to differ phenotypically, particularly if they arise from callus.

In actual practice, however, genetically stable plants, phenotypically identical to the original, are produced by all of these methods. On the other hand, aberrant or mutant plants are also produced by all of these methods. The result is that one must know well the plants being tissue cultured and develop experience to know the best means of handling them. For example, Boston fern (*Nephrolepis exaltata bostoniensis*), which tends to be unstable, may yield up to 25% aberrant plants from tissue culture (A. Donnan, personal communication). This problem can be overcome by limiting the number of subcultures and starting new cultures often using clean stock plants. Some ornamental plants, e.g. *Alocasia* sp., are regularly micropropagated using shoots derived from callus without any loss of phenotypic identity (J. Rowe, personal communication).

Another example of genetically stable plants produced from callus is that of 'Seyval' grape (3,4). Callus cultures were established from various parts of the plants of 'Seyval' and somatic embryos were induced to form from the callus. Many of the embryos were successfully cultured until they grew into plants which were transferred to soil and then planted in a vineyard. These vines have now all fruited for several years. While they are phenotypically identical to one another, none resemble exactly the standard plants of 'Seyval', differing in such characteristics as anthocyanin content of the stems and shape of the fruit cluster (3,6). However, all match the original description of this cultivar more closely than do the current

standard plants of 'Seyval'. The reason for this difference is unknown but it is unlikely to be due to a difference in virus content. A reasonable possibility is that the differences are due to epigenetic changes that occurred during the years since the cultivar was first described. They would be comparable, for example, to the changes in leaf shape, growth habit, etc., occuring in *Hedera helix* as it develops from the juvenile to the mature phase.

Besides phenotypic stability, the field or greenhouse performance of micropropagated plants is a prime consideration. Evaluation for both factors is well illustrated with micropropagated strawberries in a large field experiment at Beltsville (7). Meristem-tips were cultured from virus-indexed plants of 'Earliglow', 'Guardian', and 'Redchief' and then were proliferated and rooted on a modified Boxus medium (1). Plants were set in the field at the end of May, 1979, and allowed to runner freely throughout the summer until the plants filled a square 60 cm × 60 cm. Additional runners were then cut off. The plants in the squares were evaluated in the fall for vegetative characteristics. Tissue-cultured plants produced more crowns, more runners, better filled the square, and were generally more vigorous than the standard runner-propagated plants. The following spring, the tissue-cultured plants had many more flowers in each square because each square had more crowns and each crown produced more trusses. However, the number of flowers per truss was not increased on the tissue-cultured plants. The flowering data indicated a potential for a 160% increase in yield but only a 25% increase (based on fruit weight) was realized. This difference resulted from a reduction in fruit set and a 25% reduction in average fruit weight on the squares of tissue-cultured plants. Fruit size reduction resulted mainly from a size decrease in the normally larger fruit harvested in the first 2 pickings. Much of the size reduction is thought to result from the greater competition between crowns in the squares of tissue-cultured plants.

A small portion of these tissue-cultured strawberries and all the runner-propagated control squares were grown a second season and yields were again taken. With 'Earliglow', the squares grown from tissue-cultured plants produced larger fruit and more crowns in the second fruiting season. For all cultivars combined, the fruit yield from the squares of tissue-cultured plants was about double that of the runner-propagated controls, whether measured as number of fruit or total fruit weight.

For the strawberry experiment described above, the cultural practices were those normally used for runner-propagated plants. Since the tissue-cultured plants are much more

vigorous, they could probably be planted much later in the season and still produce enough runners for an adequate crop of fruit. This has been done in a preliminary trial at Beltsville. Late planting would reduce the overcrowding that was observed in the squares produced from tissue-cultured plants. It would lead to other changes in the cultural system as well. Thus to take full advantage of the increased vigor and runnering ability of tissue-cultured strawberry plants, it will be necessary to modify the entire cultural system now being used. Studies on such modified systems are now under way at the University of Maryland.

The idea of modifying the complete cultural system to derive maximum benefits from tissue-cultured plants may be applicable to most, if not all, horticultural crops propagated in this way. Any change will depend on the use to which the plants are put, the length of time it takes them to mature, and the persistence of characteristics, such as increased vigor, which are associated with the tissue culture process.

The evidence is clear, I think, that genetic stability, as represented by phenotypic appearance and performance, will not be a serious obstacle to greater application of tissue culture propagation to horticultural crops. This does not mean that genetic abnormalities or changes will not occur, as they most certainly will, but that they can be dealt with by careful attention to detail during the tissue culture process and by careful inspection and roguing of the resulting plants.

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MODERATOR CARVILLE: We will now have questions for our panelists but first Don Dillon has something to say.

DON DILLON: One of the important products of the whole Society is the annual *Proceedings*. Now that we have grown from just the Eastern Region to the Western, the Southern, the Great Britain and Ireland, the Australian, and the New Zealand — the whole bit, there are so many papers now being produced that it is hard to keep up with everything. The International Board has been concerned that we need some way to know what each of the Regions are doing, what happened in the prior years, what progress has been made. So a plea went out to anyone with any idea on how to develop an Index that would cover the past 30 years of papers produced by this organization. The point I am making is that we are very privileged to have someone who responded to that plea; he is here today and he is up here at the table. He just presented the last paper — Dr. Richard Zimmerman. He has volunteered, free, to index the past 30 years of the *Proceedings*. This work is already underway; he has completed the author index thus far, and the subject index, and is now starting to work on the plant material index. We are most appreciative. So sometime in the future we will be getting an additional product from our Society — a 30 year Index. We are much indebted to Dr. Zimmerman for this.

MODERATOR CARVILLE: This is probably the best news that I have heard since I have been here. I have been on the International Board for a few years, and I might say that this is one of its concerns — first of all to update the current Index of the *Proceedings*, and then to find a way to do it within a budget, and along comes a sincere, dedicated member of the Eastern Region who is willing to put forth his time and effort into doing this tremendous task of identifying all speakers' topics, all generic plant names mentioned in all of these many papers. Dick, my sincere thanks to you.

Now to the subject at hand — any questions from the audience on our previous topic — plant growth regulators?

HUDSON HARTMANN: Dr. Zimmerman used the term "sub-clone" in his presentation. I would like to know how he defines "sub-clone".

RICHARD ZIMMERMAN: But, really, this is a very tricky

question. We had a symposium at the American Society for Horticultural Science meeting in Atlanta a few weeks ago on just the topic of the clone.

I really don't know what we should call these, but we had four different meristem tips that came from the same mother plant. We proliferated tissue from them so, basically, I suppose you can say they are the same clone — but what do you call them? We called them "sub-clones" in our slide. We are referring just to the plants derived from that particular meristem tip. They were all of the clone 'Earliglow,' if you will accept cultivar and clone being equivalent in this case. So this was the only way of keeping them separate. Of course, you can get into all sorts of things, for example when you start talking about Shepard's work with potato where he took the leaf of a potato and got protoplasts for regeneration, with a whole range of variation from the plants regenerated from that potato leaf. I don't know. It is a real problem. We really didn't resolve definitions or the proper usage at the Atlanta ASHS symposium.

RALPH SHUGERT: Ed Wood — would you explain your philosophy on rooting cuttings using a liquid hormone preparation: length of time that cutting should be in the hormone — 1 second, 5 seconds, 10 seconds, 24 hours; also the depth that that cutting should be inserted in the liquid.

ED WOOD: Well, the second part first. In my opinion, you dip the cutting to the depth at which you want roots to form. The hormone material tends to penetrate right through the tissue and forms roots to that depth. To approach the problem of how long an immersion — say a 5 second dip; if you dip it in and out, the liquid is going to be on for more than 5 seconds anyway, so I am not sure 5 seconds is going to penetrate that much. If you have very difficult-to-root material, you keep raising the concentration, but you may end up burning the cutting. We used to do this with *Photinia* × *fraseri*. I burned the devil out of the bottom of the cutting but the hormone seeks its own level so roots form above the burned part and you just cut the dead bottom off when you pull the cuttings out of the flat. Rather than do that, however, maybe you should try a little longer soak at a lower concentration. You are going to have to work that out because it is going to be different not only for every plant, but how that particular plant was grown — what kind of wood you are using. I think there is a good reason on hard-to-root material to use a longer soak where you get more penetration.

RALPH SHUGERT: From an economic standpoint, you can use the proper hormone but at a lesser concentration and a

longer dip. I don't think we have paid much attention to this. We are in a hurry and we just dip the cutting in and we bring it back up. Try cutting the concentration down and count to ten rather than five. You might be surprised at some of the results.

LARRY CARVILLE: I think one of the points that was made in that first question from Shugert to Wood, when he talked about a quick dip is — what is a "quick dip"? We read in the literature that it means 5 seconds to one person, or 10 seconds to another. Bob Ticknor mentioned something about his concentration as being 1 to 5; and we read in the literature 1 to 10, 1 to 15, etc. Now, is that 14 parts water and 1 part liquid, or is it the other way around. I always thought for 1 to 5 to take 1 of Jiffy Grow, for example, and 5 parts water. Bob uses it the other way — 1 part of his root stimulant, then bringing it to 5 total parts by adding 4 parts water. This can make a substantial difference in your results, and what your records show, obviously.

ED SCHULTZ: Question to Ingemars Karlsson. What hormone did you use on rooting yellow cedar and what medium was in the containers?

INGEMARS KARLSSON: When we obtained good rooting we used Rootone. We had started mixing our own but we burned the cuttings. The rooting medium was ⅓ coarse sand, ⅓ peat, and ⅓ perlite. We kept the surroundings around the cuttings very dry. We find that yellow cedar cuttings just rot if we root them under the same conditions as used for western hemlock cuttings. They need a dryer environment.

VOICE: Question about Dip-and-Grow. I noticed a large variation in the color of the liquid, while on the store shelf. I try to pick the clearest bottle but it changes color over time. Is that changing the effectiveness of the material? What would be the shelf life?

ED WOOD: Well, the chemists tell me that there may be a very slight lessening of the rooting effectiveness once it is discolored by sunlight. All organic materials of this type should be stored in darkness. To find out if there was a loss in effectiveness I tried it myself and I could not tell any difference in rooting. So I am not too worried about the discoloration.

LARRY CARVILLE: You should be aware in selecting this material from your supplier how it is stored and how it is displayed, because obviously it should be stored in a place away from direct light. If you are buying in large quantity, in gallons and then breaking it down into usable sizes, store it in a dark place.

JIM SAHLSTROM: Is there any health hazard in using the Dip-and-Grow rooting material?

ED WOOD: In the first place use good common sense. Don't take a bath in it. It has almost 80% alcohol and 20% DMSO in it. I don't really think that there are that many health hazards. Always follow the label and you are safe.

LARRY CARVILLE: Use of gloves in handling any of these compounds is good practical advice and you should have them available in your propagation department.

BRUCE BRIGGS: A general question for the panel. David Lane, you mentioned that the literature states that IAA breaks down fairly fast. You showed that when you used NAA at high concentrations in the tissue culture medium, you had better rooting. My question would be to you and the panel, first of all, why did you not use IAA, it would break down still faster? To Dave, and to the other panel members — why do we use combinations of hormones in our tissue culture? I would like to hear you comment on both of those two phases. On the one question — on the quick breakdown; the other question would be on — why the combination of the two, not just one in your formulation?

DAVID LANE: There are a number of auxins that you have to choose from for rooting in tissue culture. The ones that you think of immediately are IAA, IBA, NAA, and perhaps even 2,4-D. These auxins have different levels at which they become phytotoxic, first of all — and they also have different activities as auxins so that they initiate different numbers of roots, depending on their activity at a specific concentration. We found that NAA is a more active auxin than IBA; in other words, there are more roots produced at a certain concentration than with IBA, or with IAA. It is less phytotoxic. So when we started out we tended to use NAA rather than the others because our objective at that time was to produce the maximum number of root initials as quickly as possible. For the chronic treatment, with the Malling 9 apple rootstock, where we had just the dip and then took it out, and put it into a zero hormone mix, I guess we were just following through with the NAA that we used before. But I think it would be quite possible to use IAA, perhaps at a higher concentration than would be necessary with NAA, and it would break down more quickly and, perhaps, be just as effective.

I have no comments on using mixtures, but by using mixtures I suppose you could adjust the rate of breakdown and the concentration at different times during the incubation. With IAA, for example, there are some reports that in media

exposed to light, that it decreases in concentration, with a half-life of three days, four days, or something in that order.

RICHARD ZIMMERMAN: I am not positive of the source, but I think in the book, "Tissue Culture for Plant Propagators," by Defossard from Australia, there is a recommendation for using mixtures of both cytokinins and auxins. I don't know of any other place where this has been recommended, or has really been used. It is a problem that you get into. Trying to sort out the effects of the different ones; we intended to stay just with a single one rather than getting into combinations, so far. We may get into combinations for some materials difficult to root. I will have to see if this might be useful.

WILBUR ANDERSON: In the propagation of peas in aseptic culture, we have had to go to double cytokinins to get multiplication of shoots. If we only use one we just get green shoots; if we don't use it we lose the good, green healthy condition. The other cytokinin is necessary for multiplication. So I think each of the cytokinins and auxins have specific functions in the culture environment, or in a growing plant outside the culture. I think that we do have to look at some of these things and not forget that there are possibilities of combinations.

KEITH TURNER: I have a comment on what we have been speaking. When you are working with combinations of auxins, two different auxins, or combinations of two different cytokinins, the size of your experiment becomes extremely large, because you can't pick one concentration of one auxin, and then test a range of the other auxins. You must have at least five concentrations of each auxin. So you end up with 25 different treatments and it gets to be a huge experiment.

But my main question is to Ed Wood. What is the carrier for the active hormone in your material? You mentioned dimethyl sulfoxide, but another was said to be more effective.

ED WOOD: Dimethyl formamide.

MODERATOR PHIL PARVIN: Our next panel has speakers from distant parts of the world, Arie van Vliet from the famous nursery center at Boskoop, Holland, and Ed Bunker, one of the founding members of the Australian Region, from Queensland, Australia. Arie van Vliet will speak to us now:

WHAT'S NEW IN PROPAGATION AT BOSKOOP, HOLLAND

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Boskoop. The nursery center of Boskoop is about five centuries old. In the old days mostly fruit trees and small fruits were grown. In the last 100 years only ornamental trees and shrubs, coniferous and broadleaf evergreens have been grown.

Today Boskoop is a nursery center of about 900 hectares (2200 acres). In this center we have 1000 nurseries, of which 900 are strictly growers, and 100 are growers and exporters. Of these, 45 percent have a nursery of about half hectare (a little more than one acre). They are full-time nurserymen and are one or two person operations. The average exporter has more employees which he needs in the packing and shipping season. In the summer they work in the exporter's nursery in which specialty items are grown for customers in the countries shipped to. Most exporters only ship to one or two countries and they will visit their customers once or twice a year.

Export. About 75 percent of the nursery stock grown in Boskoop is exported to about 75 countries. West Germany gets 30 percent, England 20 percent, France 10 percent, Canada 3 percent, and the U.S.A. 2 percent.

The total export of nursery stock from Holland from July 1, 1980 to June 30, 1981 was about 100 million dollars Canadian. The export to Canada in the same period was 3 million dollars Canadian and to the U.S.A. was 2 million dollars Canadian.

Climate. Boskoop has a sea climate, which means an average temperature in July of 17°C and in January −2°C, which is most suitable for growing nursery stock. Moreover, due to the many small canals in our area we seldom have late night frosts in the spring.

Soil. Boskoop is a peaty area, but what is above the watertable is a man-made soil, consisting of about ⅓ peat, ⅓ clay and ⅓ sand, with a pH of 4.5 to 5.5, which is suitable for all ericaceous plants, and a lot of other kinds of trees and shrubs. Due to a closed drainage system the watertable is constantly 50 to 60 cm below the surface. Figures show that by the introduction of the closed drainage system production was raised by about 30 percent. Due to shrinking of the topsoil and digging rootballs of nursery plants every three years the top layer must be raised by about 10 to 15 cm. In former times this

material was dredged by hand out of the canals, nowadays it is brought in by barge or truck.

Transportation. In the old days transportation was by barge through the canals. Now, many canals have been filled in and most transportation is done by small trucks; transportation by truck is a great time-saving improvement compared to transportation by barge.

Plant Propagation. In former times many softwood and evergreen cuttings were stuck in cold frames under double glass. This method of propagation is still used on most nurseries; it is an easy way to propagate in summer as it does not take much investments or room and does not cost energy at all. Today the second layer of glass is often replaced by plastic, in the greenhouses as well as in the coldframes outside. On the outer side of the coldframes we use an extra sheet of plastic to prevent dripping of rainwater on the inner plastic layer. Nowadays plastic is also used as a tunnel in greenhouse and in the open. Concern for timing in taking cuttings and the use of growth hormones is advised by the Research Station. One of the latest developments is the use of Captan powder on the base of hardwood and evergreen cuttings to prevent fungus at the base of the cuttings.

Another development is taking hardwood cuttings in the wintertime (from early January until April) in a greenhouse kept frost-free (+5°C). The cuttings are stuck in plastic pots and the pots are placed on top of the soil, and covered with plastic tunnels. Beside propagation by cuttings many plants are still grafted because many cultivars cannot be rooted from cuttings. Grafting is done through the whole year.

In late winter and early spring a lot of grafting is done on bare-root rootstocks (understocks) which have been kept in cold storage. Many rootstocks are also potted and grafted right after potting, or kept in pots half the growing season, or kept in pots until the next spring. Latest developments in grafting are grafting of miniature tree roses, rhododendrons, *Salix caprea* 'Pendula', *Populus canescens* in cultivars on unrooted hardwood cuttings, Rosa *multiflora*, *Populus alba*, *Salix smithiana*, as unrooted rootstocks without leaves, and Rhododendrons ('Cunningham's White', 'Catawbiense Grandiflorum', 'Roseum Elegans'), with some leaves kept on the unrooted cuttings. It might be of interest, too, that the unrooted cuttings of the *Salix* are 2 meters long (6') and for roses 60 cm (2'); in all cases results are very good.

Growing in Containers. During the last 10 years there has been a new development in growing plants in plastic pots, mostly in 7 or 9 cm pots. One of the reasons for doing this is to

extend the planting season, as well as transplanting time. Moreover, in our area, as I pointed out before, the average nursery is about 2½ acres in size and by switching from field-grown to container-grown material, the number of plants per acre can be increased substantially. This is another reason by which a small nursery in the Boskoop area can survive. This new development, which originally came from the U.S.A., is very important for the existence of Boskoop as a plant production area.

Watering Plants in Containers. Small units are watered with nozzles. Larger units are watered with overhead sprinklers. Larger pots are watered by trickle irrigation. When using trickle irrigation the water has to be of very good quality, otherwise the small tubes will be clogged. Capillary watering is of no interest in our area, the lower part of the plant is kept too wet (fully soaked).

Fertilizing Plants in Containers. Most plants in pots are fertilized with a total soluble fertilizer called Kristalon, based on 17N-6P-18K, in quantities of 20 grams per square meter per week. When we use granular fertilizer we mostly use the eight month Osmocote, three grams in the potting mixture when potting early spring, and another three grams in middle July.

Assortments. Although individual growers and exporters will try to obtain new cultivars, the most important work in this field is done by the judging committee of the Royal Boskoop Growers' Association. They will judge collections and new cultivars brought together at the trial grounds of the Research Station to examine their possible use in gardens. Judging of plant collections is the most valuable. The plants will be criticized several times and provided with merit stars as follows:

Excellent ★★★ (three merit stars)
Very Good ★★ (two merit stars)
Good ★ (one merit star)
S = for special purposes (for instance for a botanical garden)
O = can be eliminated.

During the judgment of the collections, attention is paid to their growth, flowering, resistance to diseases, winter hardiness, etc. Moreover, attention is paid to the reduction of the number of species and cultivars; this is important as well. There is no sense in growing very extensive collections. Too many cultivars closely resemble another one.

Cultivars recently under cultivation in nurseries in Boskoop are:

Amelanchier lamarckii 'Ballerina'
Rhododendron (*Azalea*) (*viscosa*-hybrid) 'Jolie Madame'
Buddleia davidii 'Nanho Blue'
Caragana arborescens 'Walker'
Cercis canadensis 'Forest Pansy'
Cornus nuttallii 'Monarch'
C. nuttallii 'Ascona'
Clematis tangutica 'Aureolin'
Cotoneaster (*dammeri* hybrid) 'Eichholz'
Cedrus deodara 'Golden Horizon'
Elaeagnus pungens 'Goldrim'
Genista pilosa 'Goldilocks'
G. tinctoria 'Golden Plate'
Hamamelis intermedia 'Diane'
Hedera colchica 'Sulpher Heart'
Hydrangea arborescens 'Annabelle'
Magnolia 'Susan'
Mahonia aquifolium 'Smaragd'
Malus 'Red Sentinel'
Pieris japonica 'Debutante'
P. japonica 'Red Mill'
Populus balsamifera (Syn.: *P. candicans*) 'Aurora'
Potentilla fruticosa 'Red Ace'
P. fruticosa 'Royal Flush'
P. fruticosa 'Goldstar'
Spiraea japonica 'Shirobana'
S. nipponica 'June Bride'
Ulmus elegantissima 'Jacq. Hillier'
Viburnum plicatum 'Cascade'
Wisteria floribunda 'Issai Perfect'
Dicentra 'Luxuriant'
Hosta 'Royal Standard'
H. sieboldiana 'Frances Williams'

GROWING CERTAIN AUSTRALIAN NATIVE SHRUBS AND TREES FROM SOFTWOOD CUTTINGS

EDWARD J. BUNKER

Redlands Greenhouses
Redland Bay, Queensland, Australia

All of us know that many plants in our gardens are hard to propagate, and yet are very desirable. Amongst this group of plants are many of the Australian native shrubs. Selections of our Australian native plants have been made by enthusiasts and nurserymen and some hybridization has been carried out. Also some hybridization has happened in gardens. Many of these plants in flower are very spectacular but many of them are very hard to propagate in commercial quantities.

This paper is aimed mainly at rooting cuttings in the genera *Grevillea*, *Melaleuca*, *Callistemon* and *Leptospermum*, but I will finish with one or two observations and thoughts on micro cuttings of some foliage plants.

Of course it goes without saying that without the right cutting wood from parent stock, one has very little chance of getting good results. In work carried out in our nursery over the last ten years, we have developed some techniques in managing stock plants and getting very good results in the rooting of plants in these genera. However, we still have some exceptions in very hard-to-root cultivars.

It is essential to use juvenile cuttings and juvenility needs to be induced and maintained in stock plants to have any

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Cedrus deodara 'Golden Horizon'
Elaeagnus pungens 'Goldrim'
Genista pilosa 'Goldilocks'
G. tinctoria 'Golden Plate'
Hamamelis intermedia 'Diane'
Hedera colchica 'Sulpher Heart'
Hydrangea arborescens 'Annabelle'
Magnolia 'Susan'
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Of course it goes without saying that without the right cutting wood from parent stock, one has very little chance of getting good results. In work carried out in our nursery over the last ten years, we have developed some techniques in managing stock plants and getting very good results in the rooting of plants in these genera. However, we still have some exceptions in very hard-to-root cultivars.

It is essential to use juvenile cuttings and juvenility needs to be induced and maintained in stock plants to have any

success at all. We currently have planted out, in stock areas, many of the cultivars we are using. We maintain about two acres of these now. We find that we have to prune them regularly on about a four-month rotation to get the cuttings we require. The stock bushes are allowed to grow to a reasonably mature stage initially, during which time we take cuttings whenever required. When the bushes begin to harden off we prune severely, cutting the plant back to about ⅓ of its original size.

In the genus *Grevillea* and, in particular, the three cultivars — 'Sandra Gordon', 'Robyn Gordon' and 'Misty Pink', we find that we have plants that won't stop flowering. With 'Robyn Gordon' and 'Misty Pink', there are masses of flower buds produced on each and every terminal. 'Sandra Gordon', in winter — from the end of April till the middle of October (in Australia), does nothing but flower on every growth. With 'Sandra Gordon' we find it easier to do all of our propagation in the warmer months and, in particular, just prior to flowering. The rooting results we have with 'Sandra Gordon' vary from around about 40 to 80 percent. In propagating 'Misty Pink' and 'Robyn Gordon', we are getting close to all cuttings planted growing on.

We like to replant our stock plants every three years, and we keep them pruned so that every fourth month the bush is pruned back severely. In between we go through on a monthly basis and remove all buds. *Grevillea* 'Misty Pink' is grown from short cuttings about three inches in length from very soft material. The bush itself grows to about eight feet and we shorten it back in our major prunings by about half; some of the branches being cut are as thick as a broom handle. Depending on the time of year, about six weeks after pruning, cuttings are ready to take and from a mature bush we can harvest about fifty cuttings every two to three weeks.

In the stock area we maintain very low fertility and spray regularly for mites and leaf spot (*Verucisporum proteacarum*). Spraying is done on a monthly basis with a regular spraying schedule.

I would now like to go into more detail with one cultivar that we have perfected. *Grevillea* 'Robyn Gordon' is one of the more desirable of the cultivars available in the genus *Grevillea*. It grows in most areas of Australia very well and flowers all the year round. It is a sterile hybrid; the only way to make more plants is by cuttings. Plants flower at a very early age, and we have to remove these flowers in the first instance as soon as they are large enough to handle. We do this by going through manually with a pair of secateurs, and taking them off

just above the growing eyes. Cuttings shoot away very quickly, some of them flowering but most being vegetative shoots only.

We take the cutting about four inches long, and we always make sure we take these in the first hours of the morning before the heat of the day. Once we have collected a hundred cuttings, we drop them into a drum containing two gallons of water, into which we have put half a cup of refined sugar. The cuttings are placed in the solution while the propagating staff collects another hundred cuttings — this is for probably about five minutes. The cuttings are turned over when they are placed in the solution, so that they all get nicely wet. When the propagating staff comes back with the next hundred cuttings, they remove the ones that have been soaking and wrap them in clean newspaper, making sure that plenty of moisture is enclosed with the cuttings. The cuttings are arranged on the paper so that they are not bent when they are wrapped up; they are then wrapped fairly firmly into a parcel, and excess moisture is drained out of the bundle from one end. They are then placed in a large box until the next stage.

Once all the cuttings are taken, the staff then takes them to the workroom and unwraps the bundles and trims the cuttings. The tips are taken off, and the leaves are shortened back considerably, so that only about ⅓ of the leaf area is left. We cut all the cuttings between the nodes, not at a node; nodal cuttings tend to over-callus. These cuttings are then rewrapped in the same paper, as it is by now very moist and impregnated with the sugar solution.

It has been fairly widely known in Australia for many years, that a sugar solution to dip these very immature, soft cuttings in, makes a tremendous difference in the way they maintain on the mist benches. We think that the cuttings absorb some of the solution through their leaves, and it tends to make them more turgid, and they stand up much better. We are so confident of this theory that we use it on all of our native plant material that has to be grown from such young immature tip growth and, through tests we have carried out, I would say that it makes a difference of about 25% in our results.

The cuttings are planted in trays of perlite and peat, a 50-50 mixture, the only addition being 1 kg of dolomite (magnesium carbonate) to each cubic yard. Cuttings are dipped in a 1 to 2 second dip of 4 grams per litre of indole-3-butyric acid and water, and then planted in individual pots. Heated benches are then used on which to place the cuttings. Bottom heat is held between 70° and 80° F, with a thermostat control. The cuttings are kept on these benches, under mist, for about two

weeks. The mist is controlled by a balance-arm or a time clock; each way seems to be good, as far as we have found out.

We find that cuttings are rooted and off the bench in about 2 to 3 weeks, and again it depends on the time of the year — winter taking requires a little longer. We have found most *Grevillea* cuttings callus quite quickly — in 7 to 10 days — but, if the cutting material is not right, or they are kept too wet, or the light is not just right, they will continue to callus until the cutting pot is full of callus, but the cuttings won't root. However, if everything is right and the plants are removed from the heat and mist the moment small roots begin to appear, they will continue to root and there are sufficient roots to make the plant grow into a viable and desirable sale item.

Calistemon and *Melaleuca* are much easier to get on with. Very, very tiny cuttings are still used, and treated in the same way, but they root much better, and easier.

I mentioned earlier that I would briefly go into some results of work being done on very young foliage plants, immediately after they have been established in the nursery media, after being taken from tissue culture jars. Quite a number of trees have been handled this way; the example that I will take is *Ficus lyrata*, but the same system applies to numerous others. When these are taken from tissue culture jars they are fortunate if they are ½" long. Once they are established and growing away in the potting medium, with a nice little tip on them, we can take these tiny cuttings from the small plant, and roots will develop very, very quickly. The original plant shoots away again, and often they will break with two or three heads. Those cuttings can again be removed, and they root as well. *Ficus lyrata* has been a difficult plant to handle in volume from large cutting material, taken from trees or container stock, but in this way many thousands of them can be built up in a comparatively short space of time, and grown on to very nice plants. In all cases where we have tried taking these micro cuttings from plants originating as tissue-cultured material, we have had very good success. We wonder whether by research in this field many of the difficult to grow plants in the nursery industry may not be able to be handled more easily in large volumes.

While many of the details mentioned in this paper are basic, I feel that many practicing propagators have very little knowledge or idea on how to maintain stock beds, and it is about time we made sure that this section of nursery practice came fully under the control of our propagators. For best results, it is imperative. Putting it into practice is not so easy.

A SMALL SCALE TISSUE CULTURE LABORATORY

FRED W. DE WALD

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I started as a backyard nurseryman some 40 years ago. When I raised a few plants I found out that I had to buy a license to sell them, so on March 19, 1948, I got my first license. That was 33 years ago. When I outgrew the backyard I bought a small ranch, on the outskirts of Snohomish, Washington. De Wald Nursery sits on 7½ acres along the East bank of the Pilchuck river.

My latest project has been starting a small scale tissue culture laboratory for rhododendrons. Tissue culture is a very complex and special way of propagation but at my age and with no more scientific knowledge than I have I can make it work. There is a vast future in tissue culture for many of you younger and more qualified people.

If you have any success at all with tissue culture it will not let you stay small. It multiplies and grows. To start with I took an old refrigerator, then installed heat cables on a thermostat, Gro-Lux lights on a timer, and a fan to circulate the air and keep it cool. In the refrigerator I built 5 shelves. Each shelf held one rack and each rack held 77 tissue culture tubes at the proper angle. This was a total of 385 tissue culture tubes.

One of the first and most important things to remember about any tissue culture set-up is to keep it clean of all contamination at all times. When I started my tissue culture of rhododendrons, I did not do it alone. I worked with Dr. Wilbur Anderson, from Mt. Vernon, Washington, who perfected the formula for starting, multiplication, and rooting rhododendron explants. I went to his laboratory where he furnished me with the filled and sterilized test tubes. I would bring my rhododendron cuttings with me then we sterilized and trimmed them for the test tubes. Transferring the cuttings to the test tubes was done by using a laminar flow hood. I would then place these tubes in my make-shift lab (the old refrigerator) for growing. I also attended a short course on tissue culture propagation of rhododendrons, sponsored by Dr. Anderson and Randy Burr at Skagit Valley College, Mount Vernon, Washington.

In November or December, 1979, I outgrew the old refrigerator and built a room 10′ wide and 28′ long upstairs in my storage shed. This room contained my kitchen, transfer hood, and 2 racks, 4′ by 8′ by 64″ high, with 4 shelves. There are two

Gro-Lux lights to each shelf. Each rack has the capacity for about 4,000 tubes. The racks are mounted on wheels so they could be moved for cleaning and easy access to the shelves.

Now the media are prepared, the tubes filled and sterilized here. Also the old tubes are opened and the plantlets transferred to clean tubes under a hood that I built for this process.

One year later this room became too small. I had one rack completely full and the second well on its way. Again, it was time to enlarge so I extended the room to 40 feet. This room will now hold 5 racks. Each rack will hold 4,000 tubes, so this will give me about 20,000 tubes total. This should give me all the pleasure and trouble that I will be able to stand. So then I had to build another room for the kitchen and transfer room.

At this stage in Dr. Anderson's course, I became an outlaw with the scientific way. I skipped Dr. Anderson's third stage, which is the rooting stage. I did this to save time and space. I took the cuttings directly from the multiplication medium in the test tube and placed them in the same medium that I use to root rhododendrons in the conventional way. This medium contains 1 part peat moss and 2 parts perlite. It was placed in plastic cocktail glasses to within one inch of the top and covered with a plastic petri dish lid. Before placing the tiny cuttings in the medium they were dipped in Hormodin #3, the same as I do with conventional cuttings. Each glass holds 20 cuttings. These glasses are then placed in a 12″ by 24″ flat filled with the same medium. Each flat holds 18 glasses. The flats are then placed on electric heat cables set at 65° to 70° F. The results that I have had this way have been so good, I see no reason to change my procedures at this time.

The small cuttings, ⅜″ to ¾″ high, have a good root system in about 6 weeks. These tiny plants are then placed in the greenhouse in beds with a fine bark mixture. The mixture contains in 4 cubic feet: one 5-gallon bucket of alder sawdust; and 1 scoop shovel of used starting mix (1 part peat moss + 2 parts perlite). The balance of the 4 cubic feet is fine bark. To this I added dolomite lime, sulphur, and trace elements. This mixture is then placed in a bed on the ground in the greenhouse. The bed is 42″ wide and 100′ long and has electric heating cables under it. The fine bark mixture is then placed 4 to 5 inches deep in the bed. This is the same method that I use in rooting cuttings the conventional way. From here I add more fertilizer and watch for all the problems that occur in raising any plant.

At the present time I have roughly 12,000 rooted rhododendron cuttings started in tissue culture. They range from ½″

to ¾" tall just rooted plants to those 10" to 12" tall. The latter plants are 'Jean Marie de Montague'. They were rooted cuttings a little over a year ago and it will take 2 more years to complete the cycle. At this stage the plants are developing nicely.

It is hard to give a talk when most of your thoughts are still unanswered questions, such as: time to take the cuttings, how long to sterilize, hardness of the wood, and all the other things that a grower must know even for conventional propagation. There are so few of us into tissue culture yet that is a real problem to get such information and material. I can't even get some rhododendron cultivars to start in the tubes. So there is much for me to learn. One of the biggest problems is to learn the different chemicals for the different rhododendron cultivars and how to change the chemicals for the starting and for the multiplication media for each individual plant. I have used the starting medium at ½ strength, regular strength, and double strength.

There is no one that goes any place alone in this world. You have to listen to those who know, and watch what they are doing. Also I think much will be learned by our mistakes and by keeping in close contact with each other to exchange information. Then by applying what looks reasonable to you in your way of accomplishing what you desire. What works for one person may not work for another.

Talking with Bruce Briggs the other day, I heard another new idea on tissue culture. If you get too many tubes of one rhododendron cultivar you can put them on refrigeration until you need them again. This opens a whole new field of questions. But at what stage of the multiplication do you put the tubes in storage and, roughly, how long will they hold in storage, and at what point will they be ready to use when you do return them to the growing room? I have started refrigerating several kinds in three different stages of the multiplication. After 2, 4, and 6 weeks I will take these tubes out of refrigeration, so later I will know which group of the tubes will stand refrigeration the best and how long they may be kept in refrigeration. But it takes a long time to get the answers to questions like these, possibly 1 to 2 years or even longer.

MODERATOR PARVIN: We have time for a few questions. Yes — John Hart.

JOHN HART: Question for Arie van Vliet. On your blue spruce grafting, how does the temperature for the August date

in Boskoop, Holland, correspond with temperature in the Pacific Northwest at that time of year; is it somewhat the same? And when you place the grafts in sawdust, what is the advantage of laying them on their side? Do you get roots growing into the sawdust outside of the pots the grafts are in?

ARIE VAN VLIET: First of all, it is not sawdust, it is peat moss. In the cold frames, the inner layer is clear glass; we don't use any cover on it. Now you might think that will burn, but as soon as the sun comes out, we will cover it. We cover extra heavy; otherwise the grafts will burn very fast. But we need the light the whole day, to get that cambium growth. As soon as the sun comes out, we run out real fast and cover it. Our average temperature in July is 17°C (63°F).

JOHN HART: The other thing in which I am interested is when you have such a high concentration of nurseries in Boskoop, do you have any problems with chemicals being sprayed by another nursery coming down on yours?

ARIE VAN VLIET: There have been a few claims, yes.

JUDY GARLOCK: I have a question for Ed Bunker. You were talking about *Grevillea* nutrition in relation to rooting. Our nursery has had a problem this past year with rooting *Grevillea* cuttings. I was wondering about a couple of things you said; one of them was about the superphosphate, to which you said they are sensitive. Another one is fertilization — if they are fertilized too heavily maybe the cuttings wouldn't root as well. Do you know whether that might extend to all *Grevillea* species?

ED BUNKER: As far as I know, it applies to all *Grevilleas*. I have talked to quite a few people around Australia about this. Everyone has had similar experiences; as soon as the fertilizer levels get out of balance, the plants won't grow properly. Consequently, you don't get good cutting material and you don't get good rooting.

MODERATOR BRUCE MORTON: The last panel of the meeting will deal with the topic of "Hard-to-Root Cultivars." Dr. Wilbur Anderson will be the lead-off speaker:

ETIOLATION AS AN AID TO ROOTING[1]

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Abstract. Delicious apple cultures of 'Supreme Red' and 'Wellspur' incubated in a shoot multiplication medium were etiolated by placing them in darkness under culture room conditions for 2 weeks. Etiolated and non-etiolated cultures were exposed to light culture room conditions for 0, 1, 2, 4, 8, and 16 days regreening prior to reincubation on a rooting medium. The treatments were incubated 3 weeks on this medium before rooting was evaluated. Average rooting percentages from etiolated treatments were 53% for 'Supreme Red' and 82% for 'Wellspur'; from non-etiolated treatments 2% and 10%, respectively. Treatments of 0, 1, and 2 days of regreening resulted in many cultures callusing and subsequent loss of the apical shoot tip.

The clonal propagation of self-rooted apple trees is a desirable technique as this would reduce time in producing trees and eliminate the costly step of either budding or grafting scion cultivars on rootstocks. *In vitro* production of self-rooted scion cultivars has been reported by several researchers including Boxus and Quoirin (2), Lane (5), Jones, Pontikis, and Hopgood (4), Zimmerman (6), and Zimmerman and Broome (7). It is recognized that there is variation in rooting difficulty between scion cultivars. The 'Red Delicious' group must be considered one of the most difficult to root cultivars. I have attempted rooting 'Red Delicious' and cultivars derived from it with the objective of determining the genetic stability and growth characteristics of the various cultivars.

We have conducted many experiments in my laboratory attempting to establish the appropriate conditions for rooting. These have included testing auxin concentrations in a range of 0 to 4.5 mg per liter IAA, IBA, and NAA. None of these treatments resulted in significant rooting. Concentrations of GA_3 were tested in a range of 0 to 15 mg per liter with no effect. Activated charcoal in concentrations up to 600 mg per liter has not been effective. Phloroglucinol, both autoclaved and cold sterilized, in concentrations of up to 325 g per liter, which is 2x the strength suggested by Jones (3) was not effective. The concentration ranges of inorganics have also been studied with minimal effect on root initiation.

A common practice used in commercial apple rootstock layering beds has been to etiolate the stems as a necessary

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[1] The following abbreviations have been used: IAA (indole-3-acetic acid); IBA (indole-3-butyric acid); NAA (B-naphthaleneacetic acid), BA (N_6-benzyl adenine) and GA_3 (gibberellin A_3).

practice for successful rooting. A natural extension of our research effort therefore turned to exploring the use of darkness for root enhancement of Red Delicious shoots propagated in culture.

METHODS AND MATERIALS

Two 'Delicious' apple cultures, 'Supreme Red' and 'Wellspur', were chosen for this experiment. These were cultures that were maintained on shoot multiplication media. The cultures were allowed to reach their climax multiplication by incubating them 3 weeks and then dividing the stocks between etiolated and non-etiolated treatments. These treatments were incubated for 2 more weeks in the multiplication medium. The etiolated cultures were placed in a light tight box for 2 weeks and maintained at normal culture room conditions of 20°C. The lighting in the room was cool white light with 16 hours duration per day and 1000 lux.

Table 1. Apple culture medium composition.

	Quantity per liter	
	Shoot Multiplication	Rooting
Sucrose	30 g	30 g
Inorganics - Anderson's (1)	1 x	0.5 x
Organics		
1 inositol	100 mg	100 mg
Adenine sulfate-dehydrate	80 mg	80 mg
Thiamine-HCl	0.4 mg	0.4 mg
Growth regulators		
IBA	0.1 mg	0.1 mg
BA	1.0 mg	
Agar	8 g	8 g
pH adjusted prior to addition of agar at:	5.7	5 7

In a previous experiment we observed that transferring etiolated shoots directly to a rooting medium resulted in many shoot tips forming a callus layer a few millimeters below the apex and, subsequently, the apex would die. The treatments of this experiment consisted of allowing the etiolated shoots to regreen in the shoot multiplication medium prior to reculturing onto the rooting medium. The regreening periods were 0, 1, 2, 4, 8, and 16 days before the shoots were recultured onto rooting media. The cultures were incubated in the rooting medium 3 weeks before evaluating the root and shoot development.

Each treatment consisted of 10 replicate recultures (1 shoot per 25 × 150 mm culture tube). The harvested shoots were evaluated for percentage of the cultures rooted and the rooting index. The rooting index was: 1 = no roots; 2 = root initials and up to 1 to 2 extended roots; 3 = numerous ex-

tended roots. The rooting index is an average of the 10 replicate shoots in each treatment. Each culture was rated for the percentage of intact shoot tips.

RESULTS

The etiolation treatments compared to the non-etiolated control improved the average percentage of rooting with both Red Delicious cultivars, 51% for 'Supreme Red' and 72% for 'Wellspur' (Table 2). 'Wellspur' consistently had a higher percentage of rooting than 'Supreme Red'. The average rooting index was greater in the etiolated treatments but there was a decline in the average quantity of cultures with intact shoots.

Table 2. Apple rooting percentages of etiolated and non-etiolated shoots and the effect of regreening treatments on maintenance of intact shoot tips.

		ETIOLATED			NON-ETIOLATED		
Cultivar	Days of Regreening	Percent rooted	Rooting[a] Index	Plants with intact shoot tips	Percent rooted	Rooting Index	Plants with intact shoot tips
Supreme Red	0	70%	1 7	30	0%	1 0	100
	1	70	1 7	30	0	1 0	100
	2	60	1 7	70	0	1 1	100
	4	60	2 2	90	0	1 1	100
	8	40	1 4	100	10	1.1	100
	16	20	1 3	100	0	1 0	100
	Average	53	1 7	70	2	1 0	100
Wellspur	0	60	1 7	60	10	1 1	100
	1	80	1 8	60	10	1.1	100
	2	100	2 0	70	50	1 5	100
	4	100	1 6	100	10	1 1	100
	8	80	2 0	100	0	1 0	100
	16	90	2 2	100	10	1 0	100
	Average	82	1 9	82	10	1 2	100

[a] The rooting index is an average of all the cultures in each treatment The rooting index 1 = no roots, 2 = root initials and up to 1-2 extended roots, 3 = numerous extended roots

Regreening of etiolated shoots from 0 to 4 days duration had no effect on the percent rooting. There was a reduction in rooting of 'Supreme Red' for 8 and 16 days regreening but this was not observed with 'Wellspur'. The major concern with the 0 to 2 day regreening was a significant number of plants forming callus and losing their shoot tip; with the 4 day regreening period this was of no concern.

DISCUSSION

Etiolation as a continuation of the shoot multiplication stage resulted in substantial improvement of root initiation. However, a regreening step must be added to reduce the shoot tip callusing and a subsequent loss of the shoot apex. Regreening for 4 days reduced this problem. These results suggest that the addition of the cytokinin BA in the shoot multiplication medium has a significant effect on maintaining integrity of the apical shoot tip in the regreening process.

The use of darkness in root initiation on difficult-to-root apple cultivars appears to have merit. The major problem with the system described is the general low vigor of plantlets established and the low survival rate in the planting out step. Plantlets that are rooted but have lost their apical tip frequently are established in soil but do not grow as rapidly as the plants with intact apical shoots. The dark treatment may not require conditions that cause true etiolation of the shoots. Etiolated shoots seem to be weakened and are difficult to acclimate the plants in the greenhouse. It may only require a short duration of darkness of less than 1 week to change the endogenous growth regulator balances to favor root initiation.

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CUTTING PROPAGATION OF *JUNIPERUS SCOPULORUM* CULTIVARS

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Several *Juniperus scopulorum* cultivars have been grown commercially for many years. These handsome landscape plants, some with striking blue-gray foliage, are used throughout North America as both accent and background plants. Because of their hardiness (Zone 3), they are used quite extensively in the Northern United States and in Canada.

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Due to the great difficulty in rooting cuttings of *Juniperus*

scopulorum, most cultivars have traditionally been propagated by grafting. Grafting, of course, is a very expensive means of propagation and, if possible, the rooting of cuttings would be a commercially preferred method. Through several experiments over the years we have learned to root several cultivars with a great degree of success so that many that formerly were grafted are now being produced by cuttings.

Through experimenting with rooting hormone concentrations we have improved the rooting percentages of certain cultivars to a point where it becomes economically feasible to eliminate propagation by grafting. The rooting percentage at which the company feels justifies cutting propagation is about 25%. Rooting levels below this point are considered unacceptable.

Presently, Monrovia Nursery Company grows nine *Juniperus scopulorum* cultivars. They are 'Cologreen', 'Cupressifolia Erecta', 'Gray Gleam', 'Pathfinder', 'Table Top' ('Table Top Blue'), 'Tolleson's Weeping', 'Wichita Blue', 'Welchii', and 'Wintergreen'. At this time only 'Cupressifolia Erecta' and 'Tolleson's Weeping' are produced exclusively by grafting because of their very low rooting percentages. Of the other cultivars some are produced by cuttings and others by both cuttings and grafting. We have found that the grafted plants grow much faster during the first season of growth than the cutting-grown plants. I believe this is due to the grafted plants starting out with better developed root system than the cuttings. When we have both grafted and cutting-grown plants, often we will use the grafted plants for upgrading into larger container sizes.

Although the grafted plants develop faster during the first season, I believe the reduced cost of propagation of the cutting-grown plants to be a more cost effective method of producing *Juniperus scopulorum* cultivars.

General Cultural Practices. The propagation process of all *Juniperus scopulorum* cultivars is basically the same, with the only exception being the rooting hormone treatment. As for most plants, the timing of propagation is very important. In Southern California the wood matures or "hardens-off", in late November. The minimum temperatures at this time of year range from 35° to 45°F. We try to take the *Juniperus scopulorum* cuttings as early in the season as possible because of their extended rooting periods.

Cutting wood is taken from both stock plantings and containerized plants in production, with the majority of the wood taken from containers. The wood from healthy, young vigorous plants is preferred. After the wood is cut it is stored until it can be prepared in refrigerated units maintained at 45° to 50°F.

Approximately 3-inch cuttings are prepared with at least some hard wood at the base. Heel cuttings are preferred and are used whenever possible. All foliage is stripped from the bottom inch of the cuttings.

After the cuttings are prepared they are disinfected by dipping in a 15 ppm solution of chlorinated water and dipped a second time in a 200 ppm Physan solution. The duration for each dip is about five seconds. Before being inserted into the propagation medium, which is 90% #3 perlite, and 10% peat moss, each cutting is dipped individually into the hormone solution designated for that cultivar. The cuttings are planted in plastic flats which measure about 18 inches square at the rate of 255 cuttings per flat. The flats are placed outdoors under mist in the full sun. We use our hot water heated, concrete propagation beds for the rooting of the cuttings. The concrete surface of the bed is disinfected prior to putting the flats down by rinsing with Physan and applying Citcop 6E to the surface.

Depending on weather conditions, intermittent mist is applied at intervals ranging from 12 minutes to 30 minutes. This is the same rate at which mist is applied to all our juniper cuttings.

Bottom heat is essential in the successful rooting of *Juniperus scopulorum* cuttings. During the first six weeks the temperature in the medium is maintained at a minimum of 60° to 65°F, then increased to 70° to 75°F, thereafter. The reduced temperature in the initial six weeks allows the wound on the bottom of the cutting to callus without excessive heat that might encourage disease.

Cuttings of most *Juniperus scopulorum* cultivars root sufficiently well to be transplanted in five to six months. Before transplanting into pots the cuttings are "hardened-off" by discontinuing the bottom heat and gradually reducing the mist. After the mist has been discontinued the cutting flats are irrigated on a regular basis by impact sprinklers. The water used for irrigation at this time is injected with the same fertilizer that is used for container production. If space allows, the cutting flats remain in the propagation beds until they can be potted.

Notes on Specific Cultivars. The cultivars discussed here are ones with which we have made significant progress. Grafting still continues on some of the following cultivars, but because of higher rooting percentages we may need to reevaluate our grafting program for the future.

Juniperus scopulorum 'Cologreen'. Cuttings of this plant respond well to a liquid hormone treatment of 3000 ppm NAA

(napthaleneacetic acid) as a quick dip. They normally root about 40% for us. In one experiment we had 74% rooting with 45,000 ppm IBA (indolebutyric acid) in talc. We prefer to use liquid hormones because of the lower cost and ease of handling, but these results warrent further consideration. In another experiment, it was found that soaking the bases of cuttings in various strengths of sulfuric acid solutions prior to dipping in hormone did not improve rooting. About half of our production is still grafted for this cultivar.

Juniperus scopulorum 'Gray Gleam'. This plant will root 52% with a liquid hormone treatment of 6000 ppm IBA. Higher concentrations of IBA and NAA seem to have an adverse effect on rooting. Experiments with DMSO have not increased rooting significantly. About half of our production with this cultivar is grafted.

Juniperus scopulorum 'Pathfinder'. We have completely discontinued grafting this cultivar because of the high rooting percentages. Currently we are getting 62% with a liquid solution of 8000 ppm IBA but higher concentrations of IBA seem to have an adverse effect on rooting.

Juniperus scopulorum 'Table Top'. This spreading type juniper responds best to the higher concentrations of IBA. Currently we are using 16,000 ppm IBA in talc and getting 63% rooting. We feel the significant difference between the liquid and the talc justifies the use of talc in this case.

Juniperus scopulorum 'Wichita Blue'. We are currently using 8000 ppm IBA liquid and getting 57% rooting. This cultivar also responds well to 16,000 ppm IBA in talc, but the increased percentage does not justify the use of a powder at this time. The use of DMSO has slightly improved rooting, but not significantly.

SUMMARY

Cutting propagation of *Juniperus scopulorum* cultivars is a viable alternative to grafting. With close attention being paid to timing, wood preparation, disinfecting, and hormone treatment, satisfactory results can be obtained. The key seems to be the use of the proper concentration of rooting hormones. In general, cuttings of this species give a better rooting response from the higher concentrations of IBA and NAA. Through further research and improved technique, the rooting percentages will continue to be improved and grafting may eventually be discontinued.

PROPAGATION OF HARD-TO-ROOT RHODODENDRONS

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In light of the recent, rapid developments in tissue culture, one might wonder why we should still be concerned about improved techniques in rooting rhododendron cuttings. While dozens of rhododendron cultivars are now being successfully produced by tissue culture, there are many more that have not yet been tried, and several that have been tried but without success to date. Among the cultivars that have so far been unsuccessful are the cultivars with indumentum and, at least some of the yellow cultivars, also those with *R. fortunei* parentage, such as the *R.* Loderi hybrids (*R. fortunei* × *R. griffithianum*).

It is with those cultivars that fall in the above categories that this paper is concerned, such as all the Loderi hybrids, the various Naomi hybrids, and the cultivars with indumentum such as 'Ken Janeck', 'Bureavii', and *R. yakusimanum*.

Proper timing, to obtain just the right condition of the wood is even more important with difficult rhododendrons than it is with the rest of the genus. Cuttings of most of our difficult cultivars are propagated as early in the season as possible. In our location in western Washington we start with the earliest cultivars about mid-June. This can vary according to the weather, but usually not more than a week either way. At any rate the wood must still be soft, not mushy when squeezed between the fingers, but not yet at the brittle stage.

Cuttings that are too soft will turn dark and that portion of the stem which is in the medium will die quite rapidly. If too mature they will either take much longer to root or, not root at all.

Most rhododendron plants put on a second growth flush in late summer. The wood produced by the late growth, taken at the proper stage of maturity, which usually occurs in September, roots quite rapidly. We have found a few cultivars, however, which do not do as well at this time as the early cuttings. One example of this is 'Crest'. We usually obtain a high rooting percentage with this when cuttings are taken as soon as possible in the early summer. We have had some dismal failures from fall cuttings of 'Crest'.

In preparing these cuttings we always use a double wound, about one inch long. These cuts are made down to the wood but removing little or no wood. The basal cut is made at

a slight angle and both this and the side cuts are made with a sharp knife. We have tried making these cuts with a pruning shears, but we feel that the crushing effect of the shear has caused problems at times on difficult cultivars.

We have tried all the various kinds of hormones over the years but now use only "Dip and Grow". On the most difficult to root rhododendrons, we use this hormone at 3500 ppm. A shallow container is used to dip the cuttings in; not more than ¼ inch of the base is submerged. This shallow dip is very important. If the cutting happens to be a little soft and tender, the lower ¼ inch may be killed, but the cutting will form roots rapidly just above this point.

In trimming the cuttings we prefer to break the leaves instead of cutting as this does a cleaner job. No stub of the petiole is left to become diseased and infect the cutting. Three to four leaves are left, according to size. With large-leaved cultivars the leaves are cut back about one-half. Leaves on the small-leaved cultivars are not trimmed. Some disease problems have been reported in the past due to cutting back the leaves. We have never experienced excessive disease that we could credit to cutting leaves. Perhaps this is due to the fact that all our cuttings are dipped, before being made, into a Benlate solution (one tablespoon in two gallons of water). This is followed by an overhead application of the same strength solution about two weeks after sticking.

We prefer medium sized wood in making the cuttings. Large, heavy wood seems to root slower and is usually accompanied by large heavy leaves which take up too much space in the rooting bed. Very small, light wood usually produces a weak liner.

Our cuttings are rooted in a Gothic arch greenhouse covered with polyethylene. We have had equal success in covering the house with 50 percent shade saran cloth, or with spraying the outside with a light coat of paint before we have any hot days.

We do not maintain a block of stock plants. We collect our cuttings from the production area. Cuttings from young plants are preferred to those from older plants, as they seem to root better.

Our normal procedure is to take our cutting early in the morning; however, we have taken cuttings later in the day after the hot sun has been on them. These later-collected cuttings seem to root equally as well as cuttings taken at any other time. We do, however, spray them with water as soon as they are brought in from the field.

The benches in which these cuttings are rooted are six

inches deep, constructed of cedar and sprayed with copper naphthenate. Bottom heat is supplied by electric cables and a temperature close to 73°F is maintained. Some experimenting has been done recently with ½ inch hot water pipes placed six inches apart in the bottom of the bed. Results have been equal to electric cables.

A mist system is used, controlled by a micro switch which is activated by a moisture-balanced screen. This system compensates for dark days and nighttime. The greenhouse is ventilated by a vent fan which is thermostatically controlled to keep the house temperature down on hot days.

For many years we have been interested in the influence that sawdust seems to have on root growth of mature rhododendron plants. As a result we started experimenting with various types and quantities of sawdust in our rooting medium. The use of sawdust proved so successful that we now use a medium consisting of 90 percent sawdust and 10 percent peat moss on all rhododendron cultivars. Douglas fir and cedar sawdust seem to work equally well. Fresh fir sawdust and all cedar sawdust should be thoroughly leached before use. We accomplish this by placing it in the benches and thoroughly soaking it with a hose until the water running out is no longer brown.

The results of using sawdust are good aeration and drainage, resulting in rapid rooting and large root balls. We have avoided any serious removal of nitrogen from the cuttings by the sawdust by starting a feeding program as soon as the cuttings are transplanted.

When the above procedures are followed, we experienced no difficulty in obtaining an acceptable percentage in rooting cuttings of difficult rhododendrons.

ROOTING *ACER RUBRUM* CULTIVARS USING SINGLE NODE CUTTINGS

J.A. ENGLISH

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We have been propagating *Acer rubrum* for a number of years; however the work done by E.R. Orton of Rutgers University on single node cuttings (Sept. 1978 issue of The Plant Propagator) made large scale propagation practical due to the better utilization of cutting wood.

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Our method differs from that in the article, in that we use a potting mix of equal parts sawdust, peat, and pumice, and the cuttings are stuck in three inch square pots. Disturbing the roots, by potting from the cutting flat, increases the losses greatly. Out of 20,000 cuttings stuck last year, the rooting percentage after 20 to 25 days averaged 85 percent. The cuttings were taken during July and August, and wood up to ¼ in rooted well. The rooted cuttings are moved to a cold poly house where they remain until the following spring. Approximately 50% of these break dormancy and put on new growth before winter dormancy. The balance either die or break into new growth by April first or earlier. Our problem is how to make the cuttings break dormancy and put on 10 to 12 inches of new growth by planting time in late April or early May. Nutrition is a problem in rooting plants in containers, and even in 3-inch pots it is difficult to get liquid fertilizer into the pot, due to the large leaves. In an attempt to solve this problem we have added dolomite and superphosphate to our mix, also adding 2½ pounds of Osmocote 18-6-12. It is too early to tell yet whether this system will work.

While it is not possible to learn all of the answers in three years — we are producing a liner that does very well after it is field planted.

Some of the things we have learned are: maple leaves burn badly on hot sunny days unless kept constantly wet with mist; at the same time it is important not to let the medium get too wet, otherwise the cuttings will rot at the base.

While it will increase costs, this year we plan to keep the liners in a heated greenhouse at 50°F and, in addition, we will be using lights in an attempt to make the plants break dormancy earlier. It is hoped that the increase in the number of saleable liners will more than offset the added cost.

The plants here on the podium, are from those that broke dormancy in late April, and the 24 inches of growth indicates the "take-off" ability of *Acer rubrum* single node cuttings.

MODERATOR MORTON: Now for some questions for our panelists. Ray Maleike has one.

RAY MALEIKE: Jim English — what time of year do you take your *Acer rubrum* cuttings?

JIM ENGLISH: July and August.

RAY MALEIKE: Do they root if taken any earlier than that?

JIM ENGLISH: Yes, but generally the cutting wood is so soft it is extremely difficult to keep them from burning in the propagating house.

BRUCE BRIGGS: Did you ever try forcing growth of *Acer rubrum* in early spring for your cuttings; this is what I think Ray was referring to. If you can get growth of cutting wood early then you would have more time in the summer to grow the shoots that you want for the fall. This is what some have done in the East and in England.

BRUCE BRIGGS: My question is for Wilbur Anderson. On the apple tissue culture, after you etiolated the small plantlets, did you then put them into a medium *in vitro*, or did you go directly outside in the soil with them?

WILBUR ANDERSON: The experiment that I just discussed was terminated at that point — after we rooted or rated the rooting. We feel that some work done in Sweden, using darkness without actually etiolating the plant material, is most significant in getting good rooting percentages. I think that is the way to go. I would say that the results that we have are just confirming that etiolation, or say darkness, is doing something to get the endogenous growth regulator balance in favor of rooting. The manipulation, the actual way of handling it, is still up for grabs but I think that is where we are going to learn how to root all the apple cultivars. Good rooting is probably tied up with the darkness treatment.

BRUCE BRIGGS: That is what I was trying to get to, Andy; whether you had tried the work the lady had done in Sweden. Now, one other thing, you people in the room — don't think that etiolation is just for tissue culture. What you have heard here is a general principle that will work on rooting of any plants, tissue culture or on the outside.

RALPH SHUGERT: How about your *Juniperus virginiana* 'Skyrocket' propagating procedures? Is it all cuttings, or some grafts; what are your hormone treatment, etc.?

RODGER DUER: 'Skyrocket' roots from cuttings, they root very easily. For the hormone I believe we are using 3000 ppm IBA.

VOICE: You said after your cuttings are rooted you cut the bottom heat and start sprinkling with fertilizer injected into the water. Do you get growth on the cuttings before they are transplanted?

RODGER DUER: Oh, yes. We usually end up pruning them a couple of times before they are potted.

VOICE: So what size are they when they leave the propagating trays?

ROBERT DUER: We like to keep them nice and short, only about four inches or so; with too much growth on them, browning out of the foliage underneath develops.

VOICE: In your situation, how long do they sit in the propagating trays before they are transplanted?

RODGER DUER: Ideally, you should get to them right away but we have approximately 12 million conifers and it takes time to get around to all of them, to get them potted. Sometimes they sit in the flats as long as 6 to 8 months.

BRUCE MacDONALD: Question for Jim. Have you tried, with your *Acer rubrum* cuttings, removing one of the pair of leaves after they are well-rooted?

JIM ENGLISH: No, I haven't Bruce, but that is one of the things I am going to do this year because somebody else is suggesting that too.

We root *Acer palmatum* cuttings in pots, simply because they do not transplant worth a darn. If you root them in a flat, and move them into a pot, your losses become staggering. I mean it is nothing at all to lose 25 to 30%. Exactly the same as with magnolias. We find that if we root them in a pot, there are no problems, but if we root them in a flat and then pot them up, the losses are heavy. One other thing I should stress is that one of the problems in rooting in pots is that of getting fertilizers into the plants as soon as they are rooted. We haven't been using any fertilizer in the propagating mix at all and it is difficult to overhead liquid-feed because the fertilizer washes off. So what we have done this year is to put 2 lbs of 18-6-12 Osmocote per cubic yard in the rooting mix in order to have a little nutrition immediately for the plants as soon as they have rooted.

VOICE: We use 5 pounds per yard of 14-14-14.

JIM ENGLISH: And you don't get any burning?

VOICE: No.

JIM ENGLISH: As a matter of fact, that is one of the things I have written down and am going to try this year. Thanks.

VOICE: I have a question for Rodger. I am wondering do *Juniperus scopulorum* cuttings catch up in growth with grafts after the first year or so? Do they ever catch up?

RODGER DUER: Yes, usually by the second season they do catch up. In the first season, the grafts make about double the growth of the cuttings.

A DEVICE FOR HOT CALLUSING GRAFT UNIONS OF FRUIT AND NUT TREES[1]

H.B. LAGERSTEDT[2]

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Hot callusing is a method used in grafting to expose the graft union to elevated temperatures for a short time to accelerate cell division. Trees to be hot callused usually involve dormant scions grafted to rootstocks that are either bare-root or potted. Hot callusing is often achieved by plunging the grafted tree into warm, moist media, by using a special grafting case (double glass) or by just bringing a potted plant into a warm greenhouse. For limited production, some propagators have placed grafts in barrels of heated media that are placed out-of-doors or in a cool room. The disadvantage of these methods is that the elevated temperatures designed to callus the graft union also cause the scion buds to break dormancy and begin leafing out.

To avoid bud break, propagators have tried grafting and hot callusing in October or November, before the chilling requirement of the scion buds has been satisfied (3). Once callused, the grafted trees are placed in cold storage to satisfy the rest period, then planted to the nursery in the spring. This timing has met with varying success, partly due to scion mortality during the long storage period. Also, the callused graft unions are fragile and easily broken during handling. Another limitation on fall grafting is early availability of rootstocks because, ideally, leaf drop should occur before the rootstocks are dug.

Hot callusing is most frequently done in the spring, prior to planting, but this timing also has its problems (1). Forced buds are tender, require special handling care and dessicate readily. Cool, wet weather may prevent ground preparation so that planting is delayed and additional bud forcing may occur. Since timing is so critical with spring hot callusing, there is a relatively short period of time during which it can be done successfully. This places a serious limit on the number of grafted trees that can be produced by this method.

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[1] Contribution of the U S Department of Agriculture, Agricultural Research Service, in cooperation with the Agricultural Experiment Station, Oregon State University, Technical Paper No 6247 of the latter. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply approval to the exclusion of other products or vendors that may also be suitable.

[2] Research Horticulturist

To overcome some of these problems and achieve a faster turnover of trees in the hot callusing location, some nurserymen allow only 7 to 14 days of heat treatment. This is sufficient time to get the callusing process started, but is insufficient time to cause bud elongation. It is really a compromise in time and efficiency, sacrificing a well-callused graft union for reduced scion growth.

Spring nursery grafting of the Persian walnut (*Juglans regia* L.) has been improved, both by delaying the time of grafting until ambient air temperatures have increased and by tenting nursery rows to increase air temperatures by trapping solar radiation (4,8). In the Pacific Northwest, walnut nurserymen tie brown paper bags over the grafted scions to raise the temperature and promote callusing of the union (7,8). Unfortunately, both tenting and bagging accelerate not only callusing, but growth of the scion buds as well.

Over 50 years ago Sitton discovered that the optimum temperature for callusing black walnut grafts was 27°C (9). Filbert trees also have been shown to have a marked callusing response to temperature. Uniform sized wounds were made on potted trees which were then subjected to 16, 21, and 27°C. There was a 16% increase in callus growth as the temperature was increased from 16 to 21°C and a 67% increase in callus as temperatures of 16 and 27°C were compared (5). The conclusion reached in this study was that the optimum callusing for filbert trees exceeded 21°C. As a group, most temperate zone nut trees are difficult to graft with consistent success. This could be related to the possibility that their optimum temperature for callusing is higher than that of temperate zone fruit trees (6). For example, apples and pears have been reported to callus at 4.5°C (2,8). At such low temperatures, most nut tree grafts would exhibit very little callusing and chances for their survival would be minimal.

In an effort to improve the grafting success of dormant fruit and nut trees, a device for hot callusing has been developed (7). The device has been in operation for two seasons and used with a variety of plants.

METHODS AND MATERIALS

The basic member of the hot-callusing device is PVC pipe, 38 mm (1½") inside diameter. Slots, varying in width from 7 to 10 mm were routed into the pipe, perpendicular to its length (Fig. 1). The pipe usually comes in 6.1 m (20') lengths with each length accommodating about 240 slots. The grafted unions of trees are placed in the slots. The source of heat for the hot callusing device is a thermostatically controlled electric

heating cable. The strands of the heating cable must be physically separated to prevent short circuiting. This is accomplished by taping them to a smaller 7 mm (½″) PVC pipe which is inserted into the larger slotted pipe (Fig. 2). This inner pipe has been filled with water and capped to provide better heat stabilization. The thermostat sensor is placed in one of the slots in the same position as one of the graft unions. The thermostat is usually able to maintain the temperature of the pipe at 24 to 28°C.

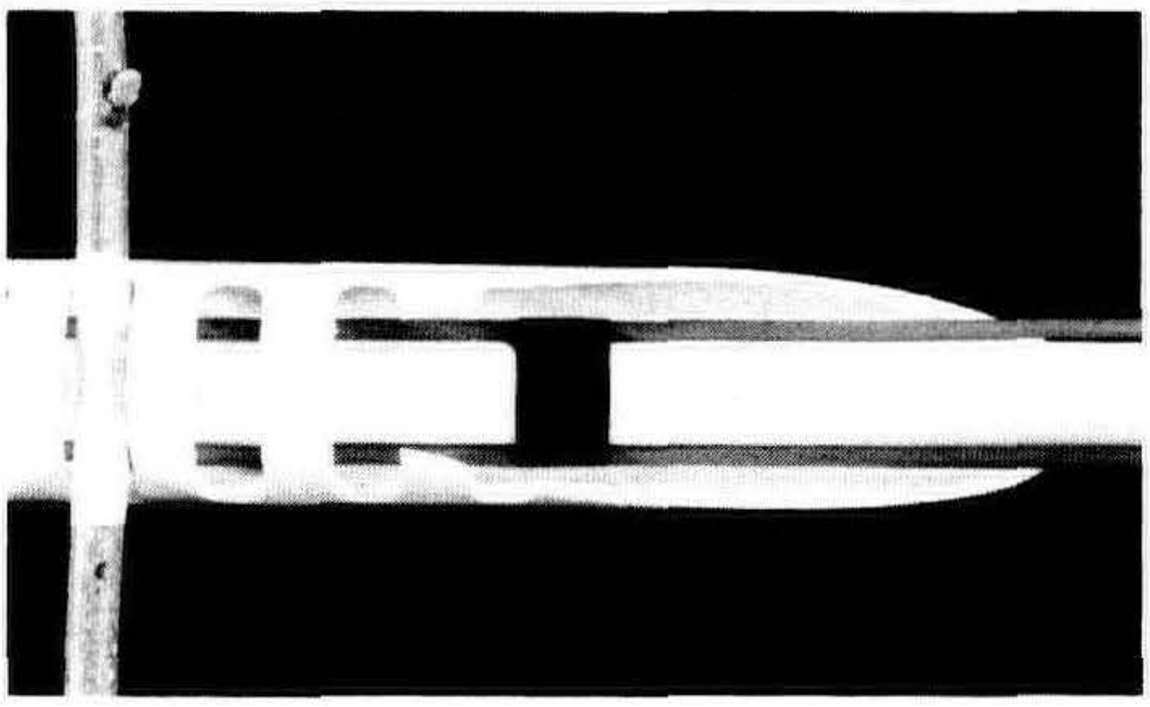

Figure 1. Top view of the hot-callusing device showing the slots routed across the outer PVC pipe and one graft union in place. A smaller, inner pipe can also be seen with the two strands of a heating cable taped to its sides.

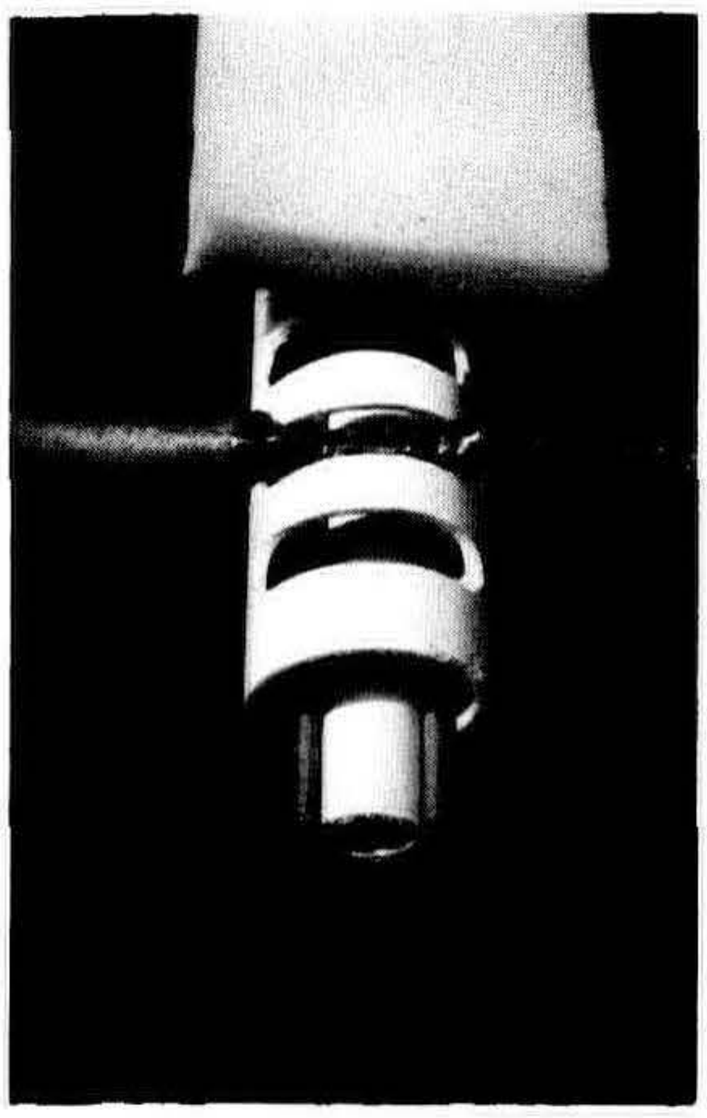

Figure 2. A cross section of the hot-callusing device with a graft union in place. The arrangement of inner and outer PVC pipes and the heating cables are shown. A strip of foam rubber is used on top of the graft unions and slots to retard heat loss.

With the grafted trees in place across the pipe, the scion buds will be exposed to ambient air temperatures and the root systems of the rootstocks can be heeled into sawdust. A strip of foam rubber 10 cm wide should be placed over the unions to retard the escape of heated air (Figure 2). Scrap lumber can be used to prevent the foam rubber from blowing off. The hot-callusing device can be located out-of-doors or in an unheated structure. The only requirement for the device is an electrical outlet for a source of electricity. The device has no moving parts. It is relatively simple to construct and simple to maintain.

In 1980 the device was tested from January to April with filbert trees only. In 1981, apple, pear, prune, peach and Douglas fir grafts were evaluated in addition to those of filbert. Also tested were different types of tying materials and several different types of grafts. Graft evaluations were always made during the summer, several months following planting.

RESULTS

An Omega grafting machine was used to graft the first trees to be placed on the hot-callusing device January 24 and February 4, 1980. The trees were hot callused 40 and 29 days, respectively, and planted directly to the nursery, March 4. Grafting success, evaluated during July, was 91 and 82%, respectively (Table 1). In a separate experiment, field grafts of the filbert were made comparing the hand-made whip and tongue graft to that made with the Omega machine. Twenty grafts of each type were made at bi-weekly intervals from May 13 to July 8. The whip and tongue grafts averaged 93% success as compared to 2% for the Omega grafts. The poor results with the latter were due to the relatively small area of tissue available for forming a union with the machine-made graft, and the use of the filbert as the test plant. Being slow to callus under outdoor conditions, the smaller cuts of the Omega graft became a limiting factor with the filbert. By contrast, when the hot-callusing device was used to heal the Omega-made unions, grafting success nearly equalled that of hand-made grafts. Though the area for union formation was small, the Omega grafts were completely callused (Fig. 3). When scion buds began growth, a translocation system was available to prevent scion dessication and death. This is the major advantage of the hot-callusing device in its use with difficult-to-graft trees.

A second 1980 grafting experiment produced 100% success for hot-callused trees as compared to 7% for those not so treated (Table 1). Another experiment, initiated April 3 as the

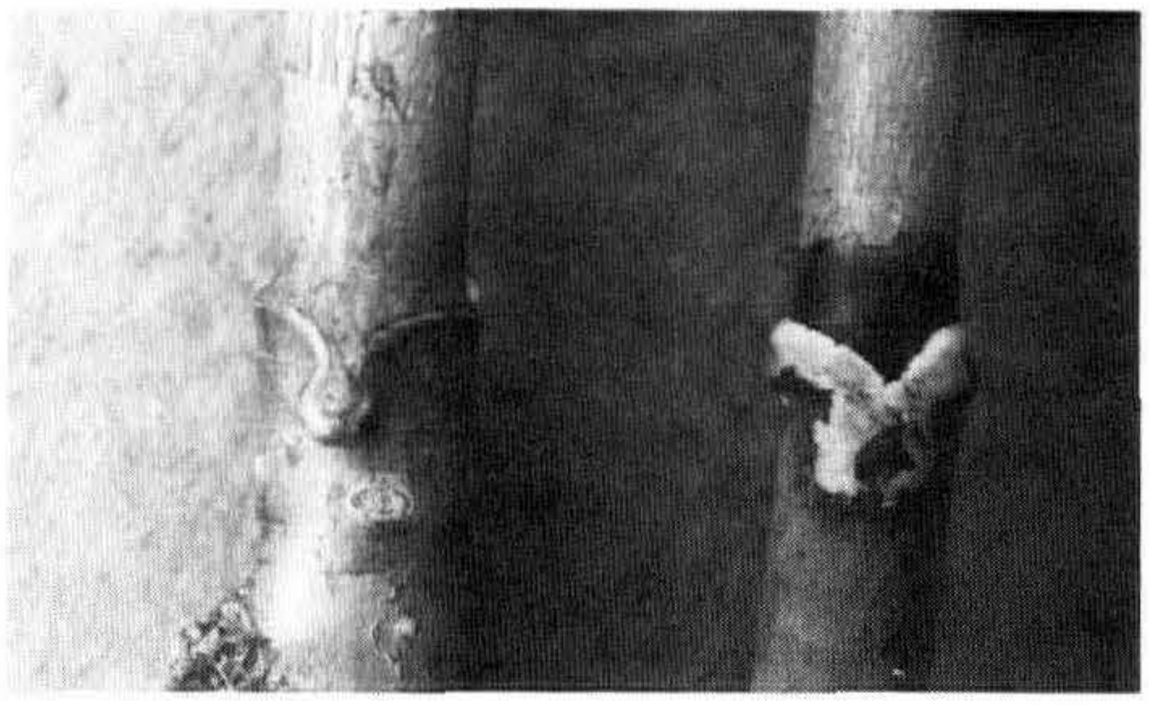

Figure 3. Two Omega-grafted filbert trees following 28 days on the hot-callusing device.

growing season was starting, yielded 77% success after only 14 days of hot callusing. At the time of planting, scion buds were enlarging, and transplanting conditions were less than ideal.

Table 1. Evaluation of Filbert Trees Grafted and Hot-Callused During 1980.

Date of Grafting	Date of Planting	Percentage Grafting Success
Jan. 24	Mar. 3	91
Feb. 4	Mar. 3	82
Feb. 29	Feb. 29*	7
Feb. 29	Mar. 28	100
Mar. 20	Apr. 17	96
Apr. 3	Apr. 17	77

* Trees were planted directly to nursery following grafting. These trees were not hot-callused.

After two seasons of experience, it has been noted that overall grafting success and subsequent tree growth is more dependent on root system quality and time of planing than it is on the hot callusing process per se. When graft unions are lifted from the hot callusing device, nearly 100% of them have a satisfactory union formed. Subsequent failure of the union was often found to be due to breakage of the delicate union during handling or planting. Failure of the tree was most often due to a poor root system, but also to late planting. The latter had a pronounced effect on tree growth. Growth analysis of an apple grafting trial, where 100% success was obtained regardless of the time of grafting or time of planting, shows that late-planted trees produced fewer lateral branches and less total stem growth than trees planted earlier (Table 2).

In 1981, the primary experiment involved a comparison between filbert and apple grafts. All trees were wedge-grafted by machine to reduce any variability that might occur from hand-grafting. Table 3 shows that all apple grafts grew regardless of treatment, but that only hot-callused filbert trees were successful. Relatively little or no callusing of filbert grafts

Table 2. Stem Growth of Grafted Apple Trees Planted from February Through April, 1981.

Treatment	Total Number* of New Stems	Total Cm Stem Length	Average Cm Stem Length
1. Not hot-callused, planted Feb 24 or 25	85[bc]	2181[a]	25 7[a]
2 Hot-callused 28 days, planted Mar 26	112[a]	2822[a]	25.2[a]
3 Not hot-callused, planted Mar. 26	86[bc]	2067[a]	24.0[a]
4. Hot-callused 28 days, planted Apr 14	66[c]	276[b]	4.2[b]
5. Not hot-callused. planted Apr. 14	73[bc]	489[b]	6.7[b]

* Values in a given column followed by different letters are significantly different from each other at the 5% level.

Table 3. 1981 Evaluation of Grafted, Hot-Callused Filbert and Apple Trees.

Treatment*	Percentage Grafting Success** Filbert	Apple
1. Not hot-callused, planted out the same day as grafted.	0	100
2. Hot-callused 28 days, and planted out to the nursery.	94	100
3. Not hot-callused, plant out 28 days after grafted	3	100
4. Hot-callused 28 days and planted out in April.	91	100
5. Not hot-callused, planted out in April	0	100

* All apple trees were grafted Feb. 24 and filbert trees Feb. 25, 1981. Treatments 2 and 3 were planted in the nursery March 25. Treatments 4 and 5 were polanted to the nursery April 14. Treatments 3, 4, and 5 were heeled into sawdust, out-of-doors, until time of planting. Each treatment involved 35 grafted trees for each plant type.

** Grafting success evaluated in June, 1981. Filbert trees were 'Ennis' on 'Daviana ' Apple trees were 'Golden Delicious' on 'Malling-Merton 111.'

occurred at ambient air temperatures, resulting in only 1 of 105 grafts being successful.

To determine the universal use of the hot-callusing device for other fruit trees, several types were grafted during 1981. Hot-callused grafts of 'Bartlett' pear on Calleryana rootstocks averaged 76% success. In this instance a few losses were noted as being caused by direct contact between the heating cable and the graft unions. The strands of the cable were not adequately taped down and several loops of cable caused overheating of the union. 'Brooks' prune scions were grafted on both Myrobalan and *Prunus besseyi* rootstocks with an average

of 73% success. The 'Sandoz' filbert was grafted to both 'Daviana' and 'Barcelona' rootstocks with 93 and 84% success, respectively.

Bare-root grafting of a conifer was also tried using Douglas-fir seedlings as rootstocks and CT-25, a Christmas tree selection, as the scion. The trees were veneer grafted, tied with rubber grafting bands and hot callused with the scion placed uppermost in the slot of the PVC pipe. Both large and small scions were used with the effect of needle removal being evaluated. There were no differences due to scion size or needle removal and overall grafting success was 84%. After hot callusing, the grafted trees were either field planted or potted and brought into the greenhouse. Of the latter, half were placed on a greenhouse bench and half were placed under mist. The misting promoted fungus growth on expanding buds of both the stock and scion, causing their death in nearly every instance.

DISCUSSION

The greatest benefit of the hot-callusing device lies in the quick formation of a callus union between scion and rootstock. As shown int he Omega machine grating trial, when conditions are less than ideal or plants difficult to propagate are used, hot callusing can serve as a means to successful propagation. With proper use of the hot-callusing device, the subject plant is essentially obliged to form callus in response to the localized heat stimulus. The uniqueness of the device lies in its ability to direct that heat to the graft union to the exclusion of other plant parts. In effect, it causes selective plant growth so as to provide greater control over the grafting process by the propagator.

While most hot-callused graft unions result in a union being formed, the process can not substitute for other factors that may limit success. Poor grafting technique, tying unions too tight or leaving gaps, poor quality scion wood, a lack of good root systems, rough handling, and late planting may each nullify the potential success of a properly hot-callused union. Most of the grafting losses observed following two seasons of hot callusing work were caused by either failure of the rootstock or late planting.

The greatest promise for the hot-callusing device is probably associated with plants that are difficult to propagate. With trees such as apple that have the ability to produce callus at low temperatures, the device may only offer limited benefit. As shown in Table 2, early planting of apple trees was more important to subsequent growth since all grafts callused regardless of temperature. However, the hot-callusing device

could serve to permit earlier tree planting. Time of tree planting will have to vary with location. In western Oregon, where these trials were conducted, the mild winter climate permits planting trees directly to the nursery as they complete the hot-callusing process. When, this system is used in colder climates, other timing schedules or techniques would have to be implemented. Also, the slot size in the pipe may have to be made larger or smaller to better fit the size of the plant being propagated if different from those mentioned.

It appears that a wide variety of fruit, nut and ornamental plants can be propagated by use of the hot-callusing device. It is, of course, limited to those that can be grafted and is best suited to those where scionwood with long internodes can be produced. It is desirable to separate the scion buds as much as possible from the heat source. To do this, a 3- or 4-bud scion is used and the lower 1 or 2 buds are removed. Usually, 2 lateral stem buds are retained and they would be located farthest away from the pipe.

More trials need to be carried out with hot callusing bare root conifers. Conifer grafting usually involves potted, root-bound rootstocks. If bare root conifers such as the Colorado blue spruce could be propagated via the hot-callusing device, significant economic advantages might be realized. It was especially valuable to learn that needle removal had no detrimental effect on subsequent scion growth. With needles removed and only scion buds remaining, the conifer scion not only resembles the scion of a deciduous trees, but can be handled in much the same manner for propagation purposes.

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TISSUE CULTURE AND PLANT PROPAGATION: COMING DOWN TO EARTH

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The use of tissue culture. The technique of plant tissue culture has captured the imagination of the nursery industry, the media, and the general public. To the layman, the use of aseptic methods brings an aura of science and science fiction to the seemingly mundane business of plant propagation. To the nurseryman, the very high multiplication rates which can be achieved *in vitro* are most attractive from the commercial viewpoint.

Progress in the horticultural applications of plant tissue culture has been spectacular in the last 15 years (9,11). Aseptic methods of vegetative propagation have become standard procedures for production of pathogen-free materials and for the routine multiplication of many high-value ornamentals. A large number of species can now be regenerated *in vitro* by the induction of somatic embryos or adventitious organs and the technique of micropropagation is assuming special importance in horticulture (6).

The commercial value of aseptic methods for propagation of ornamentals such as orchids and ferns is well established, and a number of other specialized applications of plant tissue culture have proved themselves in the market place However, in the present atmosphere of enthusiasm for tissue culture it is well to remember that it is just a *technique*. As with any technique in plant propagation, tissue culture is appropriate in some instances and inappropriate in others, and its use is founded upon the requirements of the crop or plant concerned.

Genetic variation in vitro: The case of fruit crops. Most deciduous and evergreen fruits are highly hererozygous outcrossers and they do not breed true from seed. The object of plant propagation in fruit crops is to perpetuate specific genotypes and high fidelity reproduction is the basic requirement of all methods of propagation. There is risk in the use of tissue culture for clonal propagation of fruit crops because genetic changes, both gross and subtle, can and do occur *in vitro*.

Many fruit cultivars arose as bud sports (somatic mutations) and are chimeric in structure (5). Rearrangements in chimeric structure during organogenesis or embryogenesis would change the nature of the cultivar. A warning is contained in the observation of Barlass and Skene (1,2) that shoots

produced *in vitro* by fragmented apices of the grapevine are of both axillary and adventitious origin. It follows that the use of this method for propagation of cultivars which are periclinal chimeras is likely to produce solid mutants and solid normal plants, as well as the original chimera

It has been assumed hitherto that micropropagation, a technique which avoids the genetically-unstable callus stage, is a high-fidelity method of plant multiplication. This assumption has yet to be proven in orchard trials. A degree of variation in the ornamentals which are produced by aseptic methods may be quite acceptable but variation in named cultivars of apple, grapes, or citrus, especially in economically-significant characters, could have serious consequences for growers and for the nurserymen who supply the trees.

Genetic variation which arises in cultivars as a result of the procedures of tissue culture, although highly undesirable for plant propagation, is of considerable interest in plant improvement. Recent research on regeneration of crop plants from cells and protoplasts has revealed the presence of much useful covert genetic variation which is not expressed in conventionally-propagated plants (10,12,13). Cabernet Sauvignon vines which were raised in this laboratory from somatic embryos (8) are exhibiting considerable variation in the field (7). These results, although preliminary, raise the possibility of greatly expanding the scope of clonal selection in fruit crops by exploiting the somatic heterogeneity of long-established asexually propagated cultivars through the use of tissue cultures.

Two contributions to this conference are concerned with the application of plant tissue cultures to the genetic improvement of fruit crops. Mr. K. Rajasekaran (University of Sydney) will review the regeneration *in vitro* of grapevine species, hybrids, and cultivars by embryogenesis and organogenesis. Included will be a description of plantlet production from isloated ovules and anthers. Mrs. Sridevy Sriskandarajah (University of Sydney) will describe methods for inducing prolific adventitious rooting *in vitro* in the apple cultivars, Jonathan, Granny Smith, and Delicious. These cultivars are very difficult to root by conventional methods. Aseptic methods of propagation of own-rooted apples (14) were developed primarily for use in a mutation-breeding project, but if the trees produced *in vitro* remain true-to-type, these methods could be of interest to fruit tree nurserymen.

Developments in conventional methods of propagation. The decision to use aseptic methods for plant propagation should be made only where it is clear that conventional meth-

ods are inadequate or unsuitable. Another contribution from the University of Sydney, by Dr. Peter Goodwin, will illustrate (i) the importance of defining the objectives in a plant propagation programme, and (ii) the selection of a mode of propagation which is appropriate to the achievement of these objectives. With the potatoes, it is possible to produce very large numbers of very small plants by use of tissue culture, but Dr. Goodwin will show that propagation by single node cuttings is a much superior method for rapid multiplication of pathogen-free material, particularly for potato improvement programmes in underdeveloped countries.

Developments in conventional methods of plant propagation, especially in the rooting of cuttings, have been overshadowed in recent years by interest in tissue culture. Clonal selection for ease of rooting, conditioning of mother plants to enhance the regenerative capacity of cuttings, and rooting *in situ* of shoots on hedged trees are all topics of considerable significance for propagators of hardy nursery stock. Up to now most research on these subjects has been with fruit trees, notably by Dr Brian Howard (4) and his colleagues at East Malling Research Station, England. The time is ripe to extend these approaches to woody ornamentals, including native Australian species A start has been made at the University of Sydney. Dr J. Clemens and Mr G.P. Lamont will present some of their results on propagation of, respectively, *Grevillea* spp. and *Boronia serrulata*, later in this Conference.

CONCLUSIONS

Tissue culture is an important new tool for the plant propagator. Rapid multiplication of scarce material, including newly-bred cultivars, and propagation of bulb plants, orchids, and ferns are areas in which aseptic techniques have much to offer. The experienced plant propagator is a craftsman and the mark of the craftsman is that he chooses the right tool for the job. Sledgehammers are not needed to crack nuts and tissue culture is not needed for most propagation tasks in general nursery work.

Tissue culture is an indispensable tool for research in genetics and morphogenesis, and for production of pathogen-free stock. It is also a vehicle for the production and exploitation of genetic variation in crop and ornamental species, and it is in this sphere that tissue culture holds greatest promise for the advancement of horticulture.

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NURSERY RECORD KEEPING IN PROPAGATION

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Birkdale Nurseries
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The aim in plant propagation is to achieve a 100% result. All of us, as we have developed our techniques over the years have made many mistakes and learned many lessons. Having learned from these experiences, we have developed skills

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which make us the efficient operators that we are or should be.

Many of those lessons that we have learned have become basic knowledge to us, but unavailable to others if not recorded or communicated.

In my own case, having started in a very small way, and having built up a business that is supporting 13 people, it is not good enough for propagation knowledge to be directed solely from myself to my propagation staff. In the event of accident, possible hospitalization or even death, that knowledge is suddenly cut off and what was previously a flourishing business, could well get very quickly into trouble.

A few examples of where recorded information is vital, the result of lessons learned over many years, will be discussed. Plants in propagation do have many environmental responses. For one, we have found in our nursery that dracaenas respond much better without mist, but with bottom heat

We have also learned from bitter experiences that some plants have very critical hormone tolerances. For example, the melaleucas, particularly 'Revolution Gold' and 'Golden Gem' root quicker and better with either no hormones at all or a very weak one, say strength 1 in a grade of 6. When stronger hormones are used, say in the area of 3, burn results and basal rot sets in, resulting in foliage drop and general collapse of the cutting.

Other plants that we have found to be extremely intolerant of hormones are *Leptospermum* 'Pacific Beauty,' and even the hardy and normally easy to propagate hibiscus. The Hawaiian cultivars seem to be extremely intolerant of high hormone strengths.

We had an experience years ago where there was sudden massive loss of cuttings, accompanied by a typical pattern of basal rot and gradual defoliation of cuttings. After much retracing of steps, checking into bottom heat temperatures, media, mist, etc. it turned out that the hormone formulation had been changed in the particular brand that we had been using and it was the hormone strength that was damaging the hibiscus. On cutting back the hormone markedly we were back in business with efficient rooting once again. There are some cultivars that will tolerate stronger hormones and root quicker and this information needs to be recorded.

We have also found that certain plants are very readily rooted at certain times of the year, but difficult otherwise, for example, *Petrea volubilis*. If the cuttings are taken during autumn (March) the success rate will be very high. If taken at

other times of the year, for example, early summer, the success rate will be extremely low.

Knowledge such as this should not remain solely with the proprietor of a nursery business. The moment he is not around to direct the cutting program, many hours may be wasted by propagating staff having to relearn such experiences as I have mentioned above, or to simply stop producing the plant.

If this sort of information can be recorded on an Index Card System all a propagator has to do is to refer to the card relating to the plant concerned to get up-to-date information on how that plant is to be handled, when to take cuttings, what type of cutting to use, which media, which hormone, which environment, etc.

Once information is recorded on a cultivar, the moment there is trouble in the propagation house, there is an immediate reference available for checking back on the possible cause of loss.

Recorded information can be extremely handy in the case of change or loss of a propagator. Even though a new replacement propagator will have his own ideas and knowledge, it is always an extremely handy safety factor in having recorded information as a starting point in his new job.

How do we go about recording information? We all may differ in this regard, but my method is to use what I call a Method & Stock Control Card. These are cards, 200mm × 130mm, which fit neatly into a storage case, all being stored in alphabetical order. The headings on the card naturally need to be determined according to what information you wish to record Indicate whether the plant is exotic or native, shrub, creeper, or tree; whether propagation is by cutting or seed; what media to use; method of preparing the cuttings or seeding; time of year, where applicable; any pecularities, such as type of cutting, media variation; fertilizer requirements, etc. These can all be recorded. Hormone strengths, usual time of rooting also, if necessary, addresses, phone numbers, etc. for materials to be used can be recorded.

The card can also be used for stock control on the reverse side where time of demand can be recorded, numbers sold and whether increased production is necessary. It may also be valuable to record what month cuttings should be put down to achieve a finished product at a peak time of demand.

PROPAGATION OF CERTAIN TROPICAL FRUITS

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The far north coast produces over half of Australia's bananas, from a now relatively stable area of about 7000ha. However, there has been rapid expansion in a wide range of other tropical fruits such as avocados, macadamias, custard apple, litchi, guava, papaw, mango and low-chill stone fruits.

MACADAMIA

The macadamia (*Macadamia integrifolia* and *M. tetraphylla*) is the only Australian native tree ever developed as a commercial food crop It (*M. tetraphylla*) is indigenous to the coastal areas of northern New South Wales and southern Queensland between the latitudes 25° and 32° South. Lismore, N S.W. has a latitude of 28° South.

Macadamia is one of the best edible nuts in the world and is the richest oil-yielding nut known, producing about 76 per cent of very high quality oil. It may be eaten raw, is delicious when roasted and salted, makes a nice nut paste and can be used in cakes, confectionery, and ice cream. It can also be used as a cosmetic base.

The shell is used in plastics manufacture. The husks (green coverings of the nuts) contain about 14 per cent of substances suitable for tanning leather, but as yet have not been used commercially for this purpose in Australia. Husks are used extensively as undertree mulch and trials indicate they are excellent in potting mixes.

Selecting from several trees introduced from Australia in the 1870's, Hawaii has established an industry with 2,000 hectares of trees annually producing 10,000 tons of nuts in shell. There are also plantings in South Africa, Rhodesia, Kenya, California, and Central America.

Since 1970, the area under macadamias in New South Wales has expanded rapidly to 1,900 hectares at present. The macadamia offers long-term economic potential, but is most suited to investors with large capital resources. Currently 10 to 12 hectares appears to be the minimum viable area.

The macadamia is a rainforest tree of the sub-tropics and requires high moisture. Rain in early spring and summer is necessary for a good set of nuts and to ensure the crop reaches maturity. With the dry spring/summer of the far north coast, irrigation in commercial orchards is essential. Without it, the crop can be halved in dry seasons.

Propagation. Using basic nursery techniques, propagation of the macadamia is not difficult. Shade houses are necessary but need not be as elaborate as for crops such as avocados.

Seedbeds should be made of coarse river sand and be at least 20 cm deep. Use them only for germination of the seed and not for growing seedlings through to stock size. To avoid the possibility of disease build-up, do not re-use the sand once seedlings have been transplanted.

Seed for propagation should be fresh and selected from trees that are vigorous, and produce well-filled round nuts of average size. Plant the seed soon after harvesting as it deteriorates quickly. Seed allowed to dry out will be slow to germinate. Late summer (February-March) plantings of mature new season seed should result in good germination. High temperatures experienced then, and the freshness of the seed, assist in speeding seedling growth.

If the seed cannot be used immediately, it may be stored in moist sand at a temperature of 5 to 10°C in a shaded site. It can also be kept in airtight plastic bags under refrigeration.

Nuts are planted in their shell with the suture or crease underneath. They are sown thickly but not touching and should be covered by about 2 cm of sand. If buried too deeply, losses may occur from rots and lack of air. Keep seedbeds moist at all times. This is important during the first week after sowing as the shells must absorb moisture to open freely at germination. Under warm seedbed conditions (soil temperatures of 30 to 35°C), germination should commence in three to four weeks. However, germination of the whole crop may extend over a period of six to eight weeks, especially if air temperatures fall below 24°C.

Where glasshouses are not available for germinating seeds in the colder months, use the sunny sides of buildings and fences, with a clear plastic or glass covering to provide extra heat.

For artificially heating seedbeds in the winter, some nurseries use a waterproofed electric blanket under the seedbed.

Transfer seedlings from the seedbed to nine litre plastic bags in the shade house as soon as the first two sets of leaves have hardened. If planted too soon, or when flushing, heavy losses may occur. Weak or off-type and albino seedlings should be discarded.

Potting mixtures should be free-draining. Nurseries use various mixtures of sand, loam, peat moss, and well-rotted sawdust. As mentioned, macadamia husks are also proving to be an excellent component of potting mixes. Although mixtures benefit from the addition of dolomite lime, nitrogen,

superphosphate, and potash, excessive use of these can be detrimental Too much or poorly mixed dolomite lime will cause chlorosis in young trees. The pH should be in the range 5.5 to 6.5

Do not allow seedbeds to dry out, otherwise germination will be affected. On the other hand, too much moisture and lack of aeration tends to promote fungal activity, and losses may occur through infections, which either penetrate the seed as it becomes exposed during germination or attack the developing shoot. Trained potted seedlings to a single stem. When seedlings are 12 to 15 months old they are ready for grafting.

The root system of the macadamia consists of bunches of lateral rootlets forming mats just below the soil surface As a result, plants are sensitive to soil moisture fluctuations, particularly in the seedling stage and an adequate water supply is essential.

Grafting. Conventional methods of grafting are suitable for shade house or field grafting of macadamias in late summer (February-March) and late winter (July-September). In the field, avoid the cold midwinter and hot summer periods

Experience has shown that macadamias can be whip grafted in commercial quantities if stock and scion are well matched. Because the wood is so hard, the cut surfaces are prepared with a small wood plane. This results in a very even surface and the necessary close contact between the cambium layers of stock and scion. Other types of grafts are used less.

Health, vigor and stage of growth of both the stock and scion are important in obtaining successful grafts. The most suitable stocks are vigorous, in an early flush stage of growth, and from 1 cm to 1.3 cm in diameter.

Mature, vigorous scionwood, cinctured (girdled) on the parent tree four to eight weeks before use, gives best results. This technique increases the starch content and, as the starch content in the scion increases, so does the degree of success with the operation.

To check the starch content, dip the cross-section of budstick in a saturated solution of potassium iodide. The deeper the purple colour produced, the higher the starch content.

Scions with two bud whorls are best. Tie grafts with plastic tape to hold the cut surfaces in firm contact and seal the graft with a suitable mastic. White flat plastic paint reflects sunlight and helps keep scions cool in field grafting. In nursery situations, shade can be increased during and shortly after grafting.

Seed grafting. Germinated seed with the radicle removed

and a scion inserted has been used in the past by some propagators. However, field experience has proven they develop weak root systems. Even bearing trees are easily uprooted or snapped off at ground level under windy conditions.

Mini-Grafting or cleft grafting of seedlings 1 or 2 weeks after germination gives a good result and is very quick and simple. Seedlings are lifted out of germinating seed boxes with sand still adhering to the matt of roots, headed, scion inserted, tied, turned upside down and dipped in watered down Colgraft and planted in 2″ tubes and placed under mist.

Budding. Punch, patch and chip-budding have all been used successfully and economically. The operation is much quicker and requires less budwood than grafting. A strong union results with vigorous upright growth. Buds may be taken from large wood, which would be too bulky for use in grafting. Plump buds are taken from mature uncinctured growth.

In patch budding, oval shaped punches can be used to remove the bark from the rootstock and then collect the bud from the scionwood, ensuring perfect matching. Grafting tape is then used to bind over the bud. The bud is best inserted on the side of the rootstock away from the sun.

The tape is removed after six weeks and, if the bud is alive, the rootstock is severed with a sloping cut 1 cm above the bud. Use grafting mastic around the perimeter of the patch to prevent desiccation and lifting of the edge.

Chip-budding is done in the conventional manner, ensuring that the bud chip matches the portion removed from the stock. Good contact between the cambium layers is essential for satisfactory bud union. Chip-budding is used when the bark is not lifting readily, otherwise patch or punch-budding is preferred.

After budding, stocks are cut back to within 15 cm of the bud insertion, or at a point leaving two whorls of leaves above it. New growth from the bud may be tied to this stem stub for protection against snapping off in the early stages of development.

Cuttings. Cuttings have been used widely in S. Africa to propagate macadamia but not in Hawaii or Australia. Use a hardened young flush of growth. Make cuttings about 15 to 18 cm long, with 2 whorls of leaves. Remove leaves on 1 whorl and treat the basal end with a hormone rooting powder. Place in hot beds (30°C) under mist and 80% success can be achieved.

Because macadamias have weak root systems, every at-

tempt must be taken to avoid operations that restrict the roots. Germinate seeds in very deep boxes (30 cms) and do not bend roots in repotting.

Research into improved nursery techniques have led to better growth of seedlings and quicker outturn from nurseries. The use of husks in potting mixes gives a quicker growth — 9 months to grafting size rather than 14 to 18 months. Open-earth trees are used only rarely when necessitated by restrictions in potting operations.

LITCHI

The litchi (*Litchi chinensis*) is a native of southern China, where it has been grown for over 2,000 years. The fruit has a delicious subacid flavour and is regarded as a delicacy by the Chinese Besides beıng eaten fresh, the fruit may be dried, frozen or canned without loss of flavour.

Litchi trees are evergreen, compact in shape, and very attractive in appearance. Slow growing, but long lived and very sturdy, the tree grows to a height of about 12 metres. To encourage regular cropping only one growth flush must be allowed — in early autumn.

Litchi fruits are round to oval, from 2.5 to 4 cm long, and are borne in loose clusters of between 3 and 20 fruits. The skin is red, thin and leathery, with small conical protuberances.

The edible flesh (aril) of the ripe fruit is white, translucent, succulent and high in sugar.

Fruits contain a single dark-brown seed about 1 cm long. Some cultivars have large seeds, whilst in others they may be shrivelled, allowing a higher proportion of aril.

Propagation. To obtain progeny with the same desirable characteristics as the parent tree, the litchi is propagated vegetatively by either grafting or air layering. Litchi trees grown from seed vary in tree characteristics and cropping ability and may take up to 20 years to crop.

Airlayering. Airlayering, or marcottage, is the most popular method for litchi propagation. In cooler months 12 weeks are required before marcotts can be removed. In summer months 6 to 8 weeks are sufficient.

Select branches 12 to 24 mm thick from the outside portion of the tree Remove a ring of bark about 2.5 cm wide and 50 to 60 cm from the growing point. Scrape off the cambium layer below it with a sharp knife or a strip of emery paper to ensure that there will be no overgrowing of the ringed area.

Wrap the girdled area with moist spahgnum or peat moss

enclosed in a piece of clear plastic sleeving about 25 cm wide. Squeeze the moss to remove excess water, before applying to the girdled areas.

Covering the sleeve with paper or hessian may be necessary to protect the developing roots against sunburn. Bind both ends of the sleeve enclosing the airlayer tightly around the branch and tie firmly. Pre-made bags of moss or peat can be used like a "split sausage" and save a lot of time.

Because of its brittleness, the airlayered branch may need supporting to prevent it snapping in the wind. Either tie it to a stronger branch or fasten it to a stake.

White roots can be seen growing from the airlayer, or marcot, about 8 weeks later. When enough have formed cut the marcot from the parent tree just below the sleeve.

Remember the following points before separating the airlayer from the parent tree;

* Remove 50 to 75 per cent of the foliage. The roots cannot support all the leaves at this stage. Remove excess side shoots and seal the cuts to prevent moisture loss.
* The young roots of the airlayer are very brittle and easily damaged by rough handling. Do not carry the marcots by their tops as this may wrench the young roots from the base of the plant.
* Take extreme care with newly potted marcots. Leave them in the shade house, water them well, and do not expose them to direct sunlight. Because the root system of a newly separated marcot is only partially functional, it is not capable of supporting the tree in the field.
* Marcots survive better if the potted plants are placed in a very humid atmosphere for several weeks or until the roots have made sufficient growth.

Harden marcotted plants gradually under less shaded conditions for about a month before planting out. This reduces the adverse effect of sudden exposure to full sunlight.

Grafting. Besides airlayering, a number of different grafting methods have been tried throughout the world with varying success. These include inarching, side veneer, and whip and tongue grafts. Budding (modified Forkert) can give about a 40% success rate.

When starting from seed make sure it is fresh, preferably straight from the fruit. Litchi seed dries out quickly and becomes non-viable if kept longer than a few days. If it is necessary to keep the seed longer before planting, stratify it in a mixture of damp sphagnum moss and ground charcoal and store in a cool place.

Sow the seed about 1 cm below the soil surface in deep seed boxes. Leaf mold is a good germination medium Transplant the seedlings singly into large containers (9 to 18 litre capacity) 2 weeks after germinating Seedlings grow quicker in large containers and establish a good root system. It takes between 12 and 18 months for the trees to reach a satisfactory size for grafting.

Before grafting, cincture the scion wood; remove a ring of bark about 1 cm wide from the branch, at least 21 days before use. Select new season's wood from the parent tree, to obtain a vigorous scion.

Litchi wood is hard and brittle and because of this, whip or slice grafting is regarded as the best and simplest means of grafting. Results of grafts made in various parts of the world show that an experienced operator achieves between 70 and 80 per cent success.

Cuttings. Though not widely used in New South Wales, litchis can be propagated by cuttings, with some success. Use hardwood or semi-hardwood cuttings, some 18 to 20 cms long and up to 15 mm in diameter, preferably with growth ring at butt. Place in coarse sand under mist with bottom heat at 24°C, in shaded greenhouse.

In some prelimilary trials a 3 sec. dip in 200 ppm IBA appear beneficial but this is not yet finalised.

BANANA

Banana (*Musa acuminata*) planting material is usually obtained from bits and suckers in established plantations. This material, while it is widely used, is variable and may transmit pests and diseases such as nematodes, weevil borer, and bunchy top. Its variability is related to its size (1 to 2 kg) and the status of the bud which forms the new plant.

Tissue culture offers a number of advantages to the New South Wales banana industry. These are. production of plants which are pathogen-free (no nematodes, weevil borer, or virus within the material) and which have good genetic potential.

Tissue-cultured bananas have been grown since the mid-1970's in Israel and Taiwan. They have been used on a small scale, especially for rapid multiplication of new cultivars.

Meristem tissue may be obtained from growing points in either the flower "bell," or young suckers. Bells are preferred because of: 1) ease of collection, 2) less chance of infection, and 3) allowing assessment of yielding ability. Up to 5000 new plants can be obtained from the one growing point.

Recently the Banana Growers Federation received money

from a Commonwealth Extension Services Grant to investigate the possibilities of using tissue culture methods to supply banana planting material in New South Wales. A nurseryman specialising in tissue culture was contracted to supply 10,000 plants over a period of 12 months. These plants are being supplied to the Department of Agriculture who will determine their suitability for planting in the field at various times of the year Some are being distributed to District Horticulturists who are arranging plantings in the Tweed, Richmond, Coffs Harbour, and Nambucca Districts.

Several unexpected problems have arisen in the production of these tissue cultured plants. 'Williams' is the most difficult Cavendish cultivar to grow by tissue culture. These problems have been overcome. From the bottles the plants are placed into 300 mm x 350 mm flats and grown to 10 cm in height. Problems are: nutrition, off types, initial variability, and competition among plants within the flats, and to virus contamination (CMV).

When these problems are overcome we need to determine the best type of plant for field planting. We think that plants with strong root systems, large corms, and small leaves will have the best chance of survival in the field. Top-root ratios can be manipulated by changing light, temperature, and nutrition.

AVOCADO

Because avocados (*Persea americana*) are extremely susceptible to *Phytophthora cinnamomi*, nursery standards for avocados must be exacting.

The Avocado Growers Association now operate a scheme whereby nurseries which comply with certain construction standards, maintain hygienic cultural operations, and are found to be free of *Phytophthora* and *Phythium* fungi, are granted accreditation. Such nurseries may advertise the fact that they have accredtation status.

The following conditions apply for obtaining accreditation:

TECHNICAL REPORT

1 Seed hot water treated or harvested directly off tree (specify) . . . . . .

2 Potting mix - well aerated, freely draining, holes in base of container (comment) . . . . . .
- at least 25 cm deep in container (state depth) . . . . . .
- disinfested with steam, methyl bromide, or not disinfested (specify) . . . . . .
- stored in sterile bins or on disinfested sealed floors (specify) . . . . . .

3 Water from deep well, or otherwise chlorinated (specify) . . . . . .

4 Hose nozzles kept off the nursery floor (yes or no)

5 Utensils, containers, trolleys and barrows confined to nursery area and regularly disinfested with chemicals (comments)

6 Floors of nursery and hardening-off area sealed (yes or no)

7 Nursery bench tops - at least 30 cm off floor level (yes or no)
- wire mesh or disinfested wooden slat (specify)

8 Waste soil and plant material regularly washed or taken away (yes or no)

9 Security - public and stray animals restricted entry (comment)
- loading area isolated from nursery (yes or no)
- foot baths at entrances properly maintained and installed (comment)

10 Plants from non-accredited nurseries excluded (yes or no)

11 Dust about nursery suppressed (comment)

12 Root systems (sample of a minimum of 10 containers) sound or otherwise (comment)

13 Assay for soil-borne pathogens
(bulk sample of a minimum of 30 containers).

14 General comments on nursery hygiene and/or plant health

Signed(Technical Officer)(date)

The avocado industry also aims to become established on virus-free lines. Conventional indexing takes 2 years, but is being supplemented by quicker D.N.A. methods. Grafting knives, secateurs etc. must be sterilised with hypochlorite.

Seed Division. As seed supply is restricted and expensive, seed may be divided. With care, eight plants may be gained from each seed, but simply halving of seeds is most common.

HIGH TEMPERATURE RELEASE CHARACTERISTICS OF RESIN-COATED SLOW RELEASE FERTILIZERS

ROSS J. WORRALL

Horticultural Research Station,
Gosford. New South Wales.

Abstract. Two types of slow-release resin-coated fertilizers, which control the release rate by coating thickness (Type A) or a release agent (Type B) were tested for their high temperature stability. Heating different formulations (various N-P-K ratios and/or release rates) to 25, 60 or 70°C in water for 30 minutes had little effect on their subsequent release characteristics in water at 25°C for 1 week followed by 45°C for 9 weeks Two different formulations of each fertilizer type were also held in water for 10 weeks at 25, 30, 35, 40 and 45°C The increase in release rate with increasing temperature was lower for type B fertilizers than type A fertilizers The per-

4 Hose nozzles kept off the nursery floor (yes or no)

5 Utensils, containers, trolleys and barrows confined to nursery area and regularly disinfested with chemicals (comments)

6 Floors of nursery and hardening-off area sealed (yes or no)

7 Nursery bench tops - at least 30 cm off floor level (yes or no)
- wire mesh or disinfested wooden slat (specify)

8 Waste soil and plant material regularly washed or taken away (yes or no)

9 Security - public and stray animals restricted entry (comment)
- loading area isolated from nursery (yes or no)
- foot baths at entrances properly maintained and installed (comment)

10 Plants from non-accredited nurseries excluded (yes or no)

11 Dust about nursery suppressed (comment)

12 Root systems (sample of a minimum of 10 containers) sound or otherwise (comment)

13 Assay for soil-borne pathogens
(bulk sample of a minimum of 30 containers).

14 General comments on nursery hygiene and/or plant health

Signed(Technical Officer)(date)

The avocado industry also aims to become established on virus-free lines. Conventional indexing takes 2 years, but is being supplemented by quicker D.N.A. methods. Grafting knives, secateurs etc. must be sterilised with hypochlorite.

Seed Division. As seed supply is restricted and expensive, seed may be divided. With care, eight plants may be gained from each seed, but simply halving of seeds is most common.

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centage cumulative increase in the release rate after 6 weeks of the type A fertilizers between 30 and 35°C was 23% and 16%, and between 35 and 40°C it was 62% and 60% respectively For type B fertilizers the increase between 30 and 35°C was 12% and 20%, and between 35 and 40°C it was 23% and 37% respectively

REVIEW OF LITERATURE

Use of resin-coated slow-release fertilizers in Australia is increasing. Their use as part or all of the nutrient requirements of container-grown plants offers many advantages to the grower. However, a problem of excessive salinity in the potting medium has been encountered in their use, especially in summer when container-grown plants may be exposed to high ambient temperatures. Media temperatures may exceed 45°C under certain conditions which will greatly accelerate the release rate of the fertilizer (1,2). Steam pasteurisation of media containing slow-release fertilizers also exposes them to high temperatures, although for short periods only. This may contribute to later salinity problems.

Two types of resin-coated slow-release fertilizers are available in Australia. One (type A - manufactured by Sierra Chemical Co.) relies on coating thickness (1), and the other (type B - manufactured by Chisso Asahi Fertilizer Co. Ltd.) relies on a release agent in the coat to control the release rate (2). The release period of the two fertilizers is determined by the manufacturers at 21° and 25°C, respectively.

The release rate of resin-coated fertilizers may be conveniently determined in water although this gives a higher rate (1.2 to 1.5 for type B fertilizers) than if it was determined in soil or other media (2).

One aim of this experiment was to determine the effect of short periods of high temperatures (such as those encountered in soil pasteurisation) on the short and long-term release rates of the slow release fertilizers. The other was to examine the effects of continued high temperatures (such as those found in container-grown plants in the field) on the release rates of resin-coated slow-release fertilizers.

MATERIALS AND METHODS

(a) Effect of Short-Term High Temperatures on the Release Rate of Fertilizers

Fifty g of each of 3 formulations of type A fertilizer (14N-6. 1P-11.6K, 3-4 month; 15N-5.2P-12.5K, 3-4 month, 18N-4.8P-8.3K, 8-9 month) and 3 formulations of type B fertilizer (16N-4.4P-8.3K, 4-5 month; 16N-4.4P-8.3K, 8-9 month; 13N-5.7P-9.1K, 8-9 month) were held in sealed flasks containing 100 ml of distilled water at 25°, 60°, or 70°C for 30 minutes. The

fertilizer/water mixture was then held at 25°C for 1 week then at 45°C (to accelerate the rate of release) for 9 weeks. The release rate was determined by filtering and washing of the fertilizer prills (small granules) after 30 minutes (for the 60°C and 70°C treatments) and then at approximately 1 week intervals (for all treatments). The filtrate was then evaporated at 80°C and the amount of fertilizer solubilised determined by weight. Duplicate samples were used and 100 ml of water was added to the fertilizer after each filtering.

(b) Long Term Temperature Effects on the Release Rate of the Fertilizers.

The method was as described in part (a) except that the samples were held at 25°, 30°, 35°, 40° and 45°C for the duration of the experiment and the 30 minute sampling was omitted.

Two type A (14N-6.1P-11.6K, 3-4 month; 18N-2.6P-10K, 8-9 month) and two type B (16N-4.4P-8.3K, 4-5 month; 13N-5.7P-9.1K, 8-9 month) fertilizers were used in this experiment.

RESULTS

(a) Effect of Short Term High Temperatures on the Release Rate of Fertilizers

The results are presented in Table 1. Heating of the slow-release fertilizers to 60° or 70°C for 30 minutes had little effect on their subsequent release rates compared to those held at 25°C.

(b) Long Term Temperature Effects on the Release Rate of Fertilizers

The results are presented in Figure 1. The release rate of all fertilizers increased with increasing temperature. The percentage increase in the release rate was much greater between 35° and 40°C than between 25° and 30°, or 30° and 35°C. The percentage increase between 35° and 40°C was also much greater for type A fertilizers than type B fertilizers.

DISCUSSION

The temperature regime simulating the conditions experienced when soil is pasteurized had little effect on the release characteristics of the slow-release fertilizers tested. This indicates that they may be safely incorporated into media before it is pasturized (at 60° or 70°C) greatly simplifying their use, provided the medium is quickly cooled after pasturization to prevent a significant release of nutrients, possibly creating a salinity problem. Another reason for use of the medium as soon as possible is that the prills soften with time and become

Table 1. Effect of initial (30 min) temperature treatment on the release rates of various resin-coated fertilizers in water

Fertilizer			Initial Temperature °C	Cumulative percentage released after				
Type	N-P-K formulation	Release period (mths)		20 min	7 days	14 days	30 days	65 days
A	15-5 2-12.5	3-4	25	—	15	39	65	77
			60	1 1	16	40	70	75
			70	0 9	16	38	71	77
A	14-6 1-11 6	3-4	25	—	13	25	64	73
			60	3 0	14	26	68	74
			70	2 4	13	24	67	74
B	16-4 4-8 3	4-5	25	—	6	37	56	63
			60	0 1	9	39	60	63
			70	0 1	8	36	58	62
A	18-4 8-8 3	8-9	25	—	8	27	63	74
			60	0 6	9	31	67	74
			70	0 5	9	27	66	72
B	16-4 4-8 3	8-9	25	—	4	22	43	54
			60	0 3	6	24	46	54
			70	0 2	6	21	46	53
B	13-5 7-9 1	8-9	25	—	5	13	31	43
			60	0 3	6	16	33	46
			70	0 4	6	13	35	43

much more susceptible to mechanical damage during potting operations

The release rate of the fertilizers, especially the type A, increased dramatically with temperatures exceeding 35°C. This indicates why salinity may become a problem in container-grown plants in the summer, expecially if slow release fertilizers are applied to the surface of the pot. This is often the highest temperature area of the container.

Clearly there is a need for further research into controlled-released fertilizers, especially on the effect of temperature on their release characteristics. Salinity in potting media is a problem that may arise at high temperatures. This may be corrected by leaching. However, if this is done it may lead to nutrient deficiences later if the nurseryman expects the fertilizer to last for its stated "life."

These experiments also demonstrated that although resin-coated fertilizers may be rated for the same time period, their release rates can be very different. This should be taken into account when designing a fertilizer programme.

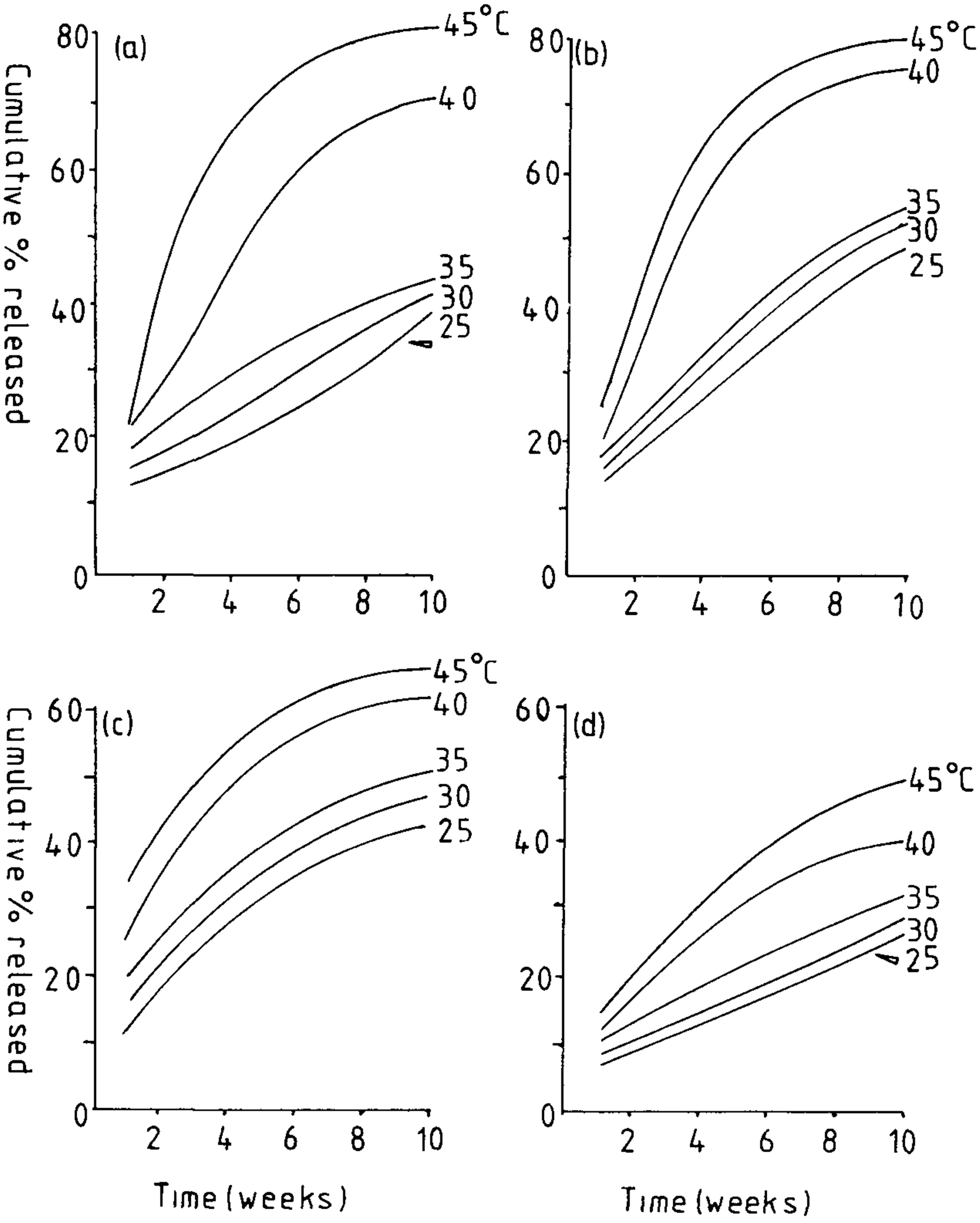

Figure 1. Release rates of resin-coated fertilizers in water at 25°, 30°, 40° and 45°C (a) Type A 14N-6 1P-11.6K, 3-4 month formulation (b) Type A 18N-2 6P-10K, 8-9 month formulation (c) Type B 16N-4 4P-8 3K, 4-5 month formulation (d) Type B 13N-5 7P-9 1K, 8-9 month formulation

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2 Shibata, A , T Fujita, S Maeda 1980 Nutricote® coated fertilizers processed with polyolefin resins *Acta Horticulturae* 99 179-186

RAPID PROPAGATION OF POTATO: WHY? HOW?

P B. GOODWIN

Department of Agronomy and Horticultural Science

University of Sydney, Sydney, New South Wales 2006

Why? Potatoes (*Solanum tuberosum*) are normally propagated as tubers. The use of tubers gives this crop the major advantage of rapid crop development, leading to higher yields in a short period (3 to 4 months from planting) than any other major crop. However, the use of tubers leads to two major problems·

1. Plants very readily become infected with serious tuber-borne diseases such as leaf roll virus, which are then passed on to subsequent crops. These crops give low yields. The spread of the most serious diseases is via aphids and, for this reason, "seed" tubers are typically produced in areas low in aphids — for example the highland areas of New South Wales. It is also possible to eliminate the most serious virus diseases from individual shoot tips using apical meristem culture.

2. The second major problem with tubers is slow propagation, normally 7 to 10 fold per year, in field conditions. This severely limits the rate of introduction of new selections, or of apparently virus-freed cultivars.

As a consequence of the previous two factors many countries operate a "pathogen-tested" "seed" potato scheme. A very small number of plants of each cultivar are grown from clean tubers in rigorous isolation. Each year about 30 tubers from these are tested for pathogens. Provided they are shown to be free of diseases, they are propagated, year by year, at first in "foundation seed" farms, then in "mother seed" farms, and finally in "certified seed" farms, until their progeny are numerous enough to provide the planting material for one crop in one year in the region. The next year a completely fresh lot of seed is used, and so it goes, in a continuous flush out system The propagation from the pathogen-tested tubers to the farmers "seed" takes about six years. Propagation is expensive, in that the prime clones must be maintained in specially

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dedicated, remote farms. There is also a considerable risk of infection over the extended propagation period.

There is obviously a need for ways to rapidly propagate potatoes under conditions where the risk of infection is low. The question is, how?

How? A large number of techniques for the rapid propagation of potatoes have been described in the last five years. These can broadly be described as either glasshouse techniques — shoot cuttings, sprout cuttings, leaf bud tubers, and a technique developed here, (single node cuttings), or tissue culture techniques (including two developed here). The generally accepted belief has been that tissue culture techniques give more rapid propagation, and are bound to be superior. However, by optimising glasshouse propagation techniques, we have been able to achieve propagation rates compatible to tissue cluture and, in fact, rates which are much higher when allowance is made for the time and effort spent in establishing plant material in culture and in its rooting and hardening after removal from culture. Furthermore, glasshouse propagation uses much simpler equipment, and makes less arduous demands on the operators. It can also be made virtually disease-secure. On the other hand, tissue culture requires the full complement of glasshouse space which would itself be enough for glasshouse propagation, and, as well, requires all the equipment needed for tissue culture.

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OUR EXPERIENCES WITH SOIL-LESS POTTING MEDIA

KEITH H. MACDONALD

Keck's Nursery
Bendigo, Victoria

Our initial soil mix consisted of the following: coarse sand, sandy loam, rice hulls, peat moss These were spread out in layers and turned four times by hand. This mix was open and dried out quickly, with very little fertilizer added. We then tried a similar mix incorporating sewerage sludge. This mix proved difficult to handle because of the sludge, and fumigation was very difficult. At this time we were fumigating with methyl bromide. We then set about installing a steam generator to pasteurise the medium, at this time we also installed a cement agitator to mix it.

We also switched across to a sawdust mix using three parts red gum sawdust to one part coarse sand. Initially the sawdust used was from heaps 20 to 30 years old. We felt that this sawdust would be sufficiently composted but found that it did tie up nitrogen and plant growth was very slow.

We then began to liquid feed with Aquasol, but the response was negligible. We were then advised to liquid feed with ammonium nitrate. This gave us a much better response. However, this old sawdust was expensive, and so we switched to fresh sawdust which needed to be composted. This was done by the following method. We added. 5 kg ammonium nitrate, 5 kg calcium nitrate, and 600 g magnesium.

These were dissolved in water and added to one cubic metre of sawdust. To this was added. 1.8 kg superphosphate, 1 kg potassium, 1.1 kg Fritted Trace Elements, and 2 kg lime.

This was mixed thoroughly with a large amount of water added. This was then stored in heaps for at least six weeks. It was then used in our potting media at the rate of: 8 parts sawdust, 3 parts coarse sand, and 1 part brown coal.

To this we added the following fertilizer mix: 1 kg lime, 850 g superphosphate, 200 g potash, 19 g Fritted Trace Elements, 1.5 kg Osomocote, 75 g sulphate of iron, 75 g G.U. 49.

However, single cultivars of plants failed at different times due to ammonia burn. Also a great deal of liquid fertilizer was required to keep the plants growing. The liquid fertilizer used was ammonium or calcium nitrate

Considering the problems of managing this mix and the crop failures that occurred a switch to bark was made.

This was done simply by replacing the sawdust with bark The bark was much more expensive but eliminated the need

for composting and the risk of ammonium burn, and plant growth was good. As time progressed the mix was changed to: 3 parts bark, 2 parts coarse sand, 1 part brown coal, and the fertilizer mix was changed to: 2 kg 8 to 9 month Osmocote, 1 kg 3 to 4 month Osmocote, 850 g lime, 850 g superphosphate, 200 g potash, 19 g Fritted Trace Elements, 75 g sulphate of iron, and 75 g G.U. 49 per cubic metre and, more recently, this has been changed to: 2 kg 8 to 9 month Osmocote, 1 kg 3 to 4 month Osmocote, 850 g lime, and 1 kg Micromax. This fertilizer blend is varied for different plants and pot sizes.

For *Proteaceae* we use: 2 kg 8 to 9 month Sierra Blend & Iron, 1 kg Micromax, 850 g lime, and 2.3 kg dolomite lime.

General Mix: 2 kg 8 to 9 month Osmocote, 1 kg 3 to 4 month Osmocote, 1 kg Micromax, 850 g lime.

For indoors the Osmocote used is: 2 kg 3 to 4 month Osmocote, 1 kg 8 to 9 month Osmocote. For large containers the Osmocote is: 1 kg 3 to 4 month Osmocote; 1 kg 8 to 9 month Osmocote, 1 kg 12 to 15 month Osmocote.

This medium has proved successful until last summer when the problems of watering were extreme. So two trial mixes were tested in an endeavour to eliminate this watering problem. These trial mixes were: (a) 2 parts bark, 2 parts coarse sand, 1 part sandy loam, and 1 part brown coal, and: (b) 3 parts bark, 1 part coarse sand, 1 part sandy loam, and 1 part brown coal

The second mix is the one we will be using as it is lighter but still gives us the required results.

PROPAGATION OF *BORONIA SERRULATA* Sm. (NATIVE ROSE) FROM CUTTINGS

GREGORY P. LAMONT

New South Wales Department of Agriculture,
Horticultural Research Station,
Gosford, New South Wales

Abstract. *Boronia serrulata* is a plant with great horticultural potential but as yet is not widely propagated and grown for amenity horticulture A study was made into the effects of applied auxin, temperature at the base of the cutting, and source of cutting material on the rooting of cuttings of this Native Rose Response to auxin depended on physiological state and genotype of donor plant Cuttings selected in the spring (November) from wild donor plants showed improved rooting percentage to applied auxin, however those taken in late summer (February) were unresponsive Cuttings selected in November from container-grown mother stock plants showed little response to applied IBA up to 8,000 ppm. Basal temperature of 29°C

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improved rooting percentage in November but in February bottom heat caused drying of cuttings

Wild populations of donor plants gave rooting percentages ranging from 6% to 93% whilst cuttings from mother stock plants showed a rooting percentage of 85% Although the treatment of cuttings with auxin and the provision of basal heating can promote the rooting of Native Rose, greatest improvement in rooting can be achieved by careful selection and management of mother stock plants.

Boronia serrulata is a medium shrub growing in heath and open woodland. The distribution of Native Rose is confined to the soils of Hawkesbury sandstone in a coastal strip extending between Gosford and Waterfall, New South Wales.

The family Rutaceae is well represented in Australia and the genus *Boronia* is endemic. Many *Boronia spp.* have great horticultural potential but vegetative propagation has been reported to be slow and difficult (1,9).

The effect of applied auxin, temperature at the base of the cutting, and donor plant on the rooting of *Boronia serrulata* was investigated.

MATERIALS AND METHODS

The response of Native Rose cuttings to four auxin treatments and four basal temperatures was investigated in November, 1978, and February, 1979, in two factorial experiements.

Auxin Treatments:

1,500 ppm each of *NAA and IBA in 50% aqueous ethanol
1,000 ppm each of *NAA and IBA in 50% aqueous ethanol
500 ppm each of *NAA and IBA in 50% aqueous ethanol
Control, 50% aqueous ethanol

Basal temperatures:

19°C, 24°C, 29°C, 34°C

The source of cuttings was wild donor plants growing in the Royal National Park near Sydney. Cuttings were all ripened shoot tips 5 to 7 cm long. They were washed in aqueous calcium hypochlorite (0.5% available chlorine) for two minutes and rinsed several times in deionized water. Leaves were trimmed from the lower 2 cm and the base was dipped in the appropriate auxin solution for five seconds. Cuttings were stuck into a steam pasteurized coarse sand/peat mixture (3:1) in 30 mm diameter plastic pots. Pots were placed under intermittent mist in the temperature beds.

Treatments were replicated 15 times; each replicate of four cuttings was a different donor plant. Cuttings were exam-

*NAA — naphthaleneacetic acid IBA — indolebutyric acid

ined for roots after eight weeks. Rooted cuttings from November, 1978, were repotted and placed in a shade house (50% shade) Establishment of cuttings was noted three weeks later.

In November, 1979, a third experiment was designed to assess rooting response of cuttings (basal temperature 27°C) to the following auxin treatments:

8,000 ppm IBA ın 50% ethanol
4,000 ppm IBA in 50% ethanol
2,000 ppm IBA in 50% ethanol
1,000 ppm IBA in 50% ethanol
Control, 50% ethanol

Cuttings were taken from 15-month-old container-grown plants propagated from one clone. These mother stock plants were grown in a shade house (50% shade). Cuttings were examined for rooting after eight weeks and observations made on the number of cuttings rooted, number of roots formed per cutting, and total root length per cutting. Cuttings were visually ranked 0-5 on root development (Figure 4).

RESULTS

In November, 1978, a greater percentage of cuttings rooted at a basal temperature of 29°C and 34°C compared to 19°C (Fig. 1) Cuttings planted ın February rooted better at 19°C and 24°C

Cuttings from wild donor plants in November showed improved rooting with the application of auxin. IBA/NAA at 1,000 ppm significantly increased percentage rooted over the control. (Fig 2) The response to auxin in February was slight and not significant

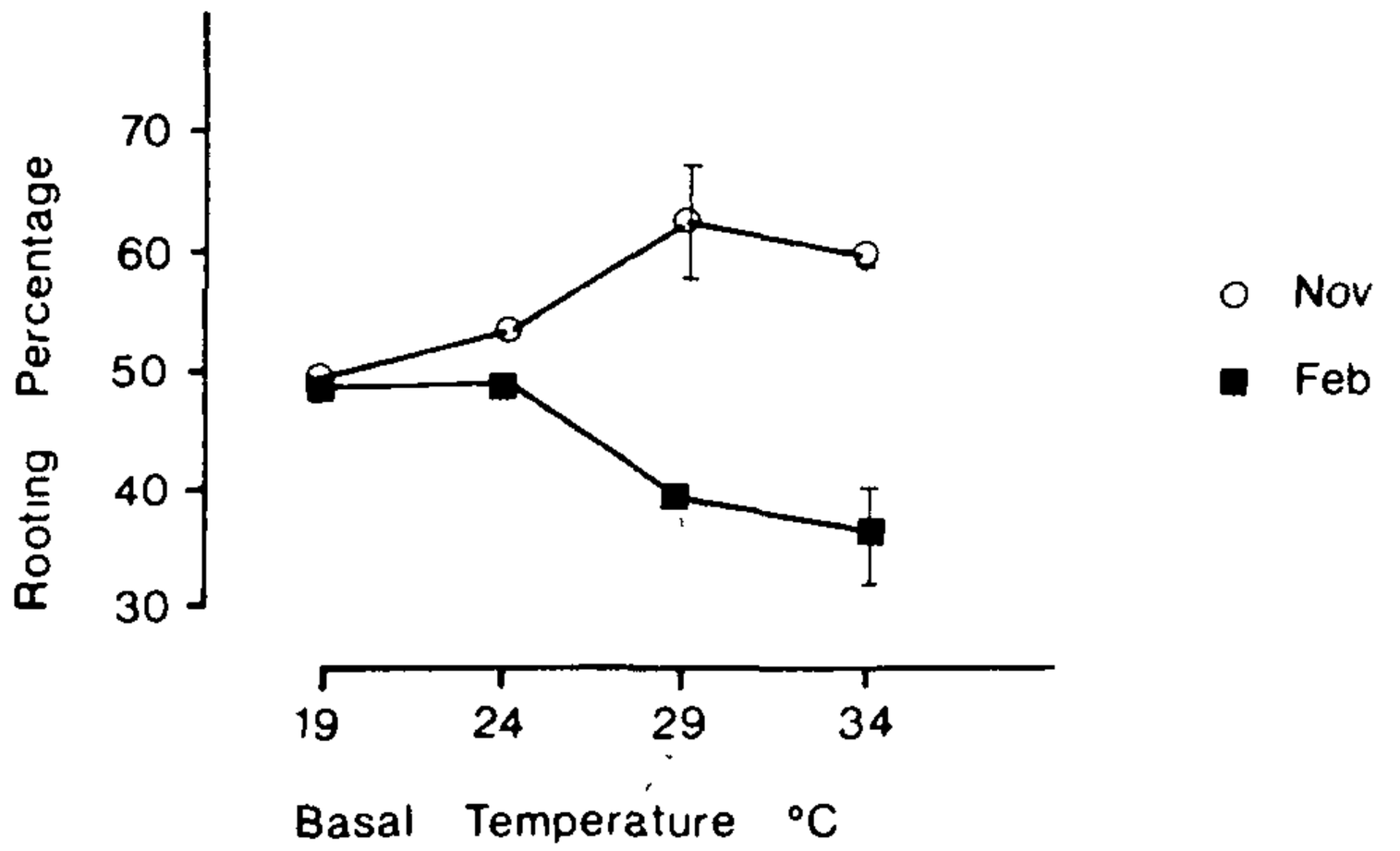

Figure 1. Response of *Boronia serrulata* cuttings to basal temperature

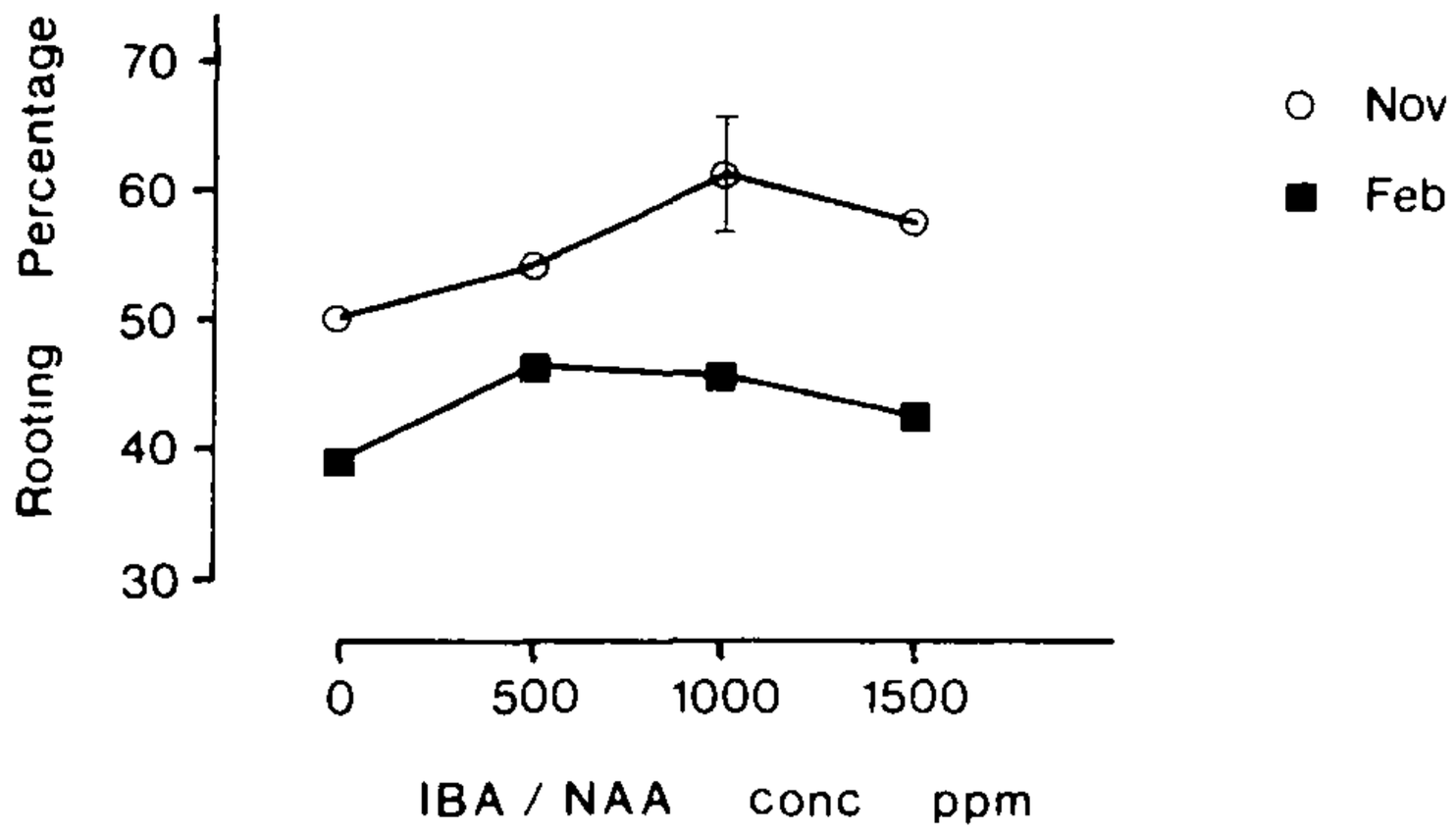

Figure 2. Response of *Boronia serrulata* cuttings to applied auxin

Rooting of cuttings (irrespective of temperature or auxin treatment) varied between 6% and 93% for the different donor plants (Fig. 3). The establishment of rooted cuttings from November 1978 is shown in Table 1. Donor plants showing a high rooting percentage did not necessarily establish better than those with a low rooting percentage

In Experiment 3 using mother stock plants, high levels of applied indolebutyric acid had no effect on the percentage of cuttings forming roots and the number of roots formed per cuttings (Table 2). Root development assessed visually (Fig 4) and total root length was greater when cuttings were treated with 8,000 ppm IBA

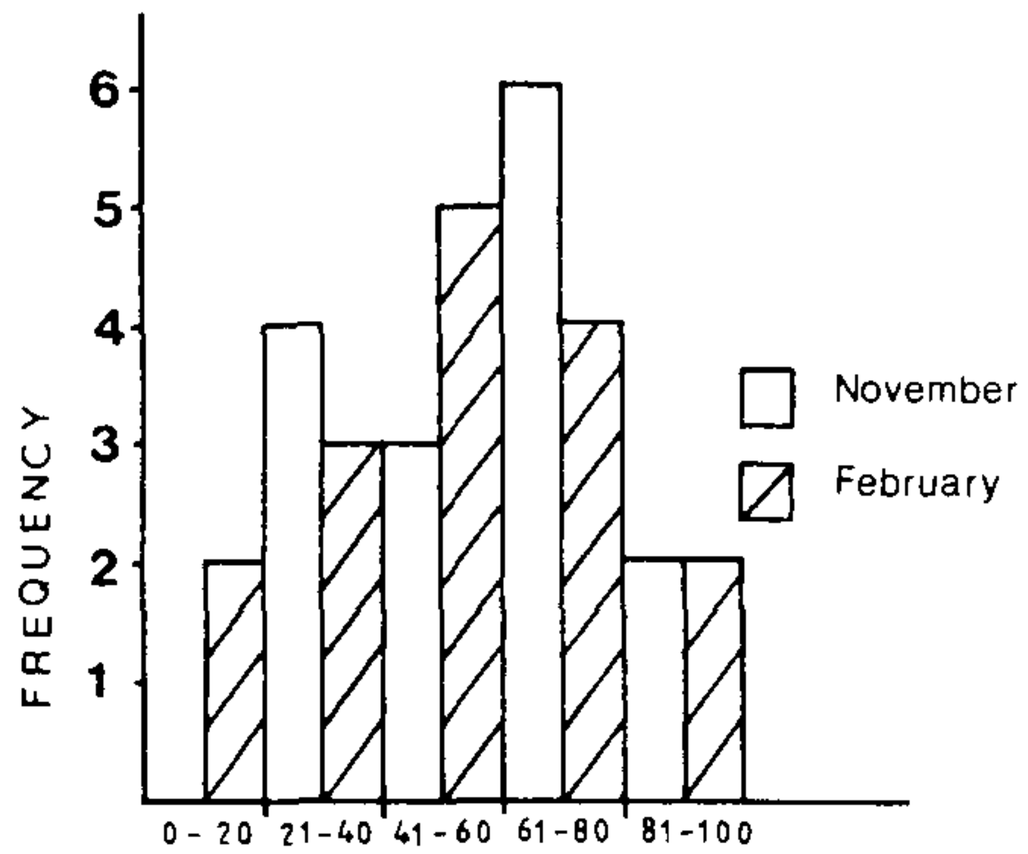

Figure 3. Frequency distribution of rooting percentage for different wild donor plants

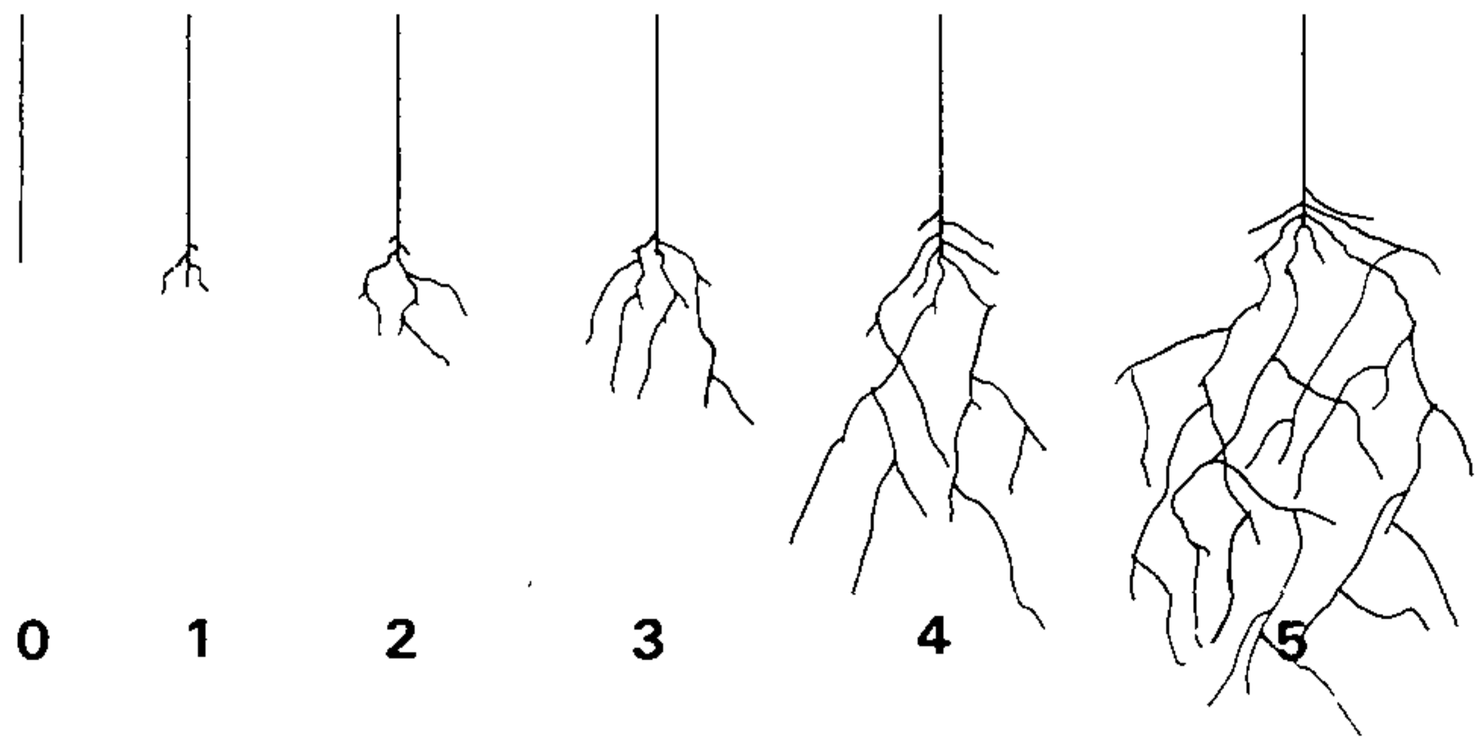

Figure 4. Rank based on degree of root development

Table 1 Establishment of rooted cuttings of *Boronia serrulata* after repotting

Donor Plant	Rooting Percentage	Percent Rooted Cuttings Established
1	70	73
2	61	100
3	53	50
4	73	73
5	63	100
6	27	100
7	33	60
8	82	84
9	52	62
10	27	100
11	93	71
12	21	83
13	67	50
14	44	55
15	75	56

Table 2 Effect of indolebutyric acid on rooting *Boronia serrulata* cuttings

IBA Conc , ppm	Percent of Cuttings Rooted	No of Roots per Cutting	Total Root Length, mm	Mean Rank
8000	87	2 5	212	2 5
4000	87	2 4	180	1 9
2000	77	1 8	147	1 3
1000	80	2 2	169	1 6
0	93	2 4	182	1 7
	N S	N S	$LSD_{5\%}$56	$LSD_{5\%}$0 61

DISCUSSION

Cuttings responded differently to basal temperature at the two planting dates. In November a basal temperature of 29°C improved rooting percentage. Other workers have found improved adventitious root formation if the basal temperature of the cutting is maintained between 25°C and 30°C (2,3). In the February planting rooting percentage was depressed as basal temperature rose above 24°C because the base of the cutting tended to dry out.

The response of *Boronia serrulata* cuttings to applied auxin varied according to the time of year and source of cutting Cuttings selected from wild plants in November showed improved rooting percentage with applied auxin (1,000 ppm IBA/NAA) although cuttings taken in February were variable in their response. When container-grown plants were used as the cutting source, development assessed visually was only marginally improved when cuttings were treated wtih 8,000 ppm IBA.

Adventitious root initiation in cuttings is a complex phenomenon controlled by several internal factors and affected by environmental conditions. Many species, which are difficult to root, display juvenile and adult phases depending on the ontogenetic age of the plant. The adult phase has been associated with the presence of rooting inhibitors and/or the absence of rooting cofactors, including auxins (5,6). The age of wild donor plants of Native Rose was up to 11 years (last bushfire, January 1967) whilst mother stock plants derived from cuttings were 15 months old. Genotypic variation in natural populations can also account for great differences in the ease of rooting. Good *et al.* (4) and Howard and Shepherd (7) note the clonal variation in rooting of trees and shrubs. Rooting percentages in wild populations of Native Rose ranged between 6% and 93% compared to 85% for mother stock plants.

Physiological state of donor plants has also been shown to influence endogenous auxin levels and the presence or absence of rooting cofactors and inhibitors (5) Mother stock plants were healthy and vigorous and provided many ripened cuttings. Wild donor plants appeared dormant in November (possibly due to moisture stress) and, in February, were undergoing the transition from vegetative to reproductive growth (unpublished data of author).

Considering the factors of age of the donor plant, genotype, and physiological status it is not surprising that cuttings selected from wild donor plants display great variability in rooting. Although the treatment of cuttings with auxin and the provision of basal heating can improve the rooting of Native

Rose, greatest improvement in rooting can be achieved by careful selection and management of mother stock plants.

ACKNOWLEDGMENT This work is part of a study for the degree of MSc Ag carried out in the Department of Agronomy and Horticultural Science, University of Sydney The author gratefully acknowledges advice and encouragement from Professor M G Mullins and Dr J Clemens The author also acknowledges the N S W National Parks and Wildlife Service for permission to collect material from parklands

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AUTOMATING AERATED-STEAM TREATMENTS

GAVIN A. WILTON

Falg Nurseries Pty. Ltd.,
Uraidla, South Australia

Since we introduced aerated-steaming of soil in our nursery in early 1962 we have gained a lot of experience and have greatly upgraded the equipment. We know the areas for cold spots, the time it takes to bring the various mixes up to temperature, etc , and with this knowledge we set out to automate these operations

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equipment proved to be unreliable. When it functioned properly it was very good and, possibly with better equipment and more reliable technicians, this could have been the best way to go. However, after many frustrations over a long period we discarded this equipment and switched to more mechanical type units. The equipment used is available off the shelf from various suppliers. I mention the equipment I have used but do not imply that this is the only or the best equipment available. At least what I have assembled is working, has more than paid for itself, and is expected to last a good few years yet.

For bulk soil we have mobile bins of ½ cubic yard capacity which are wheeled to a fixed aerated-steaming unit and coupled up with a flexible hose. The temperature of the steam-air mix is controlled by a Honeywell Modutrol Motor (M 945A) coupled to a ½" steam valve (V 5011) and linkage (Q 455), in conjunction with a Fast Response Temperature Controller (T 991). The timing sequence is by two time clocks, TESCH 60 min., set up in a control box with the necessary relays, push-button start-stop switch, and sequence indicator lamps. A steam solenoid valve is incorporated in the steam line to give a positive shut-off of steam. When we are ready to steam it is only necessary to push the start button. The steam solenoid opens, the blower runs and the Modutrol motor moves to the open position until the temperature reaches 62.5°C, then it modulates to maintain this temperature. After 45 minutes the steam solenoid shuts and the Modutrol motor closes the steam valve, the blower remains running. At the end of the cooling cycle the blower stops, the unit then resets the clocks ready for the next batch If the button is pushed during a treatment everything stops and the clocks reset; depending upon the stage reached, it is necessary to set the clocks manually to finish the treatment or the treatment will recommence when the button is pushed again. The blower we use on this unit is a high pressure type 11" diameter impeller with a 4" discharge opening driven by a ¾ H.P. 3 phase 2910 r.p.m. motor.

The steaming of bedding plant flats is done in vaults that hold two racks of 168 flats (2688 punnets and 1½ cubic yards of soil). The doors of these vaults are opened and closed by a pneumatic ram, manually or automatically controlled. The steam-air temperature is controlled by a Danfos Temperature Regulator (IVT Type), a steam solenoid is incorporated in the line. The timing is by a Paragon 6 Hour Interval Reset Timer set up in a control box with the relays, start and stop buttons, and indicator lamps. The blowers are of the high pressure type, 21" diameter, 6" discharge opening driven by a 2 h.p. 2800 r.p.m. 3 phase motor. For a treatment the time clock is

set for the desired time for pre-heat and treatment, then the start button is pushed. The steam solenoid opens, the blower runs and the door closes. At the end of the preset time the solenoid closes, the blower stops and the door opens.

The pneumatic rams are 6′ long × 1″ diameter and operate on approximately 70 p.s.i.; restrictors are incorporated to give a slow opening and closing of the doors. The doors are counter weighted so that if the air pressure is lost they will slowly close on their own weight, yet can be easily opened by hand if necessary.

This equipment has been in operation for the last five years and has been virtually trouble free for that period. The only troubles we have had are a couple of solenoids requiring new discs and vault doors requiring occasional lubricating. The seed treatment unit that we have had in operation since 4 July 1962, and still going strong is manually operated, but can easily maintain temperatures within 0.2°C.

In 1974 I had almost completed an automatic unit when a couple of electronic technicians figured they could do the job better and more accurately, electronically. Alas this was not the case and now I am virtually back to where I left off. Hopefully I will be able to report on this unit some time in the near future.

PLANTS ON WHEELS

KEVIN R. GAY
B.J. Gay & Sons,
Huntingdale, Western Australia

Why do we call this system "Plants of Wheels"? We looked at many different ways of moving plants. We looked at using as much productive space as possible and still be able to make the growing area work efficiently. We looked at a pallet system, a moving bench top, conveyor system and the uneconomical fixed bench. None of these were what we wanted in making plants totally mobile all around the nursery. Taking some of the ideas from each of these systems, we made our own design, which is a totally mobile bench.

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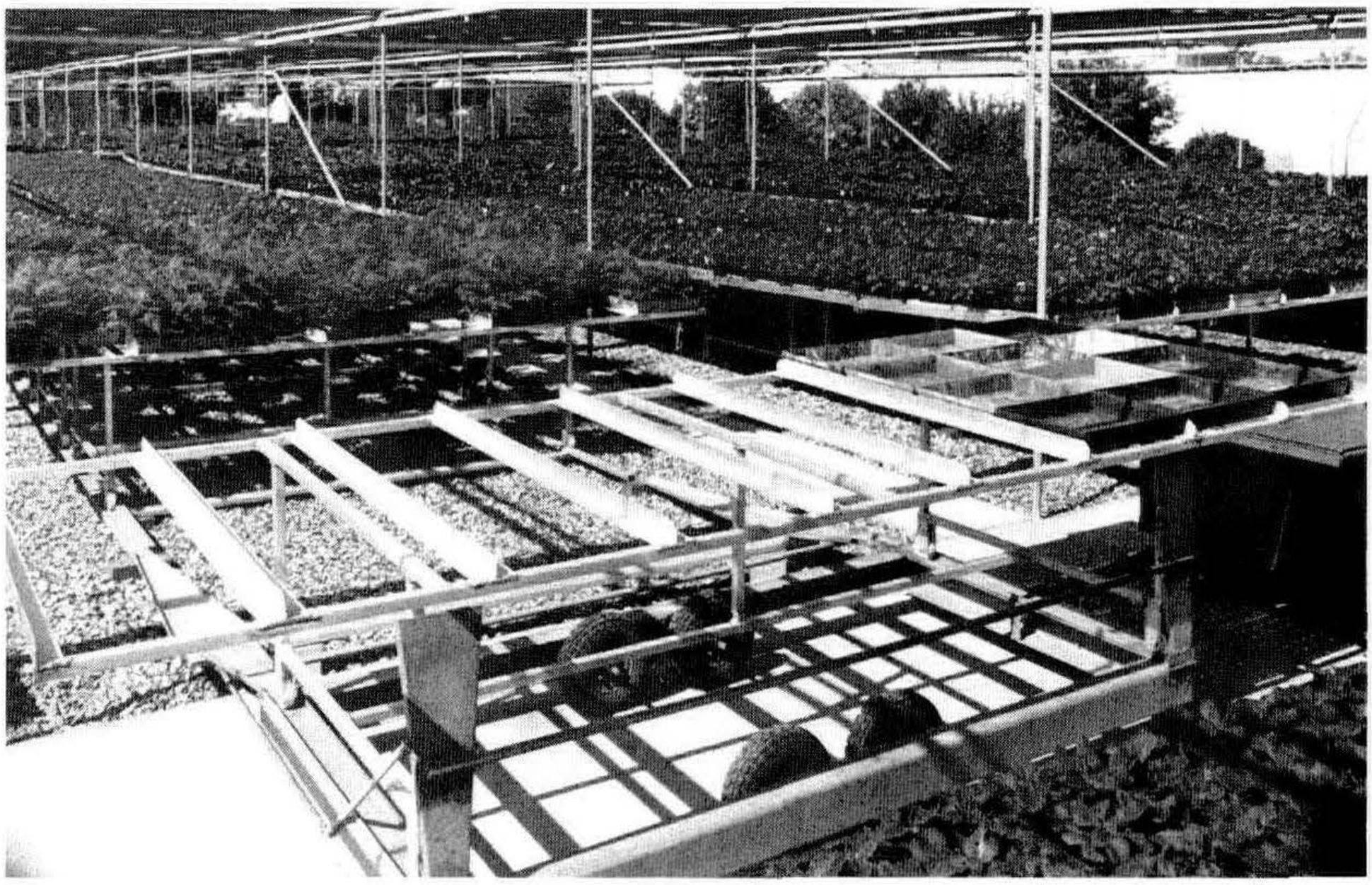

Figure 1. An aluminum frame which holds 36 plastic trays set in the rubber-tired trailer for moving. The frames are on four wheels, which run on two tracks. These frames are 500 mm high for good hygiene and for ease of handling. We used aluminum because of the rust problem with other metals and for the light weight. It cost a bit more, but it is worth it.

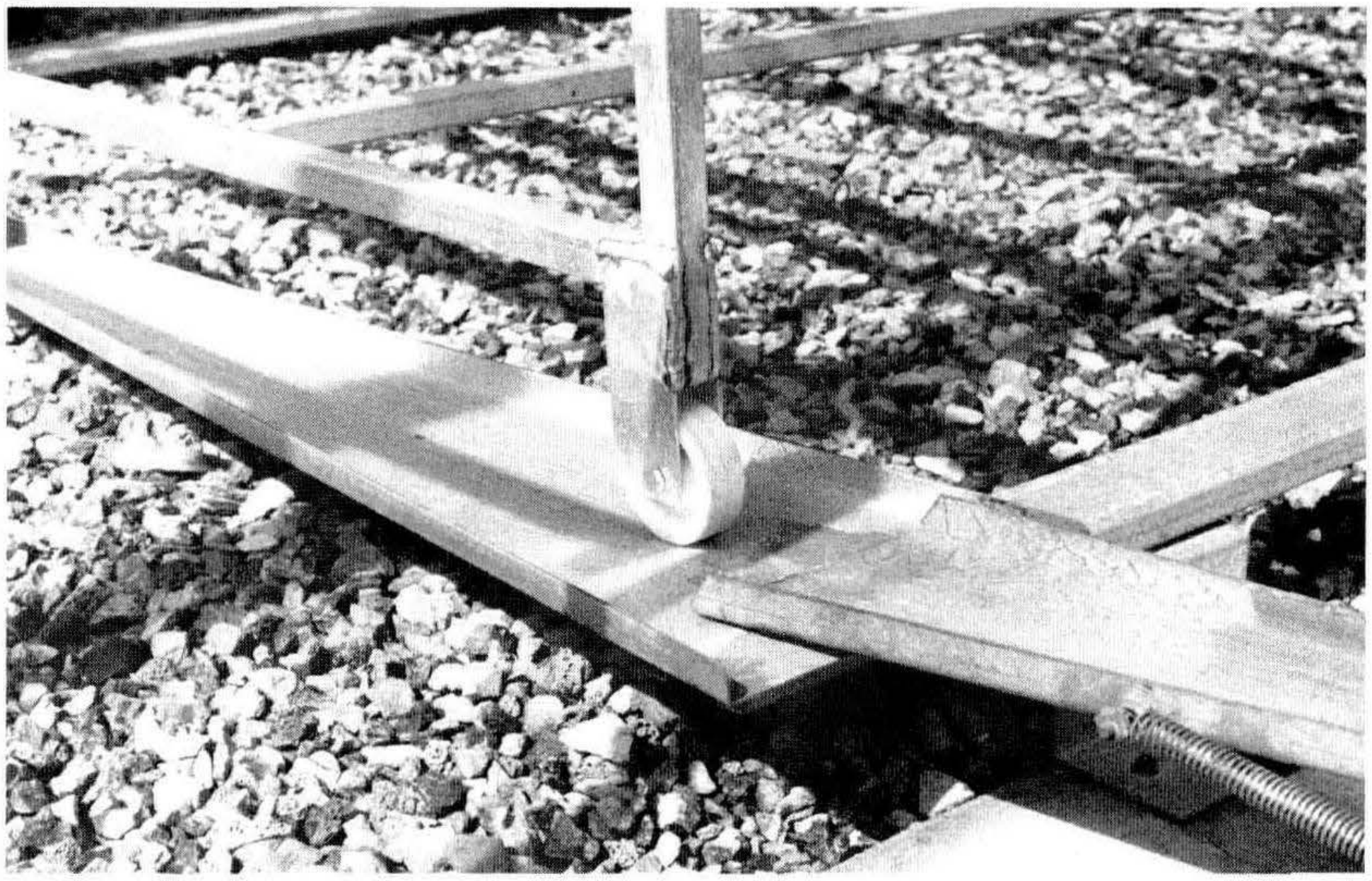

Figure 2. The tracks are made of two "Z" shaped sections, separated by sleepers every two metres. The wheels on the bench run on the outer bottom section of the "Z" shape. At the end of each track, on both sections, there is a "V" shaped lead-on used to direct the wheels on and off the track.

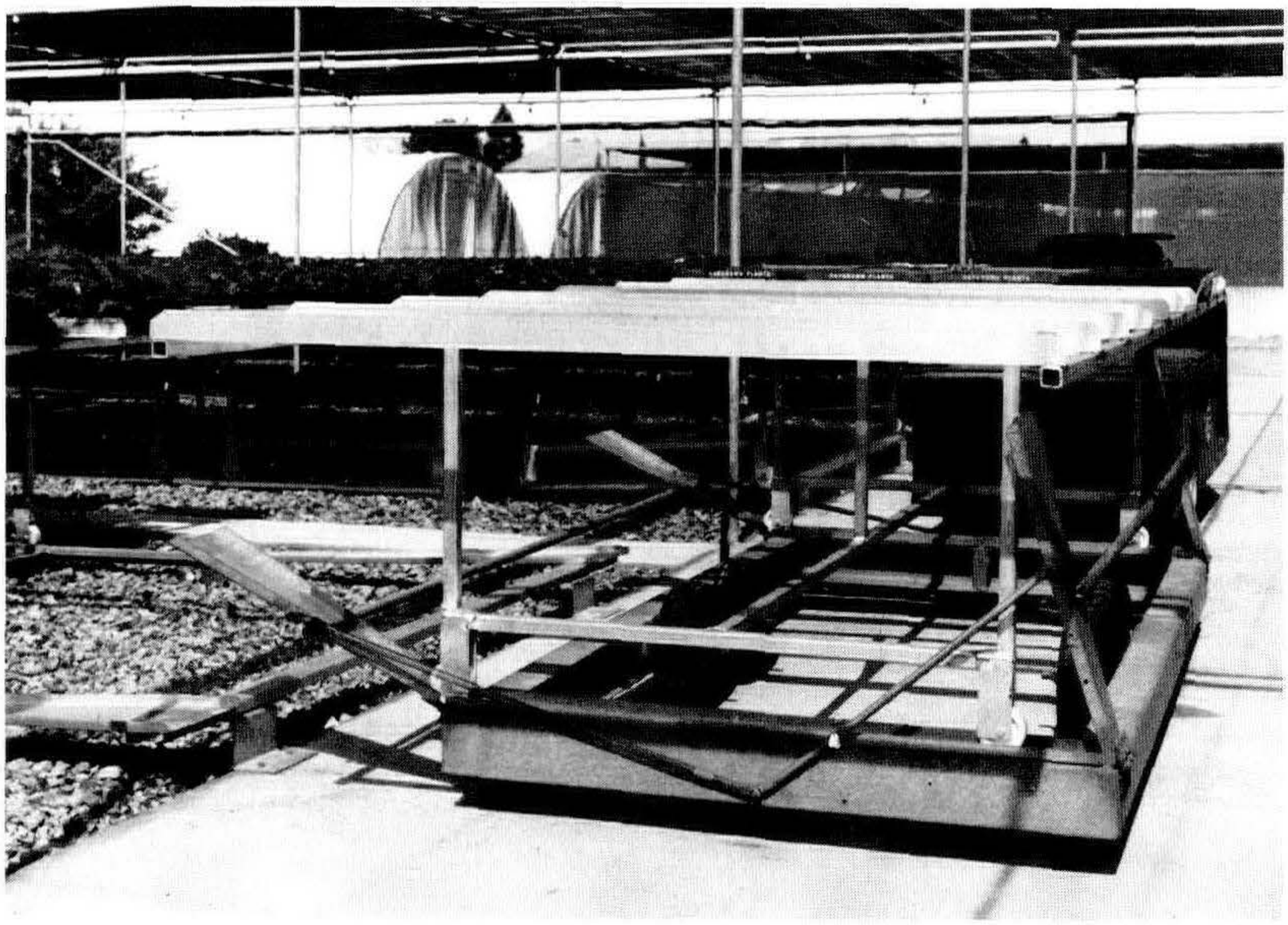

Figure 3. The benches are transported on a trailer towed by a small tractor or electric truck. The trailer is the key to the whole system because with the trailer you can move the benches anywhere you want. The trailer is constructed on only a frame for light weight and for ease of handling the benches on and off the trailer. A "U" shaped channel runs across each end of the trailer which the bench wheels run in. On the end of the channel on both sides of the trailer there are "V" sections like the lead-ons on the end of the track. These sections are hinged at the end of the "V" shaped channel to allow the "V" sections to be placed on the track lead-ons. This enables the benches to be rolled on and off the trailer.

In conclusion, an excellent system for a new glasshouse or shade house or, if you wish, to convert any original house. With rising heating costs this system of mobile benches saves space by needing only small paths between benches. Labour is also saved because one person can move 200 to 300 pots with the aid of the trailer and towing vehicle anywhere on the nursery. This is why it is titled, "Plants On Wheels"; the plants don't need to leave the benches the whole time at the nursery.

TREATMENT FOR CONTROL OF SEED-BORNE PATHOGENS OF ZINNIA

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University of Sydney, Sydney 2006, New South Wales

The general objective of this research work is to find effective methods of controlling seed borne fungi while maintaining high levels of seed germination and vigour. The material being tested at present is alternaria-infected zinnia seed.

The transmission of fungi by seed is important because it provides an efficient means of dissemination from one place to another and it allows carryover of the fungus in time. Because there is a close assocation of the fungus and seed there is maximum opportunity for progeny infection and the seed may help protect the fungus from unfavourable environmental conditions. The planting of fungus-carrying seed introduces the disease at random through an area producing well-distributed foci for primary infection (3).

Alternaria zinniae transmission in zinnia seeds occurs when senescent flowers on the plant absorb dew at night and remain wet the next day slowly becoming mouldy from a mixed microflora of fungi including *Alternaria zinniae*. This *Alternaria zinniae* has survived in the soil from the previous season's infected seedlings. *Alternaria zinniae* grows through the petals into the attached seeds. These infected seeds then give rise to diseased seedlings on which a great number of spores are produced. Air-borne spores then infect leaves, stems and flowers of other plants.

Methods for the control of seed transmission of fungi can be either preventive, such as crop rotation and selection and breeding of resistant plants, or curative in nature. This work involves the study of physical curative measures, that is, the application of heat.

Heat treatments have been used by many workers to significantly decrease or eliminate seed-borne diseases (5,7). The two most commonly used methods are hot water and steam-air treatment. Hot water was the first method used, one of the earliest reports being that of J.L. Jensen in 1888 who used hot water to kill the mycelia of *Ustilago nuda* infecting barley (3). It is still the most commonly used method today. Usually seed is soaked at temperatures ranging from 40°C to 60°C for time periods of 15 minutes to 24 hours, dried back, then stored or germinated.

L.A. Hawkins in 1929 first devised a "vapour heat" chamber for killing disease in which steam was injected into an air

stream and the temperature maintained by a mechanical device (4). Baker in the early 1960's developed a much more efficient apparatus suitable for seeds in which the aerated steam is passed downward through the seeds so that churning is minimized and condensate can drain out (2). Treatment temperatures are usually from 50° to 60°C and time periods range up to 30 minutes.

One of the major problems associated with the use of moist-heat treatments has been the severe decrease in seed viability that sometimes occurs. For example, for good control of some pathogens on lettuce Maude (6) found that a severe decrease in germination occurred. Moist-heat treatments may also produce a delay or reduction in germination vigour.

In this work attempts were made to overcome these problems by applying various chemicals to the seed either pre, during or after the heat treatment.

Several introductory experiments showed that about 55°C was the appropriate temperature for killing the alternaria in hot water and about 58°C for steam-air. Thirty minutes was the time period used. Germination percentages were very low, 5 to 30% depending on the temperature; however lower temperatures failed to kill the fungus.

Many different combination of treatments were used. Soaking in polyethyleneglycol for a week after heat treatment was found to increase the germination percentage but not sufficiently to warrant the amount of time and effort involved. Any type of soaking prior to heating resulted in extremely low germination rates.

Two of the major disadvantages described by Baker (1) of using hot water treatment for disease eradication are, firstly, that the seeds absorb a large amount of water resulting in the leakage of soluble materials. Secondly, it has been found that the higher the moisture content the greater the susceptibility of living organisms to thermal killing. The use of steam-air overcomes these problems to an extent but from the experiments carried out using a machine similar to that described by Baker, we found that the germination was still too low for practical purposes.

In an attempt to overcome these problems of imbibition and leaching we heated the seeds in concentrated salt solutions to see if these would, perhaps, by acting as osmotic agents protect the seeds.

Several salts were tried initially to determine if different salts were likely to yield different results and also to determine the approximate concentration needed for beneficial effect.

The method involved placing the seeds in the salt solution and heating at the desired temperature for ½ hour. After this treatment, the seeds were thoroughly washed and set to germinate on moist blotters.

Of the salts initially tried $CaCl_2 \cdot 2H_2O$ appeared to be the most effective, taking into account cost and ease of use. Using a concentration of 1 Molar, germination percentages of up to 50%, a great improvement on the use of hot water alone, could be achieved at 54°C. After seven days the seedlings appeared healthy and had good strong root development.

More detailed experiments were then carried out using $CaCl_2 \cdot 2H_2O$. Firstly, the temperature was kept constant and the salt concentration varied from 0 to 3.5 Molar. It was found that the 7 day germination markedly increased with increasing salt concentration up to 2 Molar. There appeared to be no benefit in further increasing salt strength. However, as the germination percentage increased so did the infection percentage (Table 1).

Table 1 Germination and infection of zinnia seeds heated at 54°C for ½ hour in $CaCl_2$ $2H_2O$

Molarity	7 day germination, percent healthy	10 day Infection, percent
0	8	2
0 1	6	2
0 5	19	3
1 0	45	10
2 0	60	15
2 5	61	23
3 2	58	18
3 7	56	21

In order to decrease the infection levels, experiments involving varying the temperature but keeping a constant salt concentration were carried out.

The results of these trials showed that at a temperature of 56° to 57°C the infecton levels could be kept below 5% and the germination above 50% (Table 2).

Further experiments have been carried out using a wider variety of salts but it appears that $CaCl_2 \cdot 2H_2O$ is as successful as any of those tried and much better than some salts which have proved highly toxic. We are extending this treatment to safflower seed infected with *Alternaria cartharmi* to see if the method can be used on other fungal infections and experimenting using shorter time periods with higher temperatures and longer soaks at lower temperatures to try and increase the germination percentage further.

Table 2. Germination and infection of zinnia seeds with a constant concentration of $CaCl_2$ $2H_2O$, and with varying temperatures

Temperature, degrees C	$CaCl_2$ $2H_2O$ 1.5M	7 day germination, percent healthy	10 day Infection, percent
Cool water	+	58[1]	23
soak	–	51[1]	19
54	+	57	9
	–	5	3
56	+	54	4
	–	1	not read
58	+	43	2
	–	0	not read
60	+	30	0
	–	0	not read

[1] Many others rotted

Thus from the work so far it appears that satisfactory control of *Alternaria zinniae* can be achieved and germination greatly increased by incorporation of a concentrated salt into the hot water treatment.

LITERATURE CITED

1. Baker, K F 1962 Thermotherapy of planting material *Phytopathology* 52 1244-1255

2 Baker, K F 1969 Aerated-steam treatment of seed for disease control *Hort Res* 9.59-73.

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PROPAGATION OF ORNAMENTAL *GREVILLEA*

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Department of Agronomy and Horticultural Science
University of Sydney, Sydney New South Wales, 2006

Abstract. *Grevillea* species and cultivars were propagated by four different techniques The results were heavily dependent on the condition of the plant material and on the species or cultivar used Cuttings of G. × 'Robyn Gordon' are best taken from wood 10 to 20 cm from the shoot apex, i e not

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terminal cuttings, and rooted at 29°C without application of IBA Air layering of G *robusta* and G. *banksii* was 100% successful in autumn but the latter species gave only 44% success in winter under glasshouse conditions. Scions of G *bipinnatifida*, G *leucopteris* and G *johnsonii* were almost 100% successfully grafted onto seedlings of G *'Ivanhoe'* and G × 'White Wings' rootstocks gave 60% success when grafted with G *bipinnatifida* scions but the other two scion species were not compatible Seed germination in *Grevillea* is promoted by partial removal of the seedcoat and by storage of seed for 2 months at 12°C and 35% relative humidity

INTRODUCTION

Relatively little scientific research has been completed on propagation techniques of *Grevillea*.

Cuttings of *Grevillea* species and cultivars propagated in the nursery trade have often been rooted by using different treatments. Some species such as *G. rosmarinifolia* produce roots readily without growth regulators or other treatments. In comparison, *G. johnsonii* and *G.* × 'Robyn Gordon' have been extremely difficult to propagate by cuttings. Taken in February and with the application of growth regulators, only 40% of the cuttings of *G.* × 'Robyn Gordon' form roots. The time of year when *Grevillea* cuttings are taken seems to be important in determining whether or not cuttings will produce roots. Semi-hardwood cuttings of *Grevillea* seem to give the best results in the nursery trade.

Marsh (3) studied the effect of soil temperature, a growth regulator, and cutting type on *G. biternata*, *G. buxifolia* and *G. laurifolia*. She found all the species reacted differently to the treatments. She recommended that under mist *G. biternata* should have a medium temperature of 28°C, with a 500 ppm IBA application to tip cuttings. Tip or stem cuttings of *G. laurifolia* should have the same medium temperature and IBA application as for *G. biternata*. Stem cuttings of *G. buxifolia* rooted best with medium temperature 28°C and application of 2000 ppm IBA

Tay (5) successfully grafted *G.* × 'Robyn Gordon' onto *G. robusta* using three types of grafts. She found chip budding and side grafting produced better results than whip and tongue grafting. The "take" of the grafts done in late autumn (April and May) was significantly better than those done earlier (March).

In the past, *Grevillea* spp. and cultivars have been propagated mostly by cuttings and a few by seed. Various methods of propagation must be used to develop and improve *Grevillea*. Some selections, hybrids, or polyploids will have to be propagated by layering or grafting if cuttings do not produce roots readily.

MATERIALS AND METHODS

Rooting of G. × 'Robyn Gordon' cuttings: — Cutting material of G. × 'Robyn Gordon' was collected in plastic bags early in the morning on March 15, 1979, from Swane's Nursery, Dural, N.S.W. Within two hours of collection, semi-hardwood terminal stem cuttings 10 to 12 cm long, with one fully expanded leaf were soaked in a 2% solution of sodium hypochlorite for five minutes

A completely random experimental design was chosen with three levels of indole-3-butyric acid (IBA) at 0, 2000, and 4000 ppm in 50% ethanol quick-dip solution. Each of the four replicates for each hormone level and soil temperature had five cuttings. The basal 1 cm of the cuttings were dipped for 5 seconds. The cuttings were placed with the bottom ⅔ of the stem in 1:1 (v/v) steam sterilized sand: peat mixture. Each replicate was placed in a separate 6-inch pot and watered. A total of 180 cuttings were placed in the glasshouse with 80% shade under conditions of ten-second mist, every ten minutes. The medium temperature was regulated by heating cables in the soil The medium temperature treatments of 25°C, 29°C and 33°C ± 1°C were not replicated. After eight weeks cuttings were removed from the mist bed. Cuttings with one or more roots at least one cm long were considered rooted.

For a second experiment, cutting material of G. × 'Robyn Gordon' was collected and placed in plastic bags early in the morning on June 8, 1979, from Swane's Nursery, Dural. Within two hours of collection, terminal stem cuttings with one fully expanded leaf with the terminal bud removed were cut 10 to 12 cm long. Stem cuttings of older wood taken from the same material as the terminal cuttings were also cut 10 to 12 cm long. The older cuttings consisted of the stem, leaves and the fifth, sixth and seventh axillary buds from the terminal end of the stem. All leaves were trimmed from the older cuttings except for the leaf near the fifth axillary bud. All cuttings were soaked in a 2% solution of sodium hypochlorite for five minutes.

A completely random design was used in this experiment. Four replicates of five cuttings per replicate with and without hormone gave a total of 80 cuttings. A 3% (w/w) concentration of IBA in talc powder (Seradix 2) was applied to the basal 1 cm of half of the terminal and stem cuttings. The bottom ⅔ of all the cuttings were placed in 1:1 (v/v) steam sterilized sand: peat in 6-inch pots under the mist conditions described in the previous experiment. Temperature of the root environment was 29°C ± 1°C; the glasshouse was not shaded. After eight weeks all cuttings were removed and roots examined. Those

cuttings with the description of roots given in the previous experiment were considered rooted.

Air layering of G. banksii, G. robusta, G. johnsonii and G. × 'Robyn Gordon: — In the first experiment, six plants each of *G. robusta* and *G. banksii* were grown for one year in a steam sterilized medium which consisted of 1:1:1 (v/v) sand:native peat:sandy loam. The young plants were grown outdoors under 80% shade and watered daily. Soluble complete fertilizer was applied every four months. Two weeks before the layering was done, all the plants were placed in a glasshouse without temperature control.

During May 1980, all 12 young plants were air-layered. Approximately 15 to 20 cm from the end of the shoots, a sharp knife was used to girdle the stems. The girdle was along 2 cm of the stem where two or three leaves had been removed. A slurry of 0.8% IBA in talc powder (Seradix 3) was applied to the stem wound. A handful of clean moist peat moss was placed from 3 cm above to 3 cm below the girdle on the stem. Transparent plastic used to cover the layer was fastened with wire. After 12 weeks, all layers were assessed for rooting and those shoots which had any root more than 2 cm long were removed and potted on.

In a separate experiment, 18 plants each of *G. johnsonii* and *G.* × 'Robyn Gordon' grafted on *G. robusta* plus 18 seedlings of *G. banksii* were grown for one year in the same medium and the same shade conditions as the layers in the previous experiment. Every six months 7 g of Agriform (Sierra Co., Yates, Dist., Sydney) fertilizer (20:4.3:4.1) was applied to all plants. Due to the cool daily temperatures of winter, the plants were grown for two months in a glasshouse with supplemental light before the layering was done. Night temperatures in the glasshouse remained above 10°C and the maximum temperature during the day was 25°C.

In July 1980, one layer on each plant of the three different *Grevillea* was treated according to the method given in the previous layering experiment. All 54 layers were assessed for roots after 12 weeks in the glasshouse.

Grafting of Grevillea: — Under 50% shade conditions, 100 *G. robusta* seedlings were grown for one year in 1.25 litre plastic bags. The medium consisted of 1:1:1 (v/v) sand:peat:loam, and 4 g of Agriform slow-release fertilizer was added every six months. Two weeks prior to grafting, 60 *G. robusta* seedlings were selected for uniformity and were placed in a glasshouse with no temperature control. On April 25, 1979, semi-hardwood scion material was collected from one plant of *G.* × 'Robyn Gordon' at Sydney University Farms, Camden.

Thirty replicates of each of the two *Grevillea* were grafted using the top cleft graft technique.

The cleft graft was started by a 15 to 20 mm longitudinal cut made in the centre of each *G. robusta* seedling about 10 to 12 cm from the base of each seedling At this height the diameter of the seedling was approximately 4 to 5 mm. Scion material was cut so that the stem diameter matched that of the seedling to align the cambial layers Scion material had two dormant axillary buds with leaves partially removed. The proximal end of the scion was cut to make a wedge. The scion was joined to the distal end of the stock and translucent plastic tape (1 cm wide) wrapped firmly around each graft. Grafting mastic was applied to the surface of the tape and all cut surfaces of the scion All grafts were placed in a glasshouse with 80% shade and high relative humidity. Emerging shoots from the *G. robusta* stocks were removed every four weeks. After 20 weeks, all grafts were examined and the results recorded.

In a second experiment, a 3 x 8 factorial design was employed for grafting 3 scions onto 8 rootstocks. The three species used for scions were *G. bipinnatifida* (glaucous form), *G. leucopteris*, and *G. johnsonii* One-year-old seedlings of *G. robusta* were used as a control in the experiment because all three scion species were known to be compatible with *G. robusta* (Clemens, personal communication). Advanced (2-year) *G. robusta* seedlings were grafted to compare the results with the younger control stock. *G. lavandulacea*, *G. vestita*, *G.* × 'Ivanhoe' and *G.* × 'White Wings' were tested as clonal rootstocks The one and two year *G. robusta* seedlings were grown under conditions described in the previous experiment. *G. lavandulacea*, *G. vestita*, *G.* × 'Ivanhoe' and *G.* × 'White Wings' were grown from cuttings from one year prior to the grafting experiment. All stocks grew vigorously and two weeks prior to grafting were selected and placed under the same glasshouse conditions as in the previous experiment

Semi-hardwood scion material was collected from one plant of each of the three *Grevillea* species grown by Mr. Sid Cadwell, Kandos. On April 21, 1980, scion material of *G bipinnatifida* and *G. leucopteris* was grafted onto the appropriate rootstock. The grafting of *G. johnsonii* was completed on April 22, 1980. Eight replicates of stock-scion combinations were grafted using the cleft graft method described in the previous experiment Since the diameter of the stock and scion varied between species and cultivars, the height at which grafting was done for each combination varied from 20 to 30 cm above soil level. Shoots which suckered from the rootstocks were

removed every four weeks. The progress of the experiment was observed and results were recorded at 20 weeks after grafting

Seedling emergence of G. banksii: — Seeds of *G. banksii* were collected from 30 mature plants at the Sydney University Farms, Camden, during February 1979. The seed was air-dried for 15 days at room temperature before the seeds were stored or treated.

The completely random experimental design consisted of 3 x 3 factorial with three periods of storage before planting, and three seed pretreatments applied immediately before the seeds were sown. Seeds of *G. banksii* were planted directly with no storage and after 1 and 2 months storage at 12°C and 35% relative humidity. The three pretreatments were adding 150 ml of boiling water to each replicate of seeds and allowing the seed to soak for 12 hours; soaking the seed in 150 ml of water at 25°C for 3 hours followed by the cutting away of part of the testa, and controls with no pretreatment. Four replicates of 30 seeds each were used for each storage period and seed pretreatment. Seed which had been stored was allowed to equilibrate to ambient conditions for three days before it was planted. Seed was planted in trays of vermiculite at a depth of 3 to 4 cm in a glasshouse with a 12 hour day/night temperature regime of 24°C/19°C. Seed trays were watered every day. The number of seeds which had emerged was recorded after 35 days.

In a second experiment, a completely random 4 x 2 factorial design was used for four period of seed storage and two seed pretreatments. Seeds of *G. banksii* were planted directly with no storage and after 2, 4 and 6 months storage under the conditions described in the previous experiment. Seed was pretreated by soaking it for 3 hours in 150 ml of water (at 25°C) before cuttings away part of the testa. Controls received no pretreatment. Four replicates of 50 seed each were used for each storage period and seed pretreatment. Seed was germinated and data recorded as given in the previous experiment.

RESULTS

Effect of bottom heat and indolebutyric acid on the rooting of Grevillea × *'Robyn Gordon' cuttings:* —

Individual analyses of variance which were performed on the $\sqrt{\times + ½}$ transformations of numbers of rooted cuttings within each bottom heat temperature showed that IBA concentration had no effect on rooting. No interaction between IBA concentration and from within each bottom heat temperature was evident, and a chi-square test for homogeneity of variance

between temperatures was not significant, allowing data to be pooled.

Bottom heat temperature had a highly significant ($P \leqslant 0.01$) effect on rooting of G × 'Robyn Gordon' cuttings. An estimate of error could not be calculated because of lack of replication of temperature, but temperature data was partitioned into linear and quadratic effects. The quadratic portion showed that cuttings rooted significantly better with a bottom heat temperature of 29°C than at either 25°C or 33°C (Table 1).

Of those cuttings that did not root at 25°C, 56.7% formed callus. At 33°C, 86 7% of cuttings died without rooting.

Table 1 Effect of bottom heat temperature and IBA on number of rooted G. × 'Robyn Gordon' cuttings ($\sqrt{\ \times} + ½$ transformation, treatment means, percent rooted shown in parentheses)

Growth regulator	Bottom heat temperature 25°C	29°C	33°C	Mean
Control (O)	1 35 (30 0)	2 06 (75 0)	0 84 (5 0)	1 41 (36 7)
2000 ppm IBA	0 84 (5 0)	1 93 (65 0)	2 00 (15 0)	1 20 (28 3)
4000 ppm IBA	1 18 (20 0)	1 86 (60 0)	0 84 (5 0)	1 29 (28 3)
Mean	1 12 (18 3)	1 95 (66 7)	0 92 (8 3)	
S E = 0 14				

Effect of wood origin and IBA on rooting of G. × 'Robyn Gordon,' cuttings

The origin of wood used for making cuttings significantly ($P \leqslant 0.01$) influenced how well cuttings rooted (Table 2) the overall rooting of older stem cuttings being 87 5% compared to 62.5% with terminal cuttings. Cuttings of older wood tended to produce larger numbers of longer shoots. Application of IBA had no significant effect on rooting and there was no interaction of IBA level with wood origin. Unrooted cuttings produced callus tissue.

Table 2. Effect of wood and IBA on number of rooted G × 'Robyn Gordon' cuttings ($\sqrt{\ \times} + ½$ transformation, treatment means, percent rooted shown in parentheses)

Growth regulator	Terminal cuttings	Stem cuttings	Mean
Control (0)	1 93 (65 0)	2 23 (90 0)	2 08 (77 5)
0 3% (w/w) IBA	1 86 (60 0)	2 18 (85 0)	2 02 (72.5)
Mean	1 90 (62 5)	2 21 (87 5)	
S E = 0 09			
LSD (0 05) = 0 17			
LSD (0 01) = 0 23			

Air layering of Grevillea

Within 6 weeks of being treated all plants of *G. banksii* had produced abundant roots. All air layers of *G. robusta* also rooted but only after 8 to 12 weeks. When a separate collection of *G. banksii* plants were air layered, only 44% of the plants had formed roots after 12 weeks. In the same experiment 28% of *G.* × 'Robyn Gordon' layers, and no layers of *G. johnsonii* had rooted after the same length of time.

Grafting of Grevillea

In the preliminary experiment using seedling *G. robusta* rootstocks and scions of *G. johnsonii* and *G.* × 'Robyn Gordon', 67% and 60%, respectively, of grafts were successful. Shoots began to emerge from the scions 6 to 8 weeks after grafting, *G. johnsonii* growing with a strong leader, and *G.* × 'Robyn Gordon' with a low, spreading habit.

In the stock-scion factorial experiment, large differences were found between the suitability of the rootstocks and the way in which different scions survived on any one rootstock. This was borne out in a chi-squared analysis which showed that rootstock, and the rootstock by scion interaction were highly significant ($P \leqslant 0.01$). There was no significant effect of scion.

By far the best results were obtained using young seedlings of *G. robusta* onto which all 3 scions could be grafted with 88 to 100% success (Table 3). Shoots grew out from the scions after only 4 to 6 weeks. Advanced seedlings gave less satisfactory results. Of the clonal rootstocks, *G. vestita* showed promise for grafting the 3 scions with a mean success rate of 62.5%.

Table 3. Percentage survival of 3 kinds of *Grevillea* scions grafted onto 6 kinds of *Grevillea* rootstocks

Rootstock	Scion			
	G bipinnatifida	*G. leucopteris*	*G. johnsonii*	*mean*
G robusta (tube)	87.5	100 0	87.5	91 7
G robusta (advanced)	62 5	87.5	75 0	75.0
G *vestita*	50 0	50 0	87 5	62 5
G *'White Wings'*	75 0	12 5	0	29.2
G *'Ivanhoe'*	75 0	0	0	25 0
G lavandulacea	0	12 5	0	4 2
mean	58 3	43 8	41 7	

*denotes seedling rootstocks, survival recorded at 20 weeks.

In contrast, the remaining 3 scions gave disappointingly low survival, except for the combinations of *G. bipinnatifida*

on G. 'White Wings' and G. 'Ivanhoe' Highest mortalities were observed within 12 weeks of grafting.

Effects of pretreatment and storage on emergence of Grevillea banksii seed

Conflicting results were obtained in the two experiments in which emergence of G. *banksii* seedlings was studied. In the first experiment emergence rates declined after one month's storage and were still worse than the initial rates after 2 months (Figure 1 - above), whereas in the second, storage for 2 months dramatically improved emergence (Figure 1-below)

Both experiments showed that partial removal of the seedcoat was beneficial to emergence, the effect being more marked in the second experiment in which, taken over all storage times, 70% emergence was obtained following treatment, compared to only 18% in controls. The comparison in the first experiment was 36% to 25%, respectively

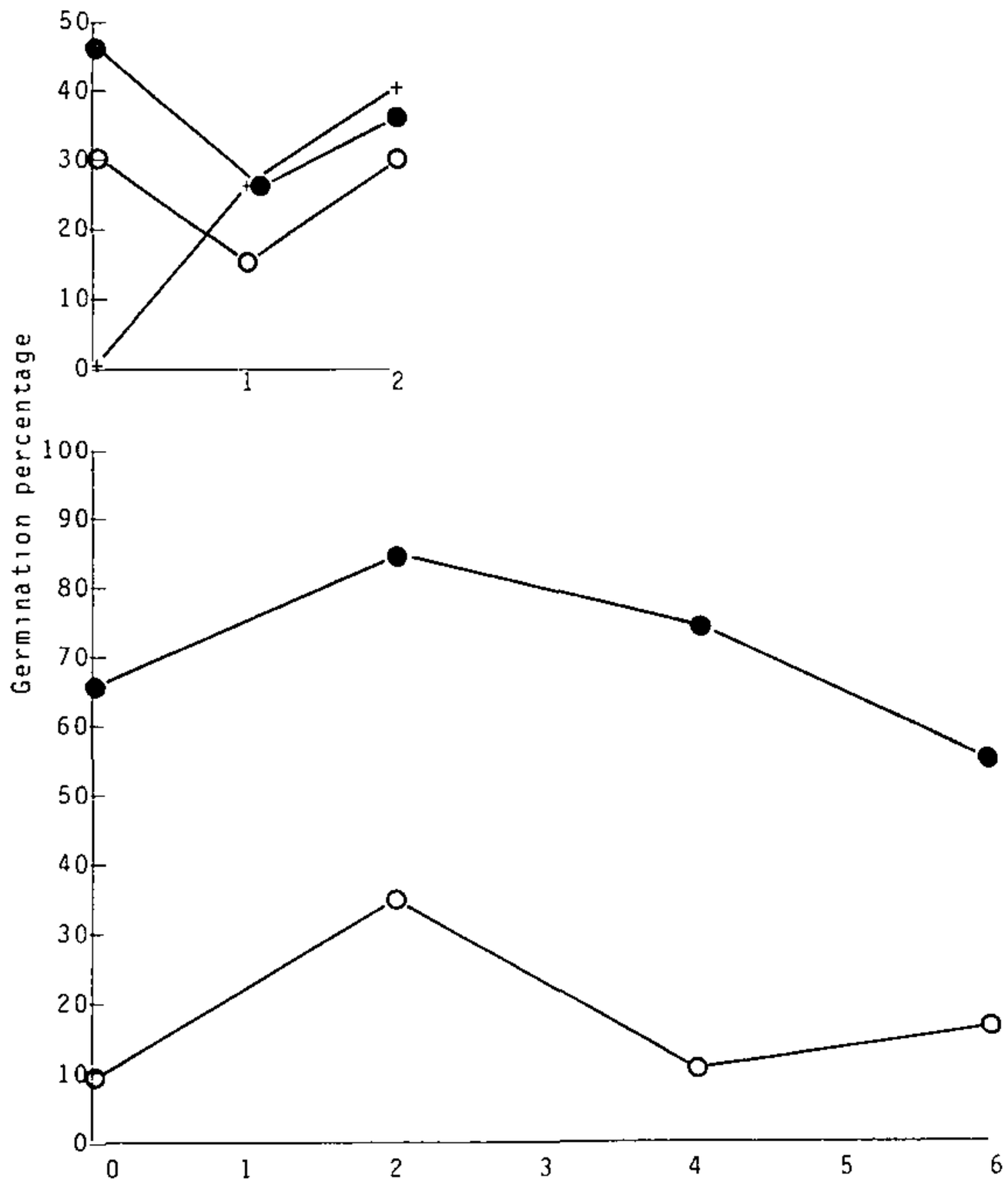

Figure 1. Effect of seed pretreatment and storage on the emergence of G *banksii* seed after 35 days in two separate experiments (see text). ○ control, no treatment, ● seedcoat cut after cold water soak 3 hours, + boiling water

Analyses of variance performed on the arcsin transformations of the data showed that main effects and interactions were all highly significant. Storage for 2 months following partial seedcoat removal gave significantly ($P \leqslant 0.01$) better emergence than no storage or 4 months storage. The analysis for the first experiment was complicated by the unusual data for the emergence of seed following boiling water pretreatment. The highest emergence at 2 months was for boiled seed that had failed completely to emerge immediately after treatment (Figure 1-above).

DISCUSSION

The results showed that ornamental *Grevillea* can be propagated in a number of ways. However, not all species respond similarly, e.g. some species could be grafted with 100% success, whereas others did not graft at all on the same rootstock; and the success of a technique for any species will vary depending on the condition of the material.

The rooting of cuttings of *G.* × 'Robyn Gordon', which was favoured by the use of older wood, was probably influenced by the greater carbohydrate reserves in this material (1). In similar propagation experiments, Marsh (3) found that stem cuttings rooted better than terminal cuttings in *G. buxifolia*, but that the result was reversed when *G. biternata* was used.

The use of IBA has been found to promote rooting in many plants in the Proteaceae (4), so it was somewhat surprising that this had no effect on rooting in *G.* × 'Robyn Gordon'. However, it would have been difficult to improve on the 90% strike obtained with older wood and a bottom heat of 29°C. This cultivar may now be regarded as relatively easy to root provided the correct material is used and collected in autumn.

The effect that growing conditions and the resultant condition of the plant material can have on propagation was highlighted by *G. banksii* in the two air layering experiments. Layering in autumn on partially hardened shoots on plants that had not grown under glasshouse conditions was much more favourable than layering of new shoots forced by favourable glasshouse conditions in mid-winter. It is of interest that *G. robusta* can be successfully air layered, a species so commonly grown from seed Vegetative propagation in this way of mature wood could reduce the time for small silky oak plants to flower after leaving the nursery. The complete failure of *G. johnsonii* to air layer was not surprising in the light of the difficulty usually experienced in rooting cuttings of this species (Clemens, unpublished results).

The results of the grafting experiments suggest that incompatibility between wood of different species and cultivars of *Grevillea* could be a problem in the raising of certain graft combinations. However, some combinations were outstandingly successful, the most significant being the grafting of *G. johnsonsii* onto *G. robusta* or *G. vestita*. This has been used in routine multiplication of *G. johnsonii* plants for further experimental studies (Dupee and Clemens, in prep.). Perhaps the results are of greatest interest in that they allow further long-term trials to be carried out to assess the rootstock effects (if any) on the flowering and development of the scion growth. Cleft grafting proved to be the most successful. Chip budding, side, and whip-and-tongue grafting were used with less success by Tay (5).

As a routine measure, *Grevillea* seed should have a portion of the seedcoat removed before sowing. However, this is a laborious procedure and is probably of greatest value in the propagation by seed of species in short supply or in breeding programmes when the highest possible emergence of viable seed is required. The results are contrary to those of Heslehurst (2) who found that seed treatments inhibited germination in *G. banksii* seed. The recovery of boiled seed after storage is an interesting phenomenon and requires further study.

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MICROPROPAGATION OF APPLE SCION CULTIVARS

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Abstract Shoots produced by isolated buds of the normally difficult-to-root cultivars, Granny Smith, Jonathan, and Delicious, were induced to form adventitious roots *in vitro* Isolated buds from adult trees were cultured in MS medium containing BA (10 μM) to produce proliferating shoot cultures These shoots were made into microcuttings for induction of roots The highest rooting percentage (80%) was obtained in 'Granny Smith' when microcuttings were grown in continuously agitated liquid culture (half-strength MS) with IBA (10 μM) The most effective culture method for 'Jonathan' was growing the microcuttings on filter paper bridges with either NAA (10 μM) or IAA (100 μM) Up to 80% of microcuttings of 'Delicious' produced roots when the bases of cuttings were dipped in IBA (750 μM) and grown in liquid medium Exogenous auxin was needed to stimulate root formation in all cultivars There was a progressive improvement in the rooting of microcuttings with increasing numbers of subcultures Newly established cultures had a low rooting capacity After 9 subcultures, 95% of 'Jonathan' microcuttings formed roots With 'Delicious' the percent rooting increased from 21% after 4 subcultures to 79% after 31 subcultures

INTRODUCTION

A wide range of plant species can now be propagated *in vitro* and the uses and limitations of tissue culture in horticulture have ben discussed in several reviews (2,13,18,15). The most extensive commercial use of plant tissue culture has been in clonal propagation of ornamentals, especially ferns and orchids. The application of aseptic methods to species that are easy-to-propagate by conventional methods is warranted only in special situations, for example, for the rapid multiplication of scarce material. In woody perennials, tissue culture could have an important role in the propagation of species which are difficult-to-root by conventional methods.

Although many species of woody plants have been successfully propagated by aseptic methods, there are still several crop and forest trees which cannot, as yet, be regenerated *in vitro*. In many recent reports on micropropagation, difficulties have been experienced in root induction in cultures derived from mature adult trees. It was also observed that tissue from juvenile seedlings and rootstocks had high regenerative capacity (7,8,10). These results are in accord with experience in conventional plant propagation. It is well established that there is a progressive loss of regenerative capacity during seedling ontogeny and that cuttings from adult flowering trees are usually very difficult to root (8). This lack of ability to form adventitious root primordia is a persistent character. When adult material is multiplied by grafting onto rootstocks the regrowth from the scion remains difficult-to-propagate. For

example, most commercially-important scion cultivars are difficult-to-root from cuttings and, with a few exceptions (1,9,16), apple cultivars have proved to be difficult to regenerate by micropropagation (3,4,14,17).

This paper summarises our work on the production *in vitro* of rooted plants of some normally difficult-to-root scion cultivars of apple.

MATERIALS AND METHODS

Establishment of cultures. Dormant one-year-old scions from virus-indexed mother trees of 'Granny Smith', 'Jonathan' and 'Delicious' were grafted onto apple seedlings and were grown either in controlled environment chambers (16 hr photoperiod, radiant flux denisty 350 μE $m^{-2}s^{-1}$) or in the glasshouse with natural illumination Regrowth from these scions was used as a source of explants The segments were surface sterilized and cut into single node segments and then planted into test tubes containing Murashige and Skoog medium (MS) (12) and 6-benzyladenine (10 μM, BA). The sucrose concentration was 30g l^{-1} The medium was solidifed with agar (0.8% w/v) Cultures were grown at 26 ± 2°C with continuous illumination provided by Osram MCFE 40W cool white fluorescent tubes

Production of microcuttings. Each nodal segment produced a single shoot 50 mm in length within 5 weeks of incubation. The shoots were cut into leafy segments and subcultured in larger culture vessels containing cytokinin medium as before. There were 3 to 4 segments per flask and within 5 weeks each segment had produced up to a dozen shoots by outgrowth of axillary meristems. These shoots were then harvested for use as microcuttings and the remains of the culture were cut into fragments and subcultured with cytokinin medium to produce a new generation of shoots

RESULTS AND DISCUSSION

Shoots were harvested from 30-day-old cultures and made into microcuttings, 20 to 30 mm in length. All experiments concerned with induction of roots were made at constant temperature 26° ± 2°C) with continuous illumination (Osram MCFE cool white fluorescent tubes, 90 $\mu E^{-2}sec^{-1}$). The microcuttings were grown by different methods, i.e., on agar-based media, on filter paper bridges with liquid media, in stationary liquid media, or in agitated liquid culture (shaken continuously on a reciprocating platform shaker — 70 strokes min^{-1}, displacement. 20 mm) Agar-based media were found to be unsuitable for induction of rooting. There were marked differ-

ences among cultivars in the most effective culture method for induction of adventitious roots. Agitated liquid culture was effective for 'Granny Smith' but not for 'Jonathan' or 'Delicious.' Up to 80% of microcuttings of 'Granny Smith' formed roots when grown with half-strength MS medium containing γ-(indole-3)-butyric acid (IBA, 10 μM) (16). The mechanism by which continuous shaking or agitation leads to the formation of adventitious roots is not yet clear.

A very high frequency of rooting (95%) was obtained with 'Jonathan' when microcuttings were grown on filter paper bridges in test tubes containing half-strength MS medium with either α-naphthalene acetic acid (NAA, 10 μM) or indolylacetic acid (IAA, 100 μM). With 'Delicious,' the bases of microcuttings were dipped in IBA (750 μM) and then grown with basal medium. About 80% of the cuttings of long-established cultures of 'Delicious' produced roots.

Exogenous auxins were needed to stimulate root formation in all cultivars. IBA (10 μM) and β-naphthoxyacetic acid (NOA, 10 μM) both promoted root formation in 'Granny Smith'. Higher concentrations of auxins produced fewer roots and soft white callus at the bases of cuttings IAA (100 μM) and NAA (10 μM) were both effective in promoting root formation. IBA (750 μM) was found to be the most effective auxin for rooting 'Delicious', particularly when given as a basal dip.

It was found that newly established cultures of 'Jonathan' and 'Delicious' had a low regenerative capacity. The initial explants, and microcuttings from the first few subcultures, produced roots at very low frequency (Table 1). A marked increase in root formation was observed in later subcultures. In 'Jonathan', for example, the rooting percentage at the 4th subculture (62%) was almost 8 times greater than the rooting percentage at the initial culture (8%).

Table 1 Adventitious root formation *in vitro* in apple cultivars effects of subculture

Jonathan				Delicious			
Culture No	No micro-cuttings	No rooted	Percent rooted	Culture No	No micro-cuttings	No rooted	Percent rooted
†0	100	0	0	0	34	0	0
*1	62	5	8	1	21	1	5
**1	105	34	32	1	85	13	15
2	117	51	44	2	86	17	20
3	106	55	52	3	90	-	-***
4	166	102	62	4	86	18	21
5	149	105	70				
9	105	100	95	31	24	19	79
25	112	108	96	32	20	14	70
28	92	87	95				

† Nodal cuttings from whole plant tested in vitro, * Initial culture, ** First subculture, *** Culture lost

Our results show that the normally difficult-to-root cultivars, 'Jonathan' and 'Delicious' can be transformed *in vitro* into easily rooted plants. The possibility that the transformation is associated with genetic change cannot be discounted until orchard testing for trueness-to-type has been completed. The occurrence of genetic change in standard apple cultivars would be of great interest from the viewpoint of clonal selection but it would render the subculture method useless for routine plant propagation.

The physiological changes in subcultured shoots which favour adventitious root formation are still being investigated. There seem to be parallels between the subculture technique and procedures such as hedging which are used in horticulture and forestry to produce cuttings with an enhanced capacity for root formation (11). In all cases the stock plants are subjected to repeated pruning and these are indications that this treatment leads to rejuvenation (5), the restoration of morphological and/or physiological characteristics of the juvenile growth phase. In subcultures of 'Jonathan' and 'Delicious' the improved root formation of microcuttings was associated with the appearance of morphological characters in shoots which are reminiscent of apple seedlings, for example, highly serrated leaf margins, a paucity of primary phloem fibres and production of anthocyanin pigment by the stem epidermis (S. Sriskandarajah, unpublished results).

Finally, it is possible that cultivation of explants in agitated media or use of the repeated subculture technique, could be applied to many other difficult-to-propagate species.

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REGENERATION OF GRAPEVINES BY ASEPTIC METHODS

K. RAJASEKARAN and M.G. MULLINS

Department of Agronomy and Horticultural Science
University of Sydney, Sydney, New South Wales 2006

Abstract. Techniques are described for high-frequency somatic embryo and plantlet formation from (i) cell suspensions derived from nucellar callus of unfertilized ovules, and (ii) somatic cells of cultured anthers Plantlet regeneration by organogenesis, induction of adventitious buds and adventitious roots, has been achieved in a few genotypes of *Vitis* and in the Muscadine grape Factors affecting the regenerative competence *in vitro* of grape tissues include genotype (species, cultivar), growth phase (juvenile or adult), and origin of explants Competence is a heritable character Evidence is accumulating that grapevines produced *in vitro* are variable and that tissue culture *per se* leads to genetic variation It is concluded that the

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Abbreviations.
BA — benzyladenine (syn 6-benzylaminopurine)
2,4-D — 2,4-dichlorophenoxy acetic acid
NOA — β-naphthoxy acetic acid
PBA — 6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine

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future of tissue culture for grape propagation is uncertain but that aseptic methods hold great promise for grape improvement, especially in clonal selection

INTRODUCTION

Plant tissue culture techniques are important tools in programmes of crop improvement. Aseptic techniques are of special interest for use in horticulture and forestry where plant improvement by conventional methods is made difficult by heterozygosity and long generation intervals. Unfortunately the number of woody species which have been propagated *in vitro* by aseptic culture methods is small as compared with herbaceous species (11,17,18)

With the grapevine, the world's most widely-grown fruit crop, there has been much interest in sterile culture methods for plant propagation and improvement. In this paper we will present a summary of our earlier work (7,15) and give details of research in progress

MATERIALS AND METHODS

Plants of grapevine cultivars and species were propagated from cool-stored (4°C) cuttings by the method of Mullins and Rajesekaran (9). Seedlings were raised from stratified seeds (4°C for 8 weeks). Explants were surface sterilised by shaking with sodium hypochlorite (1% available chlorine) containing Tween-20 (0.1%) as a wetting agent. The basal medium of Nitsch and Nitsch (13) was used in all cultures.

Preliminary work showed that agar-based media were unsatisfactory for induction of organized development. However, agar-based media (0.8% w/v Difco agar) proved to be ideal for growing embryos and for micropropagation.

All the cultures which were established for induction of embryogenesis and organogenesis were grown on a gyratory incubator (80 oscillations min^{-1}, stroke amplitude 3 cm; 2.5 Wm^{-2} irradiance; 27°C). The provision of low intensity light prevented the callus from becoming red due to the formation of anthocyanin pigment.

Further details of explants, culture conditions and of media constituents are given with results.

RESULTS AND DISCUSSION

1. Somatic embryos from unfertilized ovules of grapes

Somatic embryos were produced from cell suspensions derived from the nucellus of cultured unfertilised ovules of *Vitis vinifera* cultivars (Cabernet Sauvignon, Grenache) and

from the hybrid grape, Gloryvine (*V. vinifera* L. × *V. rupestris* Scheele.) The ovules were excised from flowers collected 4 to 7 days before anthesis Callus of nucellar origin was produced by culturing the ovule explants initially in Nitsch medium containing 5 μM 2,4-D, or 5 μM β-NOA plus 1 μM BA, and then in a medium supplemented with NOA (10 μM) plus BA (1 μM). Embryos were produced in large numbers when callus was transferred to basal medium from which auxin and cytokinin were omitted.

The propagation of grape cultivars from nucellus has interesting implications. In citrus and mango, nucellar seedlings produced *in vivo* are usually virus-symptomless, due perhaps to exclusion of virus particles by the lack of vascular contact between the nucellus and its contiguous tissues (5). Similarly, grapevines regenerated from isolated nucellus may well be virus-symptomless and this possibility is being investigated in the field.

2. Somatic embryos from cultured anthers of grapevine

Anthers containing uninucleate microspores (from flowers 2 to 3 mm long) were chilled at 4°C for 72 h before culture in Nitsch medium containing 2,4-D (5 μM) and BA (1 μM). After culture in darkness for 10 to 20 days, a yellow-white callus was produced from the anther wall and the scar of the filament. Later, this callus was dispersed to form a suspension containing single cells and cell aggregates, and the suspension was transferred to basal medium. Callus which had been grown in the dark was transferred to light at this stage. During the next 20 days adventive embryos were formed with high frequency — 2500 to 3000 embryos per 25 ml of liquid medium.

This procedure, which was originally developed with anthers of Gloryvine, has been applied to a wide range of grapevine species, hybrids and cultivars. Among the *Vitis* species which have been investigated, *V. rupestris* and *V. acerifolia* (Syn. *V. longii* have the greatest propensity to embryo formation This character seems to be heritable and the regenerative competence of anther-derived tissues is exhibited by most hybrids in which *V. rupestris* is a parent. Included are highly complex hybrids such as J.S 23-416, Villard Noir and Villard Blanc, in which the contribution of *V. rupestris* is very dilute. In the *V vinifera* grapes, Grenache is the only cultivar which has been induced to form large number of embryos.

In all the species and cultivars which have been tested, maleness, as distinct from hermaphroditism, was observed to be an important factor associated with high degree of regeneration *in vitro*. When male inflorescences of Gloryvine were

converted into hermaphrodites by treatment with PBA, according to the method of Negi and Olmo (12), the ability of anthers to form callus *in vitro* was lost.

In both the ovule and anther cultures a higher percentage of secondary embryo formation was observed.

3. Establishment of plantlets

For production of normal plantlets the somatic embryos required chilling (4°C) for 2 weeks and the chilling treatment was effective in breaking dormancy when applied at any stage of embryogeny. Grape seeds also require chilling for 90 days (5°-10°C) for production of normal seedlings. Vigorous plantlets from somatic embryos were propagated by microcuttings (1-2 nodes) and were grown on filter-paper bridges so as to facilitate subsequent transfer to non-sterile media. Later, these propagules were grown in the glasshouse (24 to 26°C) in a medium containing peat and perlite (1:3).

4. Organogenesis in internode explants of grapevine

Internode explants (ca. 3 mm in length, average fresh weight 8 mg) from vigorously growing 40-day-old seedlings were cultured either in Nitsch medium supplemented with BA (1 μM) and 2,4-D (5 μM) or in a mixture of 2,4-D (5 μM) and NOA (5 μM). Organogenesis was observed 40 days after culture. The most frequent type of regeneration in callus cultures was root formation. Bud formation occurred after 60 days only in cultures derived from seedlings of Muscadine grapes (*Vitis rotundifolia*), Gloryvine, and two hybrids, both of which had Gloryvine as the male parent. These adventitious buds were found to arise near the surface of the callus. Explants from mature vines of *V. vinifera* cultivars, or from clonal Gloryvine failed to produce buds. The formation of buds occurred only in internodes derived from seedlings.

5. Propagation and storage of grapevines by microcuttings and somatic embryos

Plantlets are normally propagated in our laboratory by culturing shoot tips or "microcuttings", stem segments bearing an axillary bud. By use of cytokinins (BA or PBA) at concentrations of 5-10 μM it is possible to induce the outgrowth of numerous axillary buds and thereby increase the rate of plant multiplication.

It has been assumed hitherto that excised meristems provide genetically stable material for rapid clonal propagation (2), and for the production of disease-free plants (3). Accordingly, much attention has been given to micropropagation techniques for preservation of grapevine genetic stocks. Morel (6) demonstrated that by culturing excised shoot apices and

nodal segments under carefully controlled conditions of nutrient and environment, germplasm stocks of grapevines could be maintained with a fraction of the time, space and cost required to maintain them in the field. He calculated that 800 different grape cultivars could be stored in culture in a space of about two square meters, and that from a single meristem culture more than 10 million cuttings could be produced within one year.

However, there is a serious flaw in these proposals in that it has yet to be confirmed by the relevant field trials that grapevines which are propagated *in vitro* by microcuttings retain the unique characteristics which distinguish the major wine grapes There is some suspicion, from virus eradication work in France, that vines which are propagated *in vitro* exhibit alterations in morphology (10). It is not year clear if these alterations represent permanent genetic change (1), or whether they are physiological in nature and are associated with reversion to the juvenile growth phase (8).

It is now firmly established that the propagation of plants from callus, either by organogenesis or somatic embryogenesis, leads to significant variation in the propagules so produced (4,14,16).

CONCLUSIONS

The biochemical nature of regenerative competence is unknown and no information is available which might account for differences in regenerative behaviour *in vitro* among *Vitis* species and cultivars and among the different tissues of the individual plant In practical terms, however, sufficient technical information is now available to enable aseptic culture techniques to be used for large-scale multiplication of grapevines. An important qualification is that the fidelity of reproduction of aseptic methods *in vitro* is either in doubt or known to be suspect. At this stage it seems that tissue culture has an uncertain future as a means of propagating grapevine cultivars. However, aseptic methods hold great promise for use in grapevine improvement, especially in the sphere of clonal selection.

Acknowledgement. Research on grapevine improvement in the University of Sydney is being supported by the Rural Credits Development Fund, Reserve Bank of Australia

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PROPAGATION OF PHILODENDRONS FROM NODE CUTTINGS

THEALA H. PETERSEN

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Dingley, Victoria

Brough, Petersen Nurseries grow and provide indoor plants, together with a maintenance service, for many business premises in Melbourne and the metropolitan area. For this reason we need a wide range of decorative plants to use under many different and sometimes quite difficult conditions.

Most city offices are closed from Friday to Monday and longer if there is a Monday holiday, leaving many inner offices in total darkness with no natural light whatsoever

The plants that go into these buildings must be strong and well grown. Unfortunately when these plants are replaced with new ones, those coming out are not as strong and healthy as they were to begin with. These, however, are the plants from which we take the cuttings.

When the old, tired plants are returned to the nursery, they are stripped of their lower leaves and lined up to wait their turn to be cut up for cuttings. I like to leave those that have come from poor conditions for several weeks to give them a chance to firm up and recover from their ordeal, thus using the best cutting material available to us.

We have found that one of the most versatile genera is *Philodendron*, as these plants will survive in almost, any situation depending on the species used.

The stems are prepared into single node cuttings, using sharp, clean, secateurs to avoid bruising, into pieces approximately 4 to 5 cms long, with 1 cm below the node and 3 to 4 cms above. There is a straight cut across the bottom and a slight angle at the top, sloped away from the eye.

The cut suface is dipped into Seradix cutting powder No. 1, or IBA 0.15% and talc. The cuttings are then placed into trays filled with damp propagating mixture of 50% German peat and 50% washed river sand. They are placed at an angle of approximately 45°, with the bud facing upward, just at surface level. There are usually around 15 rows of 10 across in each tray. These trays are then placed in a hot bed at about 27°C.

We do not have any automatic misting or watering; this is all done manually. We water Monday, Wednesday and Friday, as there is nobody available to water during the weekend. There is polythene over the beds which is rolled up or down

depending on the time of year and the weather. The beds are never fully enclosed as I like to have one corner open at all times for ventilation. We have a very good striking rate considering our material and conditions that are not perfect.

Once the cuttings have developed into good sized plants, they are potted on into either 4 or 5 inch pots. The 4″ has one single plant potted into it, selected for its size and species. Later they will be placed around tree fern totems ranging from 2 ft to 5 ft in height. The 5″ pots have 5 or 6 plants selected for compatibility placed together, which are later potted on as a multiple without a totem in 6 or 7 inch pots.

When these plants have reached maturity, they once again return to decorate the city buildings to start the cycle over again.

SIMPLE GREENHOUSE CONSTRUCTION USING LIGHTWEIGHT MODULES

ROBERT KASTEEL
Kasteels' Nursery
Duffy's Forest, New South Wales

Two years ago, Jack Paterson — a fellow nurseryman and I discussed the concept of modular greenhouses. We both became very enthusiastic about the many developments we envisaged possible, so here are some of our suggested objectives for such a "modular house".

1) That the "greenhouse" be of sufficient size to allow for economic nursery operation.

2) That the "greenhouse" can easily be erected by 2 or 3 persons in a short time.

3) That the "greenhouse" be made out of light-weight material, simple in construction, and long lasting, with good light transmission.

4) That the "greenhouse" be well insulated and include a built-in ventilation system.

5) That the "greenhouse" be of a design which provides sufficient strength to withstand damage from the elements, especially hail.

6) That under ideal conditions, the "greenhouse" be self-sufficient in terms of energy input required for heating and cooling.

With all these objectives in mind, we looked at them one by one, and also in relationship to each other, and arrived at a

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6) That under ideal conditions, the "greenhouse" be self-sufficient in terms of energy input required for heating and cooling.

With all these objectives in mind, we looked at them one by one, and also in relationship to each other, and arrived at a

structure which we consider meets most of our objectives.

1) That the greenhouse be of sufficient size to allow for economic nursery operation. When considering ventilation, heating and the building material to be used, we decided on an open-span greenhouse 12 metres (or approx 40 feet) wide, with a height of 5 metres (or approx. 16 feet) at the apex, and side walls of 2.5 metres (or approx 8 feet). The most ideal length for the greenhouse would be 30 metres (or approx 100 feet), but this could be altered in multiples of 0.5 metres.

2) That the greenhouse can easily be erected by 2 or 3 persons in a short time. When considering the handling capabilities of 2 or 3 persons and the material we planned to use, we designed a modular system 2 5 metres high, 6.5 metres long and 0.5 metres wide and a weight of approximately 50 kilos, with a tubular clip-lock system for easy assembly (Figure 1).

3) That the greenhouse be made out of lightweight material, simple in construction and long lasting, with good light transmission. The modules would be made out of fibreglass with a modified resin, which is long lasting, lightweight, and has good light transmission

4) That the greenhouse be well insulated and to include a built-in ventilation system. The module will have an inner and outer wall for insulation, with a vent on the *lower inside* of the module, and two vents in the top of the module, one on the *upper inside* and one on the *upper outside* wall for ventilation.

The air inside the module is heated by the sun, the hot air rises and escapes through the upper inside or upper outside vent, depending which is required. Air is drawn in through the lower vent.

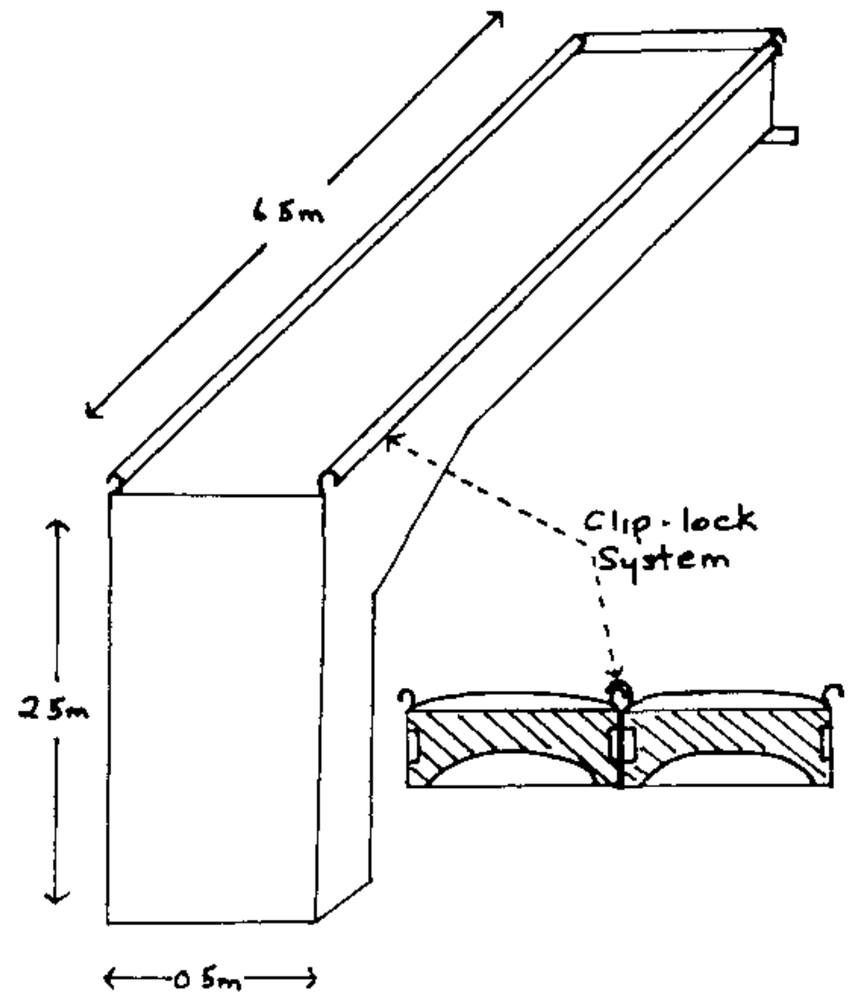

Figure 1. A module with clip lock system.

On a winter's day, when no venting is required, the *lower and upper internal* vents can be opened so that air in the greenhouse is continually circulated by convection, like a chimney.

On a hot summer's day, by opening the *lower inside* and *upper outside* vents, excellent natural venting will occur — hot air rises.

The greenhouse is almost air-tight and fresh air can be sucked in through evaporative cooling pads at the ends of the greenhouse (Figure 2).

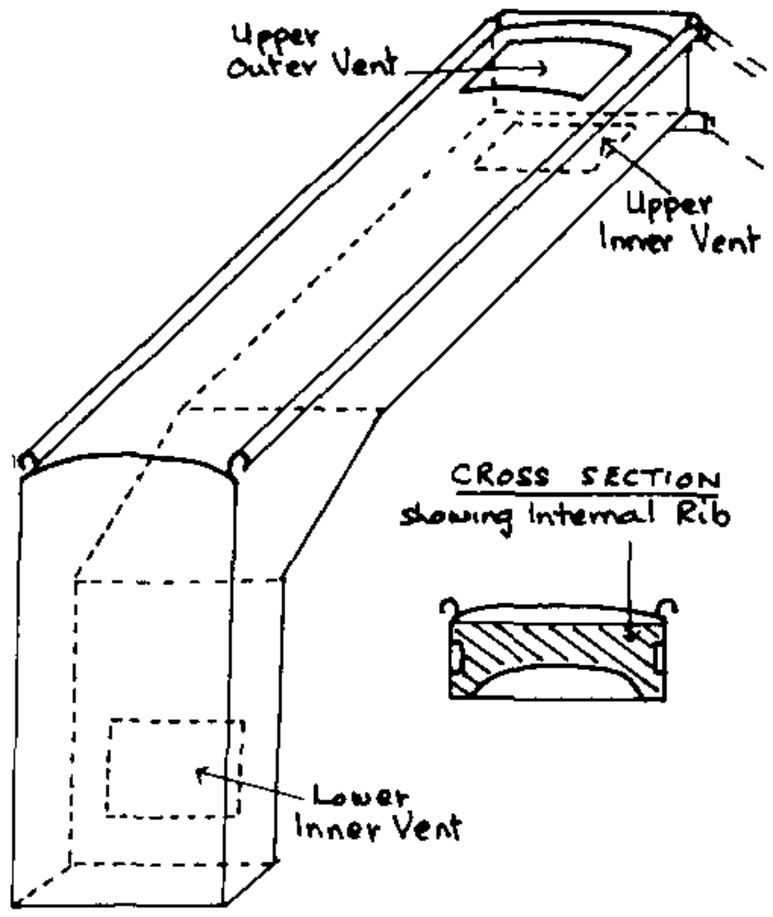

Figure 2. Module with Inner and Outer Vents and Convex Roof

5) That the greenhouse be of a design which provides sufficient strength to withstand damage from the elements, especially hail. The top of the module has a convex outer wall to withstand hail, and has internal ribs to provide for compression strength. The smooth surface and the steep angle of the roof will stop heavy snow-loading on the roof.

6) That under ideal conditions, the greenhouse be self sufficient in terms of energy input required for heating and cooling. The ventilation is based on convection and requires no energy input other than sun-light. The heating is obtained by the inclusion of solar heating pipes in every module to obtain solar energy, which in turn is stored in the floor of the greenhouse to a depth of 2 metres (Figure 3).

Some further points. Heating and cooling can also be obtained by drawing the hot air through the *top inner vent*, down through the module and out through the *lower internal vent* where it is blown or sucked through a propagation or nursery bed filled with gravel. The heat of the air is absorbed by the gravel, and cooled air is recirculated into the greenhouse, reheated by the sun, rises to the top and is drawn through the

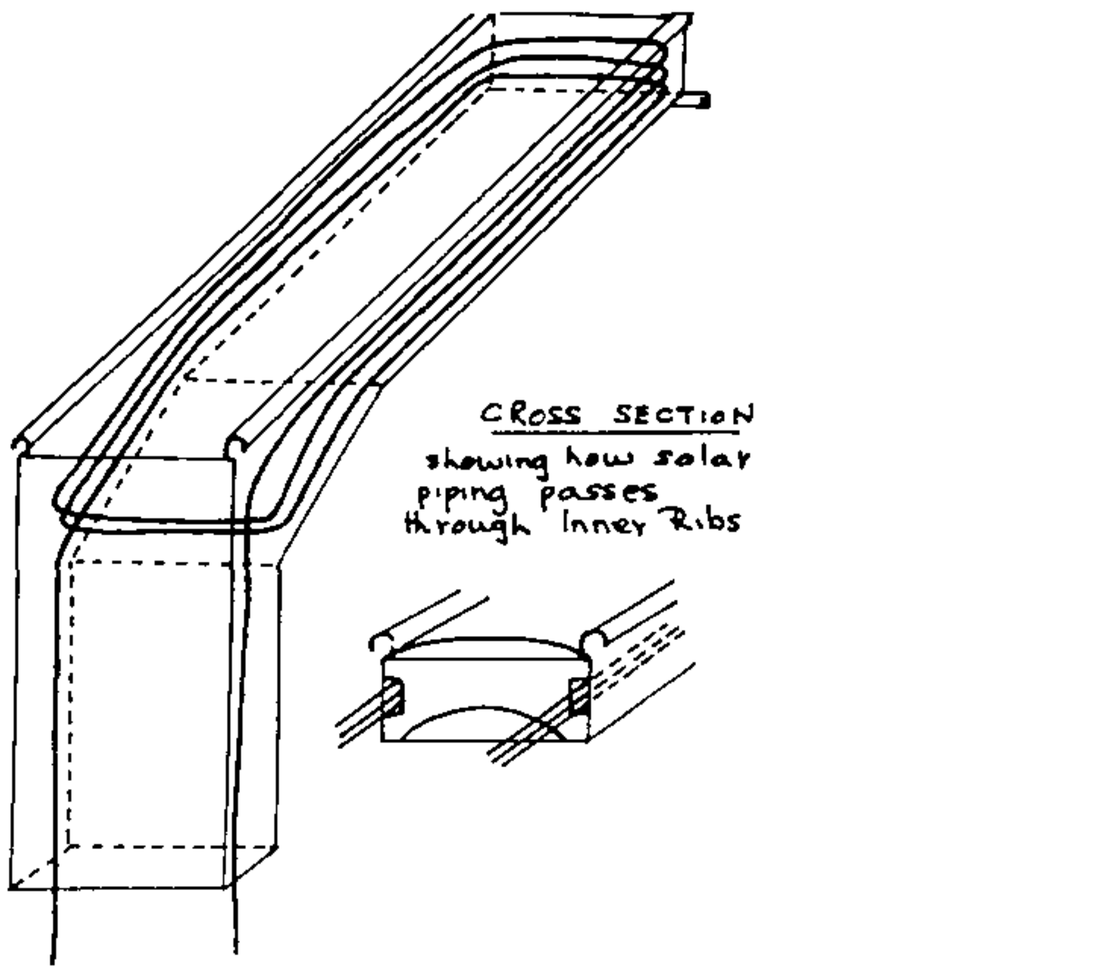

Figure 3. Pipes for Solar Heating in each module

module to the gravel bed again, repeatedly (Figure 4)

Additional insulation can be obtained at night by filling the cavity of the module with polystyrene or a similar lightweight material. This idea can also provide short day conditions for the production of certain plants, e.g. poinsettias.

Shading can be obtained by an aluminium venetian blind type of shading, or the inner wall of the module could be tinted to obtain the desired shading. Because of its smooth surface, shade cloth could be mechanically rolled on the outside of the greenhouse to provide shading.

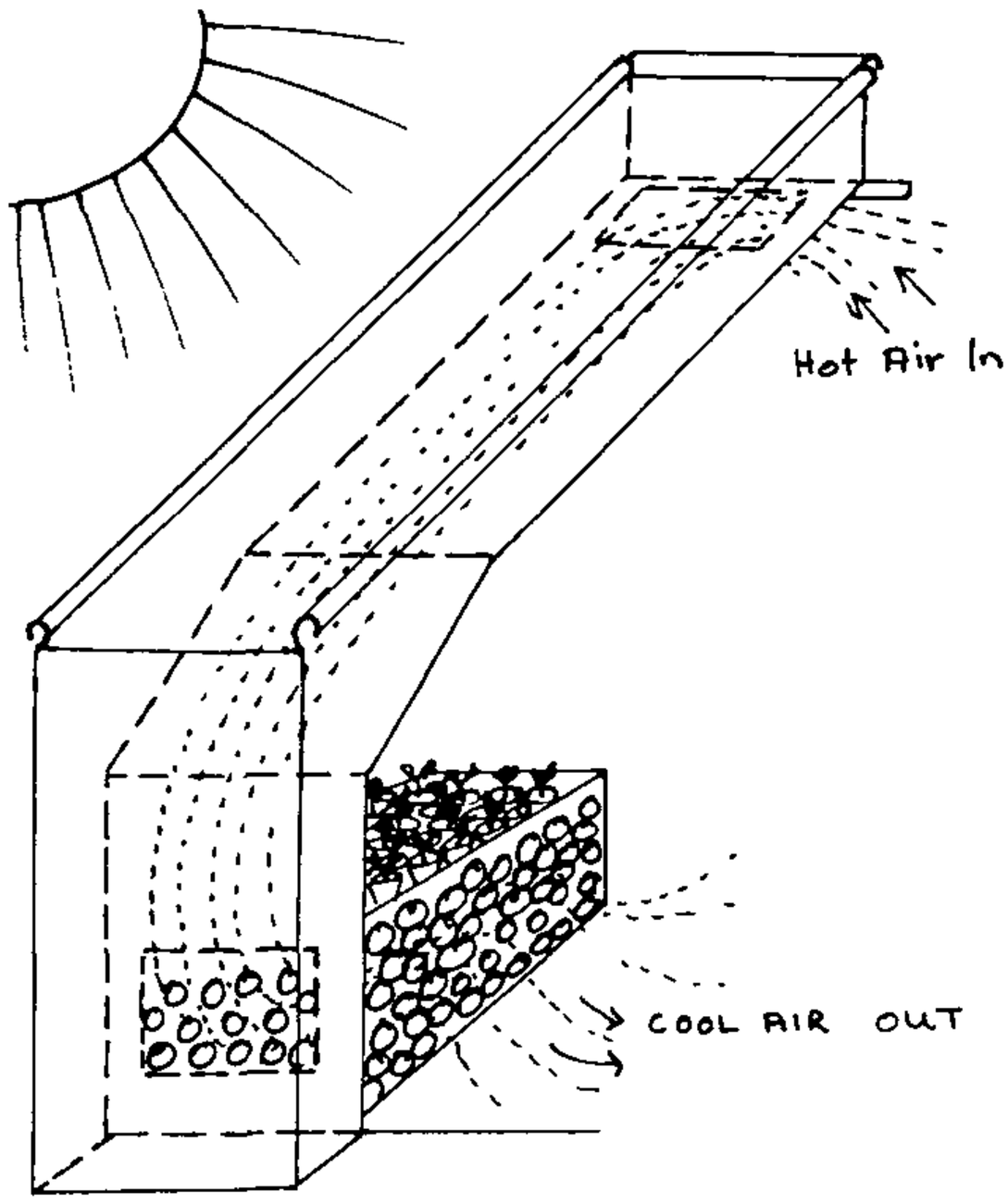

Figure 4. Air cooling

CONDITIONING OF PLANTS FROM SOIL MEDIA TO HYDROCULTURE

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HISTORICAL BACKGROUND

Civilised man has for thousands of years been endeavouring to grow plants in such a manner as to improve yields and quality. The famous Hanging Gardens of Babylon was an early attempt at the culture of plants under artificial conditions.

The early history of soilless culture of plants is closely interwoven with the study of plant physiology. In 1600 a Belgian, Jan Van Helmont grew willow shoots in a protected pot of soil and applied only water. After five years there was practically no loss of weight of the soil and he believed that plants obtain their food only from water. Since then, of course, scientists have shown that plants need 16 elements, these being supplied by gases and soil constituents, as well as by water.

Today there are many horticultural books in which reference is made to the use of soilless medium. The main reasons for such interest in alternatives to soil are that plants in such a manner can be cultured more precisely and irrigation and fertilizer practices much simplified.

SOILLESS CULTURE — WHAT, WHY AND HOW

What. The term soilless culture literally means "growing plants without soil". Mr. Steiner, the secretary of the International Society for Soilless Culture, defines soilless culture as "the growth of non-aquatic plants with their roots in a completely inorganic medium, where the roots are supplied with a nutrient solution".

The name "hydroponics", which comes from the Greek "hudor" and "ponos", which means "waterworks", was first suggested by Dr. W.A. Setchell from the University of California. The term hydroponics is popular, very widely used in the literature, and internationally accepted.

Why. Perhaps the first commercial interest in the "soilless" growth of plants was a direct result of the difficulty experienced by greenhouse growers in America in getting suitable soil during the 1920's. Professor Gericke, University of California, (1929), completely dispensed with soil and grew the first commercial crop of tomatoes in water to which all the necessary nutrients had been added. Because of a number of problems which were costly to overcome a range of solid,

inert, relatively sterile media have since been successfully used — gravel, perlite and vermiculite, expanded clay being the most popular today.

There are many reasons why there has been such interest in hydroponics in recent years in Australia, namely:

1. Lack of suitable soil.
2. Great expense involved in sterilising soils.
3. Restricted supply of suitable water.
4. Urbanisation and high cost of vegetables and flowers.
5 The "boom" in indoor plants.

One of the most recent examples of why hydroponics is being considered as the most likely alternative to normal cultivation of field grown crops is to be found in Singapore. Because of the problem of soil borne disease and the high price of vegetables and ornamentals during the wet months, a study of hydroponics was initiated about ten years ago and the results using a wide range of plants, including orchids, is most promising.

Many people in various parts of the world consider that hydroponics is the most economical way of supplying water and nutrients to plants with the opportunity of maximising results The costly operations of soil preparation, weed control, disease and pest control are very much minimised.

How — Types of Hydroponic Systems.

. There are two main types of systems for growing plants without soil, namely:

1. Liquid culture, the plant roots grow in a nutrient solution with the plant supported in some way. Here again, there are two main variations:
   (i) tank culture, where the solution is held in tanks in which the roots are immersed, and
   (ii) flowing culture systems, in which the solution flows past the roots in shallow troughs or pipes.
2. Aggregate culture, the plant roots grow in sand, gravel, expanded clay, scoria, or other inert material, which is kept moistened with a nutrient solution.

WHAT IS HYDROCULTURE?

The general definition adopted by the International Society for Soilless Culture (I.S.O.S.C.) is "all methods and systems of soilless culture, if used especially for growing ornamentals in homes and offices". More specifically it is using pots of various sizes and compositions, which contain inert material

like expanded clay or scoria. Necessary nutrients are supplied via water.

The use of soilless media for the culture of plants is really not new and in nature many plants like epiphytic orchids, of course, live in soilless environments Bark is relatively inert and only supplies very small quantities of trace elements. In England cinders have been used, again the main function being to provide support for the plant.

Thus, except in a very modern sense, the use of soilless media for the propagation and culture of plants is not a recent development.

WHY HYDROCULTURE?

A striking development of the last few years, possibly resulting from environmental problems, has been that many more people have consciously or unconsciously begun to appreciate the growing of living plants as interior decorations in administration buildings, hospitals, business premises, and homes (2,11). The use of greenery and flowers is being highlighted for their aesthetic and decorative value, but an additional advantage is the more healthful climate in living and working rooms. By releasing moisture into the atmosphere plants tend to compensate for the drying effects of air conditioning

As it will cost a little more to establish plants by the hydroculture system it is reasonable to expect additional advantages. As a consequence of research, mainly in Europe, it has been proved that soillessly cultivated plants develop better than those growing in soil. "There is no mould, no moss, no putrefaction, no smell or soil, and no soil parasites . . . The plants are healthy despite little necessary care". This is a direct quotation from Prof. Penningsfeld's paper, "Growing Ornamental Plants in Living Rooms — Using New Soilless Culture Systems" which he presented at the I.S.H.S. Congress, Sydney, August 1978.

Baumann in Switzerland first developed a hydroculture system involving — an inner culture pot containing expanded clay — a simple water level indicator — and an attractive outer pot made of pottery, glass or plastic. There were many reasons (and advantages) for the development of this simple system, namely:

Hygiene, healthy and vigorous growth due to efficient nutrition, plants need less attention, provide a nice decoration for living rooms.

The "hardware" generally required includes special hydro-

culture pots; media, such as expanded clay; and the nutrients essential for plant growth.

Characteristics to look for when choosing a trough or reservoir and/or plant container have been indicated by Bruijn (2).

1 Some thought should be given to how the plant container will fit in with its surroundings.
2. Troughs of all kinds should be watertight
3. Plastic troughs are very durable, common, and the least expensive, thus these should be given due consideration
4. Metal troughs are undesirable because the oxidation of certain metals may precipitate some nutrients from the solution and consequently make them unavailable to the plant. Other metal containers may release substances which are toxic to plant growth; for example, zinc and copper.
5. Transparent troughs or those that allow light to go through them make versatile containers but are more prone to algae growth.

The pots or troughs must be at least 10 cm high to ensure sufficient water reserve and movement by capillary action to the plant roots. The specially designed inner culture pot has holes or slits to ensure the necessary movement of air and water. A simple water level indicator shows when the water reserve is exhausted and how much water (normally the nutrient solution) must be added to replenish it to the correct level.

There has been considerable research into what is the best soilless medium to use in the hydroculture system and, up to the present time, expanded clay is the most satisfactory. This material, which is now manufactured in at least eleven countries, is used mainly as lightweight aggregate in the building trade. It is important to ensure that the expanded clay used is suitable for horticultural purposes. Also the optimum aggregate size range depends on the species and age of the plant being grown, e g for young orchids, 4 to 8 mm and for older orchids, 8 to 16 mm appears to be the most satisfactory. By attention to size, the correct balance of air and water around the roots is obtained.

Like expanded clay, the quality of the water used for making up the nutrient solution is very important. Only water of the standard of good quality drinking water should be used.

As in all hydroponic systems, it is considered that the "key" to success is the nutrient solution. Due to the inert growing media used it is most important that ALL the nutri-

ents essential for growth be provided. Only specially prepared, ready mixed salts, or concentrated solutions, should be used. Ion exchange resins, charged with the desired nutrients are being used, mainly overseas, but are more expensive in comparison to nutrient solutions.

THE ROOT SYSTEM

The utilisation of essential elements by higher plants from the supporting medium is very much dependent upon the morphology of the root system (1). Bowen and Rovira have shown, in the case of wheat, that lateral roots are very important in the uptake and translocation of phosphate and, associated with particular temperature regimes, the length and morphology of the roots are also affected.

Moorby & Graves (8) have carried out research with tomatoes and lettuce grown in a nutrient film system of soilless culture. They showed that heating the root environment resulted in faster growth rates and usually larger mature plants. This could be an advantage with leafy plants like lettuce, but was of doubtful benefit with tomatoes and perhaps other plants where reproductive development is important. Roots produced below 16°C developed more slowly, were thicker than the very branched, fine roots produced at 23°C and higher A factor not investigated, but of relevance, was the production of growth substances like gibberellins which are known to be synthesised in roots. It is agreed that there is need to study further the effect of temperature on root form and structure.

To grow and function properly, roots require sufficient oxygen for aerobic respiration, and a minimal accumulation of gases such as ethylene and carbon dioxide. Increasing concentrations of ethylene, which results under anaerobic conditions, causes a reduction in root length. Also it is considered that under these conditions, as a consequence of hormonal, nutritional, and water relationships, the growth rate of the shoot slows down, accompanied by senescence and abscission of leaves (5).

The above brief discussion of some factors affecting root development serves to indicate its extreme importance in nutrition and efficient growth of plants.

PROPAGATION

For obvious reasons, it is desirable that all propagating material be started off in a soilless medium but in practice, particularly in commercial ventures, this is not always possible (4)

The common methods of propagation in hydroculture in-

clude firstly, plants being rooted in soilless mixes; secondly, especially with aeroids, the cuttings may be planted directly into the expanded clay. The third method is to use rooting blocks of rockwool or rigid phenolic foam (13). At present, the first method is the most common and hence the procedure and precautions which receive most attention.

The germination of seeds directly in the expanded clay is also another method as an alternative to vegetative production (2)

CONVERSION OF PLANTS TO HYDROCULTURE

The obvious reason why it is desirable to start with plants that have commenced their growth cycle in a soilless medium, (in the very *strictest* sense) is the avoidance of most diseases which are soil-borne. Penningsfeld (12) has evidence that orchids, even with poor root development, completely recover in many cases when planted in expanded clay, which is indicative of the excellent micro-environment.

The increasing demand for well developed hydroculture grown plants has necessitated the initial use of plants growing mainly in normal soil mixes. The plants must be strong, healthy, not too old and preferably not a flowering type or one with a delicate root structure. Spring and summer are the most favourable times to commence (2).

It is most important that the plant roots be completely freed of the old medium by washing carefully. With some species this is a rather delicate process and some of the finer roots may be damaged and these should be carefully removed.

The expanded clay is then thoroughly washed to remove the fine particles and to make the transplanting operation simpler — strict hygiene is essential at every stage of the conversion.

Potting up is broadly similar to that with conventional plants but the inner culture pot is made of meshed plastic, black polypropylene with slits, or polystyrene.

A layer of the wet expanded clay is placed in the culture pot and the plant is firmly positioned, and then the pot is filled with washed expanded clay. It is important that the roots or base of the cutting be about 5 cm from the bottom of the pot and thus within the height of capillarity or ascent of the nutrient solution from the reservoir.

The next stage, namely the changing of the roots to so-called "water roots" is the most critical stage in the conversion process. Rochford (13) recommends that nearly all kinds of plants be regularly misted or placed into a polythene tent to reduce the risk of dehydration.

In hydroculture, plants develop a root system that is different, both externally and internally, from those in conventional soil culture It is smaller and most of the roots are thick and succulent with only a small number of the fibrous feeding roots

In the Netherlands the newly-potted plants are stood in large shallow trays on mobile benches and moved into sections of the greenhouse held at 26°C with very high humidity and sub-irrigated at regular intervals with water only. A complete nutrient solution is not used until the "water roots" are well established (personal observation, 1980).

When the plants are ready for sale (varies from 6 weeks to 6 months according to plant species), they are placed in attractive outer pots. The optimum nutrient level is visible by means of a simple water level indicator.

The dual problems of correct watering and nutrition is simplified because this is attended to by adding the nutrient solution *only* when the water level indicator falls to minimum. Regular topping up should *not* be carried out because it will prevent adequate air reaching the roots and also brown spots may form around the leaf edges (13).

With established plants and, especially during periods of below optimum temperature, if in doubt, wait, even if the indicator is at a minimum because the moisture retained in the expanded clay will last at least a week without the plants being severely stressed.

CONCLUSIONS

Australia's once leisurely nursery trade is blooming into a multi-million dollar industry with growing overseas markets (9).

The technology for conditioning of an extremely wide range of plants from soil media to hydroculture is known and no longer remains a barrier.

The knowledge gained during the last decade about all aspects of hydroponics, in the home and commercially, is most impressive (7).

I would like to forecast big developments in hydroponics in the eighties. This "Plant Growing Revolution" will help us overcome many of the present day problems (7).

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VIRUS-FREE STRAWBERRY PROPAGATION IN NEW SOUTH WALES

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First let me qualify the term virus-free strawberry plants. This has become an accepted term for strawberry plants (i.e. by commercial strawberry growers) for strawberry plants that have been grown in certified strawberry plant schemes similar to that which exists in New South Wales. In actual fact the plants we propagate should be more correctly described as plants grown from virus-tested mother stocks The scheme that presently exists in New South Wales is similar to many operating around the world The principles of virus eradication in the initial instance remain basically the same, however, varying climatic conditions and differences in pest and disease controls necessary for the many environments in which these

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plants are grown make it necessary for the certifying authorities to vary such rules as isolation, spray programs, and acceptable weed control measures.

The New South Wales scheme has been in existence for ten years and was started as a result of pressure from a group of commercial strawberry growers of which I was one, on the New South Wales Department of Agriculture to start such a scheme to ensure a regular supply of top quality virus-tested plants of the cultivars required here in N.S.W. This need was quite obvious to our Department as they also realised that it was necessary for the commercial fruit growers to use only virus-tested material if they were to remain viable in the future. Crop yields drop dramatically unless plants are kept free of the known strawberry viruses. Yields prior to the introduction of such schemes had dropped as low as one tonne per hectare; however, today yields have increased almost ten-fold with the help of virus-tested plants.

The initial work for the New South Wales scheme commences at Narara Horticultural Research Station — Gosford, where the nuclear stocks of plant material are kept. Most virus testing is also carried out there. Plants then move to the next stage where the process of multiplication begins for the supply of sufficient mother stocks to runner growers such as myself

For the next year plants are grown in screenhouse conditions, i.e. a glasshouse of the highest standard with stainless steel screening to prevent any possible movement of the main virus vector, aphids They are grown in tubs in a medium that has been fumigated to further assist in the control or spread of any soil borne diseases.

For the next stage of multiplication plants are planted the following year in isolation at the Somesby Horticultural Research Station, Somesby. Soil fumigation is normally undertaken at this stage also to further limit any possible spread of any soil borne diseases such as fusarium or verticillum wilt Plants from this last stage form the mother stock for release to certified plant growers. Growers must undergo a one year probation period when they are supplied with a maximum of 1,000 mother plants. As the mother plant supply is limited and subsequent inspection by departmental officers expensive, growers must be able to show their competence before they are able to obtain large quantities of plants.

It is necessary to make application to the New South Wales Department of Agriculture for mother plants and, in so doing, certain information must be supplied such as location of proposed block in respect to any other strawberry plantings (apart from those plants grown in the mountain lagoon quaran-

tine area). Soil tests are then carried out by the Department for the detection of nematodes. If all details of application are approved and tests prove negative then plants are released to growers in approximately mid-winter (July) each year.

Planting on established growers properties is not permitted until total removal of all previous season's plants and crop residue has been affected. In our own instance planting usually takes place in the spring (October) as removal of our cool-stored plants does not finish until late August. For the past five years total soil fumigation of our block is undertaken with 66% methyl bromide + 33% chloropicrin. This serves a two-fold purpose for us by offering excellent weed control as well as continuing the control and possible spread of soil borne diseases.

Excellent soil preparation is necessary to ensure the best possible root development. This fact is most important for successful establishment when planted in fruiting beds. Our normal fertilizer application takes place prior to fumigation and consists of 1½ tonne superphosphate, 625 Kg. sulphate of ammonia, and 250 Kg. sulphate of potash per hectare. Dolomite lime at the rate of 5 tonne per hectare is also applied. This assists in the supply of magnesium as well as lifting our pH which normally runs at 4.7 to 4.9. For a number of years we grew our crop without the use of dolomite lime as we were led to believe strawberries grew well under acid conditions. We believe, however, that they may exist in relatively acid conditions but they certainly do not thrive. I believe much of the fertilizer used in early days remained tied up in the soil and was never available to the plant.

Side dressings of nitram, which supply nitrogen in the form of nitrate 17%, and ammonium 17%, are occasionally applied depending on seasonal conditions (i.e. rainfall etc.). However, the overuse of nitrogenous fertilizer usually leads to excessive vegetative growth, not necessarily increasing plant numbers, crown or root development. It has been found under certain situations that excessive applications of nitrogeneous fertilizers can have an adverse effect on subsequent fruit crops. Work in this area is currently being undertaken by the New South Wales Department of Agriculture. Plants are set at varying distances apart depending upon cultivar and time of anticipated digging.

Digging commences in late autumn (early April) and continues to late winter (late August). As many plants are not fully mature in early April, plants to be dug at this time are usually set more closely in an attempt to achieve an economic yield per hectare. We have found that whilst vegetative growth appears to finish during late April, root growth contin-

ues until well in May, with total maturing of roots not being complete until mid to late July.

An attempt is made to keep surface soil in a moist condition; however, in the main growing months of late summer (January, February, March), this is very difficult especially in years such as we have just experienced with summer rainfall dropping to an alltime low.

The effect of rain as against sprinkler irrigation has been most noticable both in plant health and overall crop yield. Lack of health and drop in yield have been very evident due to poor rainfall.

Approximately three to four weeks after planting, trusses of flowers will appear on most plants; removal of these is carried out by hand. Our experience has shown that runners will appear more quickly if this operation is done as soon as possible. Chemical pruning has been attempted with Ethrel, however, timing is difficult as flowers appeared over an extended period and need to be sprayed before they have developed too far As hand removal is not a large task for our size of operation it would appear to be the most practical solution.

We have found that pinning of runners in the early stages of the crop development has had a beneficial effect on crop yield. The sooner runners take root the sooner further runners are produced. Once a canopy of foliage exists, runners appear to take root more easily and I suspect this is partially because the soil moisture remains closer to the surface, thus encouraging the appearance of roots more quickly Root development from newly formed runners is adversely affected by excessive movement across the soil surface by such things as wind. It appears to have the effect of causing callusing on the base of the crown where the new roots appear and at times this seems to totally inhibit root development.

Pest and disease control must be carried out at all times as the crop must be maintained in top condition to ensure certification by inspecting officers. Excessive foliage damage by pests or hail, etc. can make it impossible for a proper inspection to be done. Inspections of the crop take place at approximately one monthly intervals, so every care must be taken.

Excessive weed growth can also make inspection impossible so it is important to keep very good control of weeds. We have found the best weed control is with pre-planting soil fumigation followed by spot hand weeding. Mechanical weeding is not practical as it disturbs too many young runners in the early stages and weeding later on is not possible because the total ground surface is covered by plants

Many strawberry cultivars have been bred throughout the

world for various reasons, i.e. processing, fresh fruit production, home garden, and pick-your-own farms. In most cases it is the climate that has the greatest effect on the cultivar that will grow best in a given area. Market demands such as fruit size, colour, and keeping quality also play a big part in the selection of an acceptable commercial cultivar.

Winter chilling, i.e. number of hours below 7°C is most important to almost all strawberry cultivars, the requirements ranging for different cultivars from just a few hundred hours to many thousands of hours for those which do best in very cold climates. Plants that do not get at least their minimum number of chilling hours will not be vigorous enough to produce a marketable crop. They often flower prolifically, but the fruit produced from such flowers rarely reaches maturity. At times flowering is so minimal that the crop produced is totally uneconomic.

As far as the strawberry runner plant producer is concerned, all this means is that cultivars that are grown by us are governed, firstly, by market demands and, secondly, whether there is a supply of virus-tested mother stock available from our department of agriculture.

We have watched with great interest, as well as having involved ourselves, in the propagation of strawberry plants from tissue culture. We feel, at this time however, the economics of such a method do not compare with the method I have discussed here today. As subsequent crop yield is greatly affected by weather conditions prevailing in runner growing areas (which are usually situated in cold climates), one wonders what might be the effect on yield of plants grown in such artificial conditions, unless seasonal conditions can also be artificially reproduced to ensure sufficient chilling, etc.

I believe many questions must be answered before commercial propagation by tissue culture methods will be undertaken on a large scale for sale of plants to commercial strawberry fruit producers.

Propagation by seed is another method of reproducing strawberry plants, however, this is usually confined to breeders in developing new cultivars.

As you can see that whilst the skills required in the actual propagation may not be at all difficult to acquire, expertise in crop management is most important to achieve certification of a strawberry crop. Economic fruit yields will only be achieved on a long term basis with the use of "virus-free" plants.

RECENT DEVELOPMENTS IN VEGETABLE CROP PROPAGATION WHICH MAY HAVE IMPLICATIONS FOR THE NURSERYMAN

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Vegetative propagation is very important in the nursery industry, but propagation from seed is the usual method employed by vegetable crop producers. Conventional vegetative methods are used, however, including the use of stem tubers for potato (*Solanum tuberosum*) and cuttings or division for herbs such as mint (*Mentha* spp.), thyme (*Thymus vulgaris*) and rosemary (*Rosmarinus officinalis*). The advent of micropropagation technology has allowed virus-free clones of rhubarb (*Rheum rhabarbarum*) to be produced from apical meristems.

Vegetable growers are very well served by their seedsmen and, although seed prices continue to rise, they still form a very small proportion of the total costs of production. Seedsmen are required by law to provide information on *minimum percentage germination*, and *percentage purity*. Seed must then conform to these percentages. Bedding plant and flowering pot plant seed may also carry similar guarantees, but it is less likely. Tree and shrub seed rarely has this information. Consequently the nurseryman who raises specimen plants, rootstocks, forest trees, or hedging plants from seed has very little idea about the likely performance of that seed. He may carry out a *viability test* but that only demonstrates that the seed is alive. Germination tests indicate the percentages of seed which germinate under perfect and controlled laboratory conditions. Commercial germination conditions are usually far from perfect and it is necessary for growers to modify laboratory results in order to predict likely field performance. Thus, although the vegetable grower usually has an advantage over the nurseryman in terms of information supplied by the seedsman, the germination percentage figures require further interpretation. A more useful assessment would be of seed *vigour*.

The International Seed Testing Association defines seed vigour as "the sum total of those properties of the seed which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence". The concept of seed vigour is used to explain field differences of seed lots with identical laboratory performances Seed with high germination percentages usually gives good field establishment but seed ageing — caused particularly by high temperatures and humidities — causes severe and unpredictable reductions in emergence. This is particularly serious

when the necessary programmed plant populations cannot be achieved for processing and contract grown crops such as carrots, beetroot, brussels sprouts, etc. Similar disadvantages occur when seeds of nursery and ornamental crops germinate and seedlings emerge over long periods of time.

Seeds can be classified into vigour categories ranging from low to high. Low vigour seeds give low field emergence which is worse in adverse soil conditions such as sub-optimal temperatures (carrots) or excessive moisture content (beetroot). Reduction in seedling emergence caused by soil pathogens are also more prevalent with low vigour seed. High and medium vigour seeds perform better but close correlations between laboratory germination and likely field emergence can only be drawn when field conditions are most favorable and there are few stresses on the seed.

Vigour tests have been devised for certain crops. The vigour of pea seed can be determined by measuring the electroconductivity of the water in which seeds have been soaked for 24 hours (4). Leachate from the highest vigour seeds — which produce the best field emergence — gives the lowest electroconductivity readings. The development of vigour tests for other seeds would help the most suitable quality of seed to be used for appropriate crop production systems.

Seed vigour information would provide the basis for much more accurate production programmes and schedules but the problem of non-synchronous seedling emergence remains. Sowing untreated, dry seed often leads to variable emergence of seedlings, particularly when growing conditions and seed factors are sub-optimal. Satisfactory vegetable crop growth occurs only during periods of suitable growing conditions, and short growing seasons make it impossible to grow some vegetables in particular locations. Quicker seedling emergence may give sufficient time for previously impossible crops to be grown while earlier, synchronous crop emergence enables leaf canopies to develop more rapidly so that plants are better able to convert radiant energy into harvestable products.

Certain types of vegetable production need precise control over plant populations in order to govern crop size and development while synchronized crop maturity is needed for "once-over" mechanical harvesting. This is particularly true for processing crops (vining peas, dwarf beans, sweet corn, etc.) but more precise, programmed production is now being demanded for crops such as lettuce which are traditionally selectively hand-harvested. The need for uniform, synchronous development of nursery seedlings is increasingly important as more precise growing schedules are devised. A number of seed treatments have been used for vegetables in order to improve

synchronous emergence and some of these may be worthy of investigation with nursery and ornamental seed.

Beetroot "seeds" are really fruits which contain two or three seeds within a corky pericarp. The fruits are irregularly shaped and are often mechanically rubbed by seedsmen to produce a more spherical unit which can be size-graded and space sown The pericarp contains water-soluble germination inhibitors which can be washed out by soaking the "seeds" in running water at 21°C for an hour before sowing.

Workers in Colorado (2) hastened the emergence of tomato seedlings at low temperatures (10°C) by wetting the seed with nutrient solutions of 1 to 2% tripotassium orthophosphate ($K_3PO_4 \cdot H_2O$), or 0.5 to 2% potassium nitrate (KNO_3), and then re-drying before sowing. Emergence rate was up to 5 days quicker if seeds were soaked for 4 to 6 days. Water is imbibed and enzymes activated during the pre-sowing wetting but the nutrients maintain a high osmotic pressure around the seed and prevent the entry of sufficient water to permit germination at this stage.

Russian work (5) indicates that alternate wetting and drying of seeds before sowing confers drought hardiness on the ensuing crops. Three cycles of this technique — "hardening" or "advancement" — improved the rate of emergence in carrots and gave a 10% increase in yield. Hardening increases embryo size which, in turn, gives rise to quicker germination and seedling emergence. It seems likely that the effects of hardening are similar to using large seeds, i.e. — larger embryos give larger seedlings which emerge earlier and give yield increases.

The late Walter Heydecker at Nottingham University, England devised a technique (3) of placing seeds in contact with solutions of a high molecular weight fraction of polyethylene glycol (P E.G.). Very rapid germination follows the "priming" treatment in solutions with osmotic potentials of −10.0 to −15.0 bars for between 7 and 21 days depending on the vegetable species. The principle is similar to that demonstrated by the workers in Colorado (2). The P.E.G. acts as a germination barrier and seeds take up sufficient water to reach the "brink of germination" but are prevented from taking up any more until the P.E.G. solution is removed. Rapid and synchronous germination then follows; e.g. 50% of viable celery seed germinated in 48 hours after treatment. The best results are obtained when seeds are surface dried before sowing rather than being completely re-dried and stored. Improvements were also demonstrated with flower seeds such as *Antirrhinum*, *Mesembryanthemum* and *Nemesia*. Heydecker used polyethylene glycol as Carbowax 6000 which was supplied by Union Carbide.

(290g. P.E.G. in a litre of distilled water produces a solution with an osmotic potential of −10.0 bars while 324g. in a liter gives an osmotic potential of −12 5 bars.)

Light is required for the germination of some vegetable seeds but there are considerable variations even among cultivars of a particular crop. Seed germination of some cultivars of celery (particularly at temperatures above 15°C), tomato, and lettuce (particularly when freshly harvested) is reduced in the dark Light is unable to penetrate more than 5 mm into the soil and the performance of light-sensitive cultivars of celery is markedly reduced when they are direct seeded. The light requirement can be overcome by soaking seeds in a mixture of gibberellins ($GA_{4/7}$) before sowing (6). Incorporation of ethephon (Ethrel), daminozide (B9), or benzylamino purine (BA) into the mixture helps to overcome thermodormancy factors.

Pre-sowing treatments of some vegetable seeds have given encouraging results but the seeds were still sown dry. Synchronous emergence of the majority of seeds is desirable but it would be valuable to know just which ones will emerge.

Germination of seed before sowing provides the grower with the potential only to sow seeds which are obviously capable of producing plants. Pre-treatment of the seed before the pre-sowing germination could help to ensure synchronous development. Seed which has germinated needs careful handling and a special method of sowing. Workers at the National Vegetable Research Station, Wellesbourne, England have devised a system of fluid drilling by which germinated seed can be sown. The technique and drilling equipment were originally devised for sowing cereals in an aqueous solution into killed grass swards (1). Modifications were made to the machinery and it has been possible to demonstrate the value of fluid drilling germinating vegetable seeds. Seeds are germinated in controlled environments where specific requirements of light, temperature (about 21°C for most common vegetables) and aeration can be provided. Germinating seeds are separated from the remainder by their differential resistance to a stream of water flowing through sloping tubes and are carried along while the ungerminated seeds remain behind.

Germinated seeds of most vegetables can be stored at low temperatures (1°C) in water or high humidity environments if conditions for sowing are unfavourable.

The germinated seeds are mixed into a protective gel immediately prior to sowing. Alginate gels were used initially but many other materials have now been tested. Mineral colloid and polyacrylate gels have given consistently better seedling emergence than alginates. Thorough mixing and correct gel

consistency ensure that seeds remain evenly suspended during sowing.

Fluid drilling of germinating vegetable seeds has produced earlier emergence in widely varying soil conditions. More uniform emergence can also occur and produce uniform growth of some crops right through until harvesting. British research shows 5 to 12 days earlier emergence and up to 20% increase in total emergence of carrots, while celery has emerged up to 21 days earlier with an increase of up to 58% in the total number of seedlings emerging.

Direct seeding pre-germinated seeds has important implications for extending growing seasons and allowing the grower more accurate control over crop production, but there are other prospects. Materials such as fertilizers for seedling growth, fungicides, insecticides or growth regulating compounds could be incorporated with the seed-gel mix and provide a completely artificial environment around the seed.

These seed treatments have not been tried with many ornamental or Australian native plants but I feel that they are worthy of investigation.

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TEACHING PLANT PROPAGATION TO HORTICULTURE STUDENTS

A.W. VINK

Ryde School of Horticulture
Ryde, New South Wales

Abstract. Horticulture students are instructed in the principles and practices of plant propagation which are employed in commercial nurseries It

consistency ensure that seeds remain evenly suspended during sowing.

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Abstract. Horticulture students are instructed in the principles and practices of plant propagation which are employed in commercial nurseries It

will be shown that not only practical aspects of plant propagation but also a thorough knowledge of plants is required to become a proficient plant propagator

INTRODUCTION

The course of instruction outlined in this paper is the Horticulture Certificate Course of the Department of Technical and Further Education in N.S.W This course is designed for students studying at technician level. On enrolling in the course, students have had little experience in plant propagation. However, their attitude is positive because they have at some time grown seeds or struck cuttings and so believe that plant propagation is an easy subject.

It is pointed out at an early stage that plant propagation on a commercial basis is not the job for an amateur. To become a proficient plant propagator the student must have both practical skills and a knowledge of the principles involved This is achieved by:

a) attendance at the college for practical and theory classes.

b) on the job training.

BRIEF OUTLINE OF TOPICS COVERED IN THE SUBJECTS, PLANT PROPAGATION I & II

Stage I:

i) An understanding of the basic difference between sexual and asexual plant propagation and the advantages and limitations.

ii) Seed sowing practices and principles

iii) Vegetative propagation
  a) Stem cuttings — soft wood
    — semi-hardwood
    — hardwood
  b) Root cuttings
  c) Leaf cuttings
  d) Stem bud cuttings

iv) Controlled environment in plant propagation
  a) Glasshouse; polyhouses, frames
  b) Misting systems
  c) Bottom heating
  d) Heating, ventilation
  e) Artificial light
  f) CO_2 enrichment

v) Media — propagation of seed and cuttings
    — potting

vi) Hormone use
vii) Hygiene and sanitation
viii) Economical use of various practices.

Stage II:

Propagation by: a) Division
b) Separation
c) Layering
d) Grafting
e) Budding
f) Tissue and aseptic culture

These topics are taught to coincide with the most appropriate time of the year Further instruction is given to the student so that he is able to grow the plants on in the best possible way

Plant propagation is taught in conjunction with botany because a thorough knowledge of morphology, anatomy and physiology of plants is the basis of plant propagation.

SEED SOWING

Principles: A large number of nurseries propagate their plants by seed and so it is important that the student have a clear understanding of the principles underlying the practice. The following are points that the student is required to understand.

1. Morphology of the seed and the function of various parts.
2. Anatomy of the seed so that it is known that the embryo is a new individual with sufficient reserve carbohydrate in one form or another to survive for a time and to be able to grow until it can manufacture its own carbohydrate after the germination process. How environmental conditions affect the seed and control of conditions during seed storage.
3. Physiology of the germination process and physiology of plant growth. With this understanding sufficient water can be provided for imbibition, adequate oxygen, and optimum temperature for the metabolism. Pre-treatment of certain seed to break down or remove inhibiting growth regulators. Provide the optimum environmental conditions.
4. Media and components to give the optimum germination of seeds, stressing the need to provide for movement of water through capillaries and an adequate supply of oxygen. Consolidation of medium.

5. Depth of sowing
6. Effect of density of seed sowing on growth and disease occurrence and transplanting of seedlings.
7 Growth of plants after germination Photosynthesis, respiration, transpiration, and how environment plays a role in this. The effect of auxins on growth habits of the plant

Skills: The students are assessed on the following skills after they have had some exercises to obtain a degree of competency

1 Pretreatment of seed, if required, by stratification, scarification, hot water, acid treatment.
2 Hygiene
3 Selection of the most appropriate medium
4. Correctly fill and consolidate medium in containers.
5 Select and use the most appropriate sowing method. i.e., hand or machine sowing, drill or broadcast, seed shaker with or without added inert material.
6 Correct distribution and density
7 Select and use appropriate seed covering material
8. Sowing depth
9. Consolidation and watering in
10 Accurately label and record
11 Select the most appropriate propagation structure.

A further step in seed sowing skills is an assignment in which the students have to collect seed. The seed from this assignment is used for exercises or assessment. The aims of the assignment are.

1. Identify the plants from which fruit is collected
2. Collect fruit at the correct stage of ripeness.
3. Extract seed from fruit by the most appropriate and economical method
4. Dry seed to the correct moisture content
5. Correctly store the seed
6. Accurately label and record

SANITATION AND HYGIENE

Sanitation and hygiene are emphasized throughout the subject. Media used in all stages of propagation and growing on are pasteurized so that as little disease as possible is transmitted via the medium.

In selecting plant material the student is taught to collect only that material which has obviously not been infected or affected by pests and diseases. All plant material is surface disinfected since it comes from varied sources. The economics are stressed with sanitation and hygiene.

ENVIRONMENT CONTROLLED AREAS AND MAINTENANCE

The controlled environmental aids to plant propagation are examined and the principles discussed so that the student will have a clear understanding of their purpose and function. Various types of propagation structures are discussed and the advantages and limitations pointed out Maintenance of environmental conditions is discussed although the skills involved can not be taught or assessed because of the time limitation. However, as many points as possible are discussed for certain situations.

VEGETATIVE PROPAGATION

Principles. The main vegetative propagation method taught in Stage I is that of stem cuttings which is carried out in a large number of nurseries. Other forms of cuttings are also taught and are applicable in various nurseries with particular or specialized plants.

Grafting and budding, which are not commonly used in general nurseries, are also treated because of their special application for certain plants or plant forms. In these a degree of competency is required in keeping with the time limitation.

The students, particularly those who will find themselves in supervisory positions in garden maintenance, should also have an understanding of the division of herbaceous softwood perennials, bark grafting, and bridge grafting

Specialised propagation of bulbs, corms, pseudobulbs, and tubers is practised, as well as layering, e.g., aerial, simple, trench.

Tissue culture techniques must be understood but since facilities are limited to small groups it is not practised any further than aseptic culture of seed.

To be proficient in vegetative propagation techniques the student must have a full understanding of the following:

1. Vegetative propagation: although this is a natural phenomenon in many plants, scientific knowledge enables man to simulate and enhance the process with more sophisticated methods.
2 Morphology of plants: an understanding of the parts of

the plant will enable the student to select the most appropriate material for vegetative propagation.

3. Anatomy of plants· an understanding of plant anatomy will give the student knowledge of tissue function and enable him to provide optimum conditions for the regeneration of tissue The student must know the position and function of the meristematic tissue in the plant and the direction of flow and types of solutes which pass through the xylem and phloem
4. Physiology of plants· an understanding will enable the student to select the correct plant material and provide the best environmental conditions for propagation. Although growth is controlled from within, the application of hormones can help the plant to produce faster and more uniform root growth. Timing of propagation method and hardening off
5. Environmental conditions. the ability to control environmental conditions will enable the best results to be obtained in the various vegetative propagation methods, e g , a gradient of temperatures in a bottom heated misting system increases the metabolism at the base of the cutting and encourages root production whereas high temperatures above the medium will increase top growth to the detriment of root production. Misting also provides increased humidity and cooling through evaporation from leaf surfaces.
6. Media and their functions, so that the most appropriate medium can be mixed for the particular plant material.

Skills. Practical exercises assess the student's grasp of the principles· e.g. students collect plant material from work or home and use this to demonstrate to the teacher the various morphological features. At the same time the student shows that he can distinguish the maturity of plant material

The stage of growth or maturity of the plant material is taught in the traditional way by determining whether or not the plant material snaps or bends and by gauging the maturity between fingers and thumb. Also the presence of the definite apical buds and leaf sizes and colour are ascertained for maturity and colour change or cork formation on stems. When this has been mastered the student must bring in appropriate plant materials in good condition for stem cuttings, grafting, or budding.

Practical Skills in Preparation of Cuttings:

1. Selection of appropriate plant material.
2. Hygiene

3 Basal cut (apical cut where applicable) just below node. Removal of lower leaves. Removal of flowers or buds if applicable. Wounding

4. Correct and safe use of propagation knife.

5 Selection of most appropriate medium.

6. Correct filling and consolidation of medium in containers.

7. Correctly apply appropriate rooting hormone.

8 Correct insertion and consolidation of cuttings in medium.

9 Correctly label and record.

10 Water in and place in appropriate propagation structure.

Practical Skills in Grafting and Budding.

1. Selection of the appropriate understock. (theory lesson on compatibility and other aspects given beforehand)
2. Selection of correct scion or budwood: e.g., budwood for roses — petals of flowers falling, etc.
3. Selection of most appropriate method of grafting or budding for the species concerned. e.g., roses (T-budding); conifers (side veneer grafting).

4 Cutting the understock correctly and evenly.

5. Cutting the scion correctly and evenly, or removing bud from budwood and dewood.
6. Align properly.
7. Tie correctly.

8 Wax where appropriate.

In stage II the students must submit a report on an assignment on a hard-to-propagate species of their choice The report will have. a summary of a literature search and a hypothesis which they have developed as how the species may be propagated. Then they will carry out a trial according to the hypothesis and report in a meaningful way the method, results, and a conclusion.

LIMITATIONS

The subjects, Plant Propagation I and II, are studied for only 36 hours each year so that trade proficiency testing cannot be *fully* implemented. However, each student should be able to perform the skills listed earlier. The College considers that quality is more important than quantity. On-the-job training in these areas is therefore vital for proficiency.

Besides Plant Propagation I and II the student will learn about other aspects of plant propagation in subjects such as Botany, Soil Science, Plant Identification and Culture, and Plant Protection.

The facilities are limited, allowing each student only 60 cm^2 of mist bench space and 90 cm^2 of glasshouse or frame space. This works out to three 10-cm pots of seeds, three 10-cm. pots of semi-hardwood cutting, three 10-cm pots of leaf cuttings, and leaf-bud cuttings, and three 10-cm pots of softwood cuttings. Similarly, in Stage II the number of grafts is limited to about 6 plants. Budding, too, is usually limited to 3 or 4 rose understocks.

Potting shed space also limits the amount of practical work. Thirty students with teacher are crowded into potting sheds designed for a maximum of 18 students. There is a student/teacher ratio of 15 to 1 but it is not always possible to find enough teachers so that often classes are greater than 20 students to one teacher

The products from the students' exercises and assessments are given to the students because there is not enough space or staff to maintain all the plants propagated In the end left-over plants are discarded.

Since the College year runs from March to November an important part of the year is missed when plant propagation practice could be carried out with less elaborate facilities, e.g., misting in open beds.

Not all minor differences in propagation method can be taught, although they are discussed, e g., type of cutting implements (razor blades, scalpels), auxin applications; methods of grafting and budding, etc.

CONCLUSION

At the end of their time at the College the students will have a good knowledge of plant propagation principles and can apply this knowledge to the plants he is likely to encounter in the industry If he has not had on-the-job training concurrently with the topics taught at the College, the students skills will not be of the same standard as his knowledge of the principles of propagation This is due to the limited time and facilities at the College.

PROPAGATION OF *DIEFFENBACHIA* BY NODE CUTTINGS

H.C JACKSON
East Malvern "Idaho" Nurseries
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East Malvern, Victoria

Importing mature *Dieffenbachia* plants from Northern Australia to Victoria was not a profitable operation as the plants arrived in a soft condition and were affected by *Rhizoctonia* and bacterial leaf spot So I decided to propagate and grow them myself.

I took tip cuttings from healthy plants, making the cuttings as short as possible, 1½" to 2" of stem, with the leaves about 6" to 9" long. All cuttings were dipped in a solution of 83% Captan fungicide at the rate of 1.25 grams in 10 litres of water. I left the cuttings in the solution for two minutes, stirring them gently to avoid bruising.

Cuttings were then lifted out and left to drain for a few minutes; the cut ends were then dried with paper towelling and dipped in Seradix No. 1 cutting powder with 3% Captan fungicide.

I then put the cuttings into individual 2" tubes using a propagating mixture of 50% perlite and 50% German peat moss. As soon as the cuttings rooted, they were potted into 4" plastic pots, using a very open potting mix, namely:

For 1 cu yd, 5 parts pine bark, 2 parts coarse sand, 2 parts ligna peat (brown coal), and 1 part peat loam, plus, as fertilizer:

7 lbs 8 to 9 month Nutricote, 3½ lbs 4 to 5 month Nutricote, 3 lbs gypsum, 3 lbs dolomite lime, and 1½ lbs Micromax.

As soon as the roots reached the side of the 4" pot, I potted 6 plants into one 12" tub, and then grew them on to about 3 ft high From here I took the tip cuttings to grow more stock plants, using the same method as before.

I then took the stems and cut them into single nodes with a bud on each; nodes were about 1½" to 2" in length. The cuttings were washed in a Captan solution as before and dried; each cut end was powdered with 83% wettable powder Captan. By so doing, I found the cuttings had no rot at all.

Cuttings were placed approximately 50 to a plastic tray, depending on size, into styrene foam chips (Isolite) with each bud facing upwards; cuttings were just covered and placed on bottom heat at 65°F.

As soon as cuttings started to grow and root, liquid feeding was commenced. When the shoots were 3" to 4" long, I cut

them off the node, leaving two base rings on the node This is where the next lot of cuttings came from — in many cases two cuttings were obtained from each node. This process was repeated each time the cuttings were 3″ to 4″ long. I have been using the same trays of node cuttings for two years, still without disease.

All cuttings taken from the nodes are rooted individually in 2″ tubes in 50% perlite and 50% peat moss; from here they are potted into a 4″ pot and then into a 7″ pot, being sold when approximately 1 ft high.

All stock plants and cuttings, etc are sprayed every 14 days for fungus and insects. I use the following fungicides and insecticides.

Captan, 83% wettable powder at the rate of 125 grams per 100 litres water for fungus, also Rovral at the rate of 100 grams to 100 litres water, Matical at the rate of 1½ ozs to 9 gallons water for mealy bug, and malathion 50 for aphis, mixing 5 mls in 3 litres water

By the method outlined above, a large area of stock plants is not required. Sixteen trays of nodes are used to produce 1200 plants yearly.

PROPAGATION OF *DAPHNE ODORA*

JOHN SLYKERMAN
Kenny Lane Nurseries
Monbulk, Victoria

Kenny Lane Nurseries specialise in the wholesale production of rhododendrons, camellias, azaleas, conifers, and daphnes. Approximately 10% of the total cutting production is in daphnes This represents an annual production of 50,000 daphne cuttings per year. Of these 20,000 are grown-on at the nursery and the remainder are distributed to other wholesalers

The stock plants are grown in a red clay loam soil at the nursery at a spacing of 1 foot between the rows and the plants. This is now thought to be inadequate; ideally the spacing should be 2 ft in each case. The stock plants are fertilized each spring with Nitrophoska "slow release" (15·4·12) which is broadcast around the plants at the rate of 1 kg per 4 square metres. In summer the plants are given a further dressing of sodium nitrate at the same rate.

The first cuttings are normally taken at the beginning of December (early summer) according to their hardness. Most of

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the cuttings are taken from the tips of the shoot with at least 6 nodes per cutting Stem cuttings are also used if there is enough growth.

The cuttings are taken in the morning and kept moist all of the time, either in plastic bags or open cardboard cartons which are frequently watered. The latter method is preferred. When sufficient cuttings have been taken for the day they are all removed to the propagation shed.

The first procedure is to cut the cuttings into lengths and remove the basal leaves so that 4 to 6 leaves remain The cuttings are then completely immersed in a solution of Previcur at the rate of 1½ mls per litre of water. A slice is next made at the base of each cutting removing a strip, approximately ½ inch in length, of both bark and cambium so that the pith is exposed. The cuttings are then dipped (quick dip) in a mixture of NAA (20 ppm) and Previcur 1.5 ml/litre. The NAA is freshly made up every day but the Previcur can be used for 2 days.

Immediately after dipping, the cuttings are inserted into a medium consisting of 2 parts sand, 1 part fine polystyrene, and 1 part perlite which is contained in bio-degradable "Net Pots", held in specially designed polystyrene trays These pots are 5 cm deep and the cuttings are inserted to depth of about 2.5 cm.

When full, the trays are removed to a heavily whitewashed, well ventilated glasshouse (380 sq. metres in area) They are placed together at ground level on about 5 cm of sand which is treated once a month with a drench of Benlate (400 g) and Previcur (1 litre) per 540 litres of water. No bottom heat is necessary but automatic misting, controlled by a moisture senser, is used until the cuttings have callused. This takes about 2 to 3 weeks. The automatic mist is then switched off and the medium is kept moist by manual control because excess moisture at this stage can lead to decay No fertilizer is used until after the roots are formed

After 2 months the cuttings are sorted. Ideally, those showing root growth are immediately potted in 125 cm pots and removed to a polyhouse. If this is not possible then the trays are removed to another polyhouse where they are placed on a layer of coarse river sand In this house the plants are liquid fed with Aquasol once or twice a fortnight. Under these conditions, there is some root growth into the sand but because of the open, loose nature of this material, the trays can still be lifted with a minimum of root damage.

The growing-on medium consists of a mixture of 2 parts pine bark, 1 part scoria, and 1 part brown coal (all media in

grades of 6 mm and less). The plants are fed with a top dressing of Nutricote and regular liquid dressings of Aquasol The bulk of the plants are sold in the spring some 9 to 10 months after the cuttings were first taken.

EFFECT OF AUXIN COMBINATIONS ON ROOTING *PERSOONIA CHAMAEPITYS* AND *P. PINIFOLIA* CUTTINGS

ROGER K. ELLYARD

National Botanic Gardens

Canberra, Australian Capital Territory

Abstract. The effect of indolebutyric acid (IBA) alone and in combination with naphthaleneacetic acid (NAA) and/or 2, 4 dichlorophenoxyacetic acid (2,4-D) on the rooting of *P chamaepitys* and *P pinifolia* was investigated The highest percentage rooting was obtained following treatment with a combination of all three auxins Retreatment of the cuttings with auxin *after a period of time under mist further stimulated rooting A possible* explanation for the findings is presented

A basic system for root initiation and development was proposed more than 25 years ago (1). In the intervening 25 years much evidence has been gathered in its support and it is on the verge of being proved correct. The endogenous auxin indoleacetic acid (IAA) was identified in 1934 and was soon being added exogenously to promote the rooting of cutting. Synthetic auxins, notably indolebutyric acid (IBA) and naphthaleneacetic acid (NAA), were soon developed and because of their greater stability and mobility were found to be of greater commercial use. Generally IBA has proved the more effective auxin. With some species, however, NAA has proven superior to IBA in promoting rooting while with a few species a combination of IBA and NAA has been shown to be superior to either auxin alone These findings suggest that the two hormones may not have the same site of action.

Furthermore, 3-methyleneoxindole, formed by the oxidation of IAA (6) has been shown to be at least 10-fold more effective than IAA as a plant auxin (9). Subsequently Haissig (4) suggested 3 methyleneoxindole rather than IAA to be the compound that conjugates with a phenolic cofactor to form an auxin cofactor complex responsible for triggering root initiation (Figure 1). However, 3-methyleneoxindole can be inactivated by reduction to 3-methyloxindole by a group of enzymes, 3 methyleneoxindole reductases, which show differential sensitivity to the synthetic auxins NAA and 2,4-dichlorophenoxyacetic acid (2,4-D) (8). With two of the reductases, which could be separated completely by column chromatography, one was found to be strongly inhibited by NAA,

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and the other by 2,4-D Since NAA cannot be oxidized to methyleneoxindole, it was postulated that its mode of action as an auxin might be in maintaining elevated levels of endogenous 3 methyleneoxindole by inhibition of 3-methyleneoxindole reductase (9); 2,4-D might be expected to act similarly. Furthermore, if several of these reductases are active in tissue then the use of a combination of both NAA and 2,4-D might be superior in initiating an auxin response.

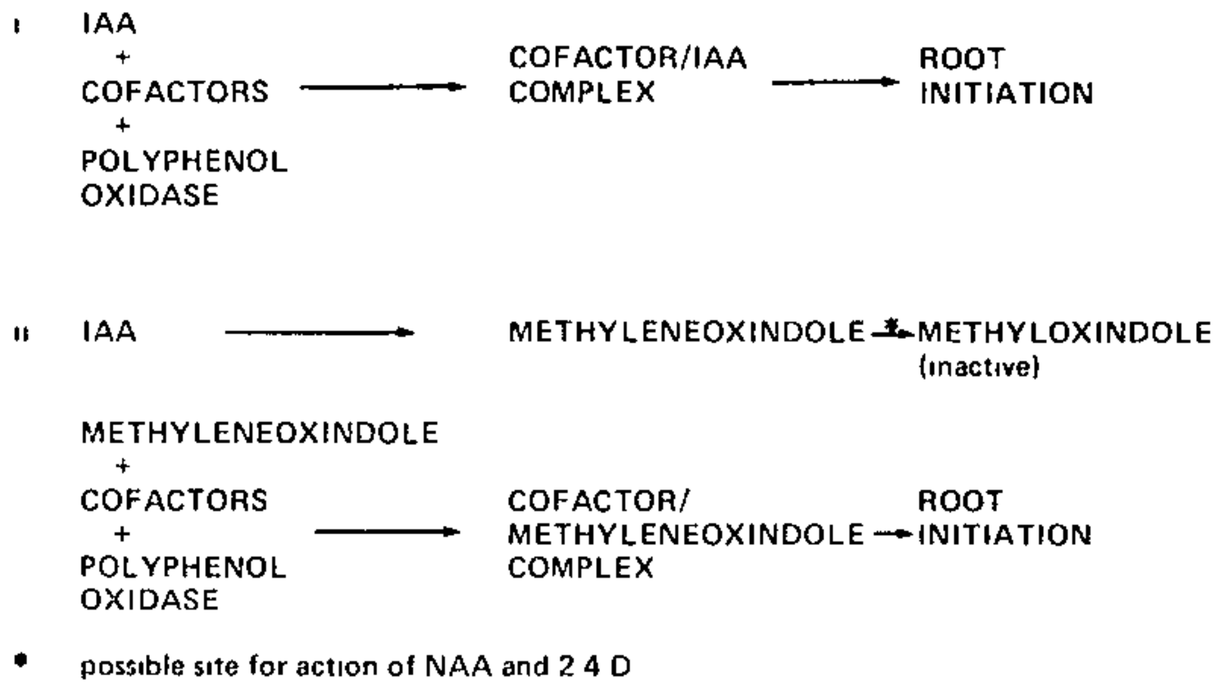

Figure 1. Two possible schemes for root initiation

The genus *Persoonia* contains a number of species of considerable horticultural merit. *P. chamaepitys* is a beautiful prostrate plant with bright, light-green foliage, and yellow flowers. *P. pinifolia* is a pendulous shrub growing to 4 metres which bears yellow flowers followed by bunches of succulent fruits. In cultivation they are generally hardy in sunny, well-drained positions. Unfortunately most have proved very difficult to propagate from either seed or cuttings. At the National Botanic Gardens, A C.T. a small number of *P. pinifolia* seed have been germinated following treatment with gibberellic acid (unpub. data). Propagation from cuttings has generally been unreliable Ellyard (2) reported a 50% strike rate with cuttings of *P. chamaepitys* taken in May and treated with a 500 ppm IBA/500 ppm NAA liquid quick-dip formulation. This strike rate, however, has not been achieved in subsequent work

In this paper the results of a study on the effect of IBA, NAA, and 2,4-D on the rooting of *P. chamaepitys* and *P. pinifolia* cuttings are reported.

MATERIALS AND METHODS

Tip cuttings, 100 to 120 mm in length, were taken from cultivated plants and the leaves removed from the basal two-thirds. The effect of six hormone treatments on rooting was investigated. All hormone treatments were applied as a five-second dip to the basal surface of the cutting and excess

solvent (ethanol, water 1.1) allowed to evaporate. The cuttings were then placed to a depth of 50 mm in 100 mm square plastic pots, 15 per pot, containing a medium of equal parts washed sand, perlite, and sieved German peat moss. All cuttings were watered and placed under mist on a sand bed heated to maintain a temperature of 25° ± 2°C in the cutting medium The pots were re-randomised and treated with fungicide, alternately benomyl and Captan, weekly.

Fourteen weeks after placing on the bench the cuttings were harvested and the number of rooted cuttings per treatment recorded.

Following the first evaluation the live unrooted cuttings in each treatment were divided into two groups. The base of each cutting in the first group was recut to expose live wood and the cuttings inserted in fresh cutting medium Cuttings in the second group were recut and retreated with the relevant auxin and inserted in fresh cutting medium. The cuttings were returned to the mist bench and re-evaluated after a further eleven weeks

RESULTS

The rooting of both *P. chamaepitys* and *P. pinifolia* cut-

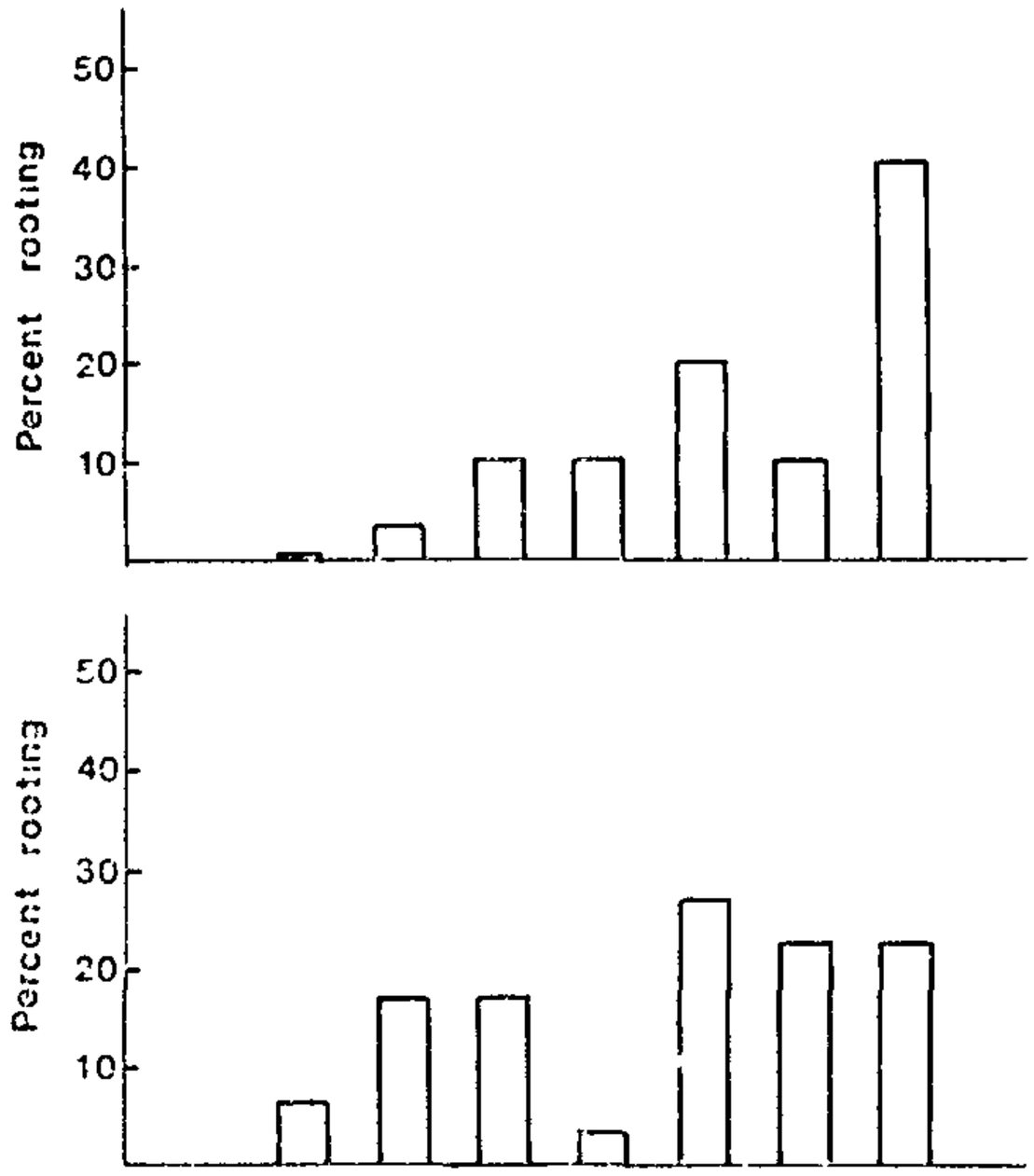

Figure 2. Effect of auxin on the rooting percentage of *P chamaepitys* (above) and *P pinifolia* (below) All treatments contained 30 cuttings and were harvested after 14 weeks Left to right no auxin, 1200 ppm IBA, 1000 ppm IBA/200 ppm NAA, 1000 ppm IBA/200 ppm 2,4-D, 600 ppm IBA/600 ppm NAA, 600 ppm IBA/600 ppm 2,4-D, 1000 ppm IBA/200 ppm NAA/200 ppm 2,4-D

tings was influenced by hormone type. After 14 weeks on the cutting bench *P. chamaepitys* had rooted best following treatment with a mixture of IBA/NAA/2,4-D (Figure 2a). Combinations of IBA/NAA and IBA/2,4-D were less effective, and IBA alone was ineffective. When the unrooted cuttings were retreated and returned to the mist bench for 11 weeks the combination of all three hormones, and the 600 ppm IBA/600 ppm NAA gave excellent rooting (Figure 3a) IBA was once again ineffective while the IBA/2,4-D combinations and the 1000 ppm IBA/200 ppm NAA were intermediate in their effect. Recutting the base only was also ineffective.

With *P. pinifolia* cuttings hormone type had less effect on the initial rooting response (Figure 2b) The highest percentage rooting was obtained with the two 600 ppm/600 ppm preparations and with the IBA/NAA/2,4-D combination. When the unrooted cuttings in each treatment were retreated and placed back on the misting bench the IBA/NAA/2,4-D combination was superior in stimulating rooting (Figure 3b)

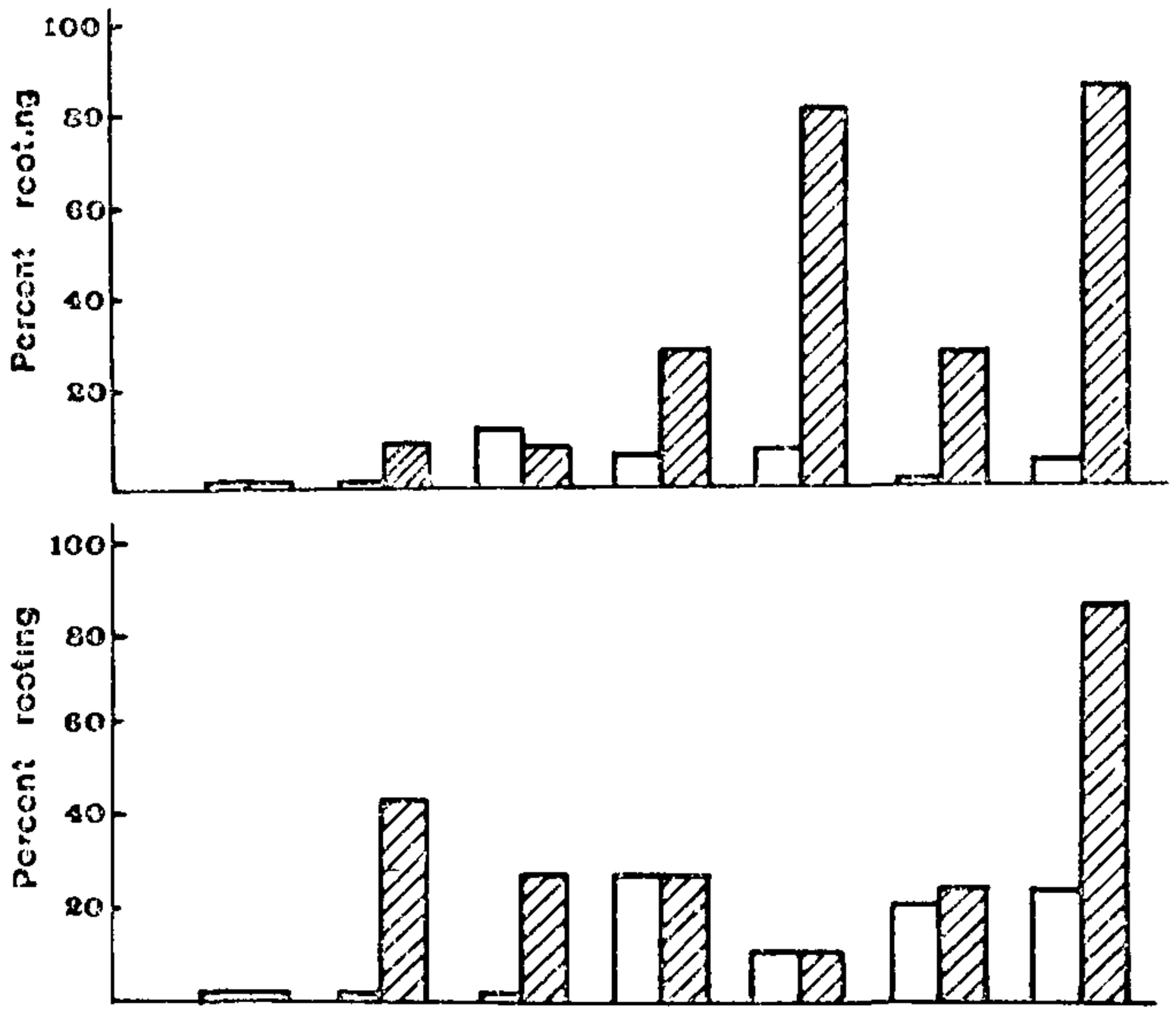

Figure 3. Effect of recutting the base (open bars) and recutting plus auxin treatment (shaded bars) on the rooting percentage of *P. chamaepitys* (above) *P pinifolia* (below) cuttings The number of replicates per treatment was dependent on the percentage rooting obtained following the initial auxin treatment The cuttings were harvested after 11 weeks Left to right no auxin, 1200 ppm IBA, 1000 ppm IBA/200 ppm NAA, 1000 ppm IBA/200 ppm 2,4-D, 600 ppm IBA/600 ppm NAA, 600 ppm IBA/600 ppm 2,4-D, 1000 ppm IBA/200 ppm NAA/200 ppm 2,4-D

DISCUSSION

The results clearly indicate that *P. chamaepitys* and *P. pinifolia* may be rooted successfully by the use of a combination of IBA/NAA/2,4-D. The superiority of this combination is evidence consistent with the proposition that the site of action of NAA and 2,4-D is the 3-methyleneoxindole reductase complex. Further studies are required, however, to establish whether all three auxins are required or whether the response is due solely to the NAA/2,4-D combination.

Although the number of replicates were small the results also indicate a beneficial response to auxin treatment after a period of time on the cutting bench Phenolic cofactors have been implicated in root initiation (5) and the production of such phenolic cofactors have been shown to be stimulated by misting (7). It has been suggested that these phenolic compounds, which are produced in buds and are translocated to the cutting base (3) are capable of conjugating with auxins to form compounds capable of stimulating rooting (3,4) (Figure 1). The present observations with *Persoonia* may reflect the slow accumulation of such a phenolic compound under mist and that this is necessary before applied auxin is effective in inducing a rooting response At this stage, however, the possibility that the leaching of inhibitors under mist is responsible, cannot be ruled out.

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TIBOUCHINAS, BEAUTIFUL — CHANGEABLE, A CHALLENGE

KEN DUNSTAN

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Pacific Drive
Alstonville, New South Wales 2477

The genus *Tibouchina*, which has over 300 recognized species is fascinating, to say the least, with the largest concentration of species in south-eastern Brazil. A secondary grouping can be found in the Andes Mountains from northern Argentina through Bolivia, Peru, Equador, Columbia, through to Venezuela. Some species extend as far north as Mexico.

Over 20 years ago, through the personal efforts and love of the tibouchina plants, they were imported from South America to Australia by Dr. George Hewitt and Mr. Bill Bewley.

Personally, I feel I have been honoured by the help and confidence these two fine men have instilled in me over the past 9 years or so. Consequently I have accepted and carried out the challenge to promote as many tibouchinas as I consider to be of merit for future propagation.

I do this, bearing in mind the importance of ready and popular sales by our retail nursery outlets.

In Alstonville, we have created hybrids from *Tibouchina* species, and have found many sports

Some tibouchina trees exceed 75 feet in height in their natural habitat, but most species are small trees and shrubs usually found in secondary forests — on mountain slopes, and along streams They are predominantly sun requiring plants; only very few do well in shade The flowers of the genus are mainly purple with exceptions such as *T. granulosa* 'Rosea', which is pink A pleasant characteristic of some of the species is their ability to change the colour of their flowers from white on opening to pale pink, then pink, and finally magenta, as in our recent release *T.* 'Noelene'.

All tibouchinas are very distinctive in their own right. They, nevertheless, have the same three-veining leaf pattern of most Melastomaceae.

Some of our releases here in Australia are: *T.* 'Alstonville' (deep purple, flowering profusely in the Lenten period). *T.* 'Elsa' (white, with purple veins in flowers; large velvety leaves). *T.* 'Kathleen' (pink — similar to *T. granulosa* 'Rosea'). Our spectacular sport at the moment is *T.* 'Alstonville Variegata' (cream and green leaves; purple flowers, as in 'Alstonville'.

In Brazil Tibouchina, the glory tree, is also known as 'Quaresmeira' or 'Quaresma Flower' — Quaresma meaning the 40 days of Lent, this being the normal flowering period. This name particularly applies to *Tibouchina granulosa*, and its cultivars

Of the large number of known species, only relatively few have found their way into the greenhouses and gardens of the world outside of Brazil, with the possible exception of Florida and California. They are highly regarded in their homeland for their magnificent floral display during the Lenten period. They are extensively planted in parks and gardens where their decorative and ornamental value is unsurpassed by any other tree or shrub.

Tibouchinas require an acid soil and respond to generous feeding together with adequate watering especially during spring and summer. A warm, sheltered position should be chosen. Any pruning that is necessary should be done after flowering

Our propagation method for tibouchina is as follows: For a rooting mix for cuttings use ⅔ coarse sand and ⅓ peat plus a small amount of Diatomite (coarse grade). Use young tip cuttings and treat with a prepared hormone such as "Rite Gro Striking Powder No. 4". Root under mist with bottom heat at about 80°F This should give 90% to 100% rooting

PROPAGATION OF FICUS SPECIES BY AIR LAYERING

DOUG WADEWITZ

Wadewitz Nurseries
Willunga, South Australia

This method can be used to propagate several *Ficus* species such as *F. benjamina* and *F. elastica*

Firstly, get an old pair of secateurs and, in the centre of the cutting blade, grind out 5/16″ deep by ¾″ wide (8 mm deep and 20 mm across) and then sharpen that gap or radius in the blade to the same angle as the original blade. To the inside of the handle end, weld a piece of steel 65 mm long and 40 mm wide and in that piece of steel, put a tapered V, 25 mm wide and 30 mm long, which is serrated similar to a saw-tooth or multi-grip plier's teeth.

Next you need a sheet of aluminum foil similar in thickness and quality to take-a-way trays (the difficulty is trying to buy this material from the manufacturers of take-a-way trays; you have to buy 28 lb rolls and months of proving you are not

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going to be in opposition to them) These rolls come in widths of about 200 mm, so you have to bend and cut them in half, making a sheet 100 mm × 100 mm

Now you require moist sphagnum moss for each sheet of tin foil, one handful of moss in the centre of the sheet. (The foil is very sharp, so treat with respect.) Using the secateurs, you now place them around the stem of the *Ficus* branch and squeeze gently till you can hear a light noise as you cut into the cambium. Now gently go around with the same tension till you have completely cut around the outer layer.

Again repeat the same operation 1" or so above or below the first cut With the sharp point of the secateurs cut up the back, then with the handle end where the saw tooth is, move that around and remove the collar of bark Here you dust or paint rooting hormone in the cut area. The air layer is usually 1½" to 2 feet long

Now with the moist sphagnum moss in the sheet of aluminum foil, wrap the foil around the exposed branch and squeeze the edges of the foil together. Some people tie a stake above and below the air layer, otherwise sometimes the top may break off.

Using this method it takes about 6 weeks or more before roots grow into the sphagnum moss.

EFFECT OF PROPAMOCARB AND pH ON THE GROWTH OF FERNS AND *PILEA*

ROSS J. WORRALL

Horticultural Research Station
Gosford, New South Wales

Abstract. Propamocarb applied at the rate of 0 17 mg per litre of medium every three weeks, stimulated the growth of *Pilea cadierei* 'Minima' apparently in the absence of any phycomycetous fungi, against which it has a narrow spectrum of activity It however inhibited the growth of the ferns, *Thelypteris nymphalis*, *Polypodium membranifolium*, *Nephrolepsis exaltata* 'Fluffy Ruffles' and *Pteris tremula*, but had no significant effect on the growth of *Cyrtonium falcatum* or *Selaginella kraussiana* There was no interaction between propamocarb and the pH of the medium The optimum pH for *T nymphalis* dry weight was 5 96, frond area 5 97, *C falcatum* dry weight 5 98, frond area 6 01, *P membranifolium* dry weight 6 41, *N exalata* dry weight 6 12, frond area 6 08, *P tremula* dry weight 6 11, frond area 6 03, *Salaginella* dry weight 6 30 The optimum pH for the growth of *P cadierei* was equal to or in excess of 6 57

REVIEW OF LITERATURE

Propamocarb has been recently registered as a fungicide in New South Wales for the control of *Pythium* in ornamental

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REVIEW OF LITERATURE

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crops It also has activity against a range of other Phycomycetous fungi, i.e. *Phytophthora*, *Peronospora*, *Pseudoperonospora*, and *Bremia*.

The manufacturers of the product claim that it is relatively non-phytotoxic. Even after repeated application and at high dosage rates no growth retardation has been observed, and in many instances crops have shown an increased foliar and flower development (1,2,3). It's residual life is usually 3 to 4 weeks, this being increased by low pH conditions (1,2,3). Ferns are relatively slow-growing plants and any stimulation of growth would be of great commercial significance.

The aim of this experiment is to examine the stimulatory effects of propamocarb on growth of a number of ferns free of pathogens over a range of media pH.

MATERIALS AND METHODS

The ferns *Thelypteris nymphalis*, *Cyrtomium falcatum*, *Polypodium membranifolium*, *Nephrolepsis exaltata* 'Fluffy Ruffles', *Pteris tremula* and *Selaginella kraussiana* and the non-fern *Pilea cadierei* 'Minima' were grown in a glasshouse with 60% shade and a 17 to 27°C, day-night temperature at the Gosford Horticultural Research Station from 15th August to 24th October, 1980. The 125 mm pots used to grow the plants contained 1 liter of a 50% sphagnum peat, 25% sand, 25% perlite medium with 1 g superphosphate, 0 25 g magnesium sulphate, and 0 12 g of both potassium sulphate and potassium nitrate added per liter before steaming at 70°C for 30 minutes. After steam 4 g/liter of a 16N-4.4P-8.3K resin-coated slow-release fertilizer (Nutricote® 4-5 month formulation) was added. Plants were irrigated after 1 and 4 weeks with a 23N-4P-18K liquid fertilizer with added trace elements (Aquasol®) at the rate of 0.15 g/pot, and at other times with chlorinated tapwater.

The treatments were:

(1) The medium was adjusted to a range of pH's by adding a 2·2 (w/w) mixture of $CaCO_3$ and $MgCO_3$, which was added at the rates of 0, 1, 2, 4 and 8 g/l.

(2) Fungicide application: Either 0.00 or 0.17 mg of propamocarb was added per pot in a drench at the commencement of and every three weeks during the course of the experiment (a total of 4 applications).

Treatments were applied in factorial arrangement giving a total of 10 treatments and there were 10 replicates per treatment.

After 10 weeks, leaf area (where possible) was measured with a photoelectric area meter and the dry weight of the

aerial portion of the plants was determined A 2·1, water-medium ratio was used to determine pH.

RESULTS

pH. The rate of calcium and magnesium carbonate was related to the pH by the equation.

$$\log pH = 0\,16 + 0\,66 \log (X + 1) \qquad \text{equation 1 } (r = 0\,99)$$

where X is the rate per litre of liming materials.

This equation shows that the pH increased at a diminishing rate as the rate of calcium and magnesium carbonate increased.

Growth responses. Initially the data was analysed as a two factor analysis of variance. No interactions were significant, thus only the main effects of fungicide and liming material are considered.

The effect of propamocarb. Results are given in Table 1 Application of propamocarb significantly increased the growth rate of *P. cadierei* but either had no effect on *C. falcatum*, *S. kraussiana*, or reduced the growth rate of the ferns tested (*T. nymphalis*, *P. membranifolium*, *N. exalata*, *P. tremula*)

Treated *P. tremula* plants were also a much darker green and had a shorter frond length than untreated controls.

Table 1. The effect of propamocarb on the growth and ferns and *Pilea*

Species	Parameter measured (g or cm^2)	Propamocarb not added	Propamocarb added	Level of significance (P = 0 05)
T nymphalis	Dry wt	2 06	1 61	significant
	Frond area	602	441	significant
C falcatum	Dry wt	1 54	1 47	not significant
	Frond area	387	356	not significant
P membranifolium	Dry wt	1 86	1 66	significant
	Frond area	728	530	not significant
N exalata	Dry wt	2 97	2 68	significant
	Frond area	605	580	not significant
P tremula	Dry wt	2 42	1 66	significant
	Frond area	784	527	significant
S kraussiana	Dry wt	2 30	2 34	not significant
P cadierei	Stem dry wt	0 51	0 63	significant
	Leaf dry wt	1 71	1 99	significant
	Leaf area	360	413	significant

The effect of liming materials (calcium and magnesium carbonates). The results are given in Table 2. The optimum level of liming materials was derived from differentiation of the second degree polynomial regression equation:

$$Y = 1 + aX + bX^2 \qquad \text{equation 2}$$

where X is the rate of liming material and Y is the parameter measured. The optimum pH level was derived from equation 1 by substitution of the optimum value of X.

The optimum value for the liming materials for the growth of ferns tested lies between 4 07 and 6.08 g/*l* and the optimum pH values for ferns tested between 5.97 and 6.41. The regression equation for *P cadierei* indicated that the optimum level of liming materials (and hence pH) had not been reached in this experiment The data given for *P. cadierei* in Table 2 was the highest rate of liming materials used and the highest pH reached

Table 2 Optimum pH and rate of liming materials (magnesium and calcium carbonates) for the growth of ferns and *Pilea*

Species	Parameter measured	Optimum rate of liming materials g/l	Optimum pH	Level of significance (P=0 05)
T *nymphalis*	Dry wt	4 07	5 96	significant
	Frond area	4 11	5 97	significant
C *falcatum*	Dry wt	4 16	5 98	significant
	Frond area	4 59	6 01	significant
P *membranifolium*	Dry wt	6 75	6 41	significant
	Frond area	5 52	6 22	not significant
N *exalata*	Dry wt	4 91	6 12	significant
	Frond area	4 71	6 08	significant
P *tremula*	Dry wt	4 87	6 11	significant
	Frond area	4 45	6 03	significant
S *kraussiana*	Dry wt	6 08	6 30	significant
P *cadierei*	Stem Dry wt	8[1]	6 57[1]	significant
	Leaf Dry wt	8[1]	6 57[1]	significant
	Leaf area	8[1]	6 57[1]	significant

[1] This was the highest rate level used in this experiment

DISCUSSION

Propamocarb stimulated the growth of *P. cadierei*. The manufacturer suggests the mode of action in stimulating plant growth is by the control of previously unconsidered sub-clinical effects of pathogens (1) Since the *P. cadierei* plants were vegetatively propagated they may have been infected with a phyctomycetous fungi, although they showed no visible symptoms of this on either the roots or foliage. The fungicide, however, inhibited the growth of a number of ferns when applied at a rate to which a large number of plants have exhibited no phytotoxicity (1,2,3). In the case of *Pteris* it also caused noticable visual symptoms, viz a shortening, distortion and greening of the funds The usual symptoms of propamocarb phytotoxicity is necrotic tipping of leaves (1). The effect of propamocarb was not modified by pH. This may have been due to the reapplication of the fungicide at regular intervals maintaining a critical level in the medium despite the higher rate of destruction of the fungicide at high pH levels.

Although propamocarb may stimulate the growth of a wide range of plants it may also have an inhibitory effect; especially on ferns. Before propamocarb is applied generally in any nursery there is a need to determine its effect on the

target species, particularly in the absence of potential pathogens

The optimum pH for the growth of ferns in this experiment was 5.96 to 6.41 and that of *P. cadierei* was equal to, or in excess of 6 57. Recommendations for the optimum medium pH vary widely. Baker (4) recommends a pH of between 5.5 and 6.5 for growing most plants while Bunt (5) recommends a pH of between 5.0 and 5 5 for growing most plants in medium high in organic matter. Hipp and Morgan (6) recommend a pH of 4.5 for growing *Nephrolepsis exalata* 'Rooseveltii'. This is contrasted to the pH of 6 7 recommended by Hoshizaki (7) for fern culture. The pH of a medium has a large effect on the availability of nutrients in potting medium as does the organic matter content (4). The different nutrient regimes and media used by these writers probably accounts for most of the differences in optimum pH for the growth of ferns under different environmental conditions Nurserymen should be aware that pH can have a large effect on the growth of plants and it may be worthwhile for them to do experiments under their own conditions

LITERATURE CITED

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RAPID PROPAGATION OF CITRUS IN CONTAINERS

G.I MOSS and R. DALGLEISH

CSIRO Division of Irrigation Research
Griffith, New South Wales 2680

Abstract. Closer spacing of citrus trees, rapid expansion, and a more dynamic situation means that the need is for a cheaper and faster method of propagation A method is described of producing citrus on a rootstock in containers in less than one year The work was done with *Poncirus trifoliata* It was grown immediately from seed throughout the winter, microbudded, the scion induced to grow and material was ready for early summer planting This method is compared with another which produced material in one year where the rootstock was grown during the summer and

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Abstract. Closer spacing of citrus trees, rapid expansion, and a more dynamic situation means that the need is for a cheaper and faster method of propagation A method is described of producing citrus on a rootstock in containers in less than one year The work was done with *Poncirus trifoliata* It was grown immediately from seed throughout the winter, microbudded, the scion induced to grow and material was ready for early summer planting This method is compared with another which produced material in one year where the rootstock was grown during the summer and

the scion induced to grow during the winter months This produced better quality trees The estimated costs of production are presented Alternative methods, advantages and disadvantages, are discussed in the context of the whole system of citrus production

INTRODUCTION

The work was initiated in 1971 when we realised that the cost of new citrus trees was likely to be a limiting factor in the move towards closer plantings to improve efficiency in citrus production (10). Also, we recognized the need to provide planting material quickly, especially in periods of rapid expansion or in periods of change-over to other cultivars. Another factor that should be taken into account is the increased use of sophisticated irrigation systems. The use of trickle or under-tree sprinklers, especially where nutrients are supplied through the water, would enable citrus growers to "grow-on" young trees "in-situ" rather than in the nursery. Thus growers could make use of small budded stocks with a considerable saving in cost. Some nurserymen produce citrus trees in containers, but there is buyer resistance to this because the small containerized trees are less suited to planting out under conditions of relatively primitive irrigation systems (i.e., furrow irrigation with infrequent application). We have, therefore, considered likely changes in grower demand resulting from technical improvements.

THE PROPAGATION SYSTEMS

The traditional system of producing citrus trees is outlined in Figure 1, as well as the two systems we have developed:

System A Rapid propagation in small containers,

System B Propagation in 12 months in plastic bags which produces a plant more similar in size to open-field produced trees.

All our work was done with *Poncirus trifoliata* rootstock, which will normally go dormant in winter, and 'Valencia' sweet orange scion. Three experiments were carried out using 500 trees in each case. All propagation procedures took place in a glasshouse.

(a) **Seedling Production.** To save time (in System A) seed was extracted from fruit as soon as it ripened in the autumn (March). Large quantities of seed could be extracted by crushing the fruit, washing the pulp, then subjecting it to an enzyme treatment (1). The product would be improved by grading seed for size as variation in seed size could be the cause of variations in the initial size of seedlings. Seed germination is often slow and variable so we soaked the seed in 1000 ppm gibberellic acid for 24 hours to improve germination (2). Seed

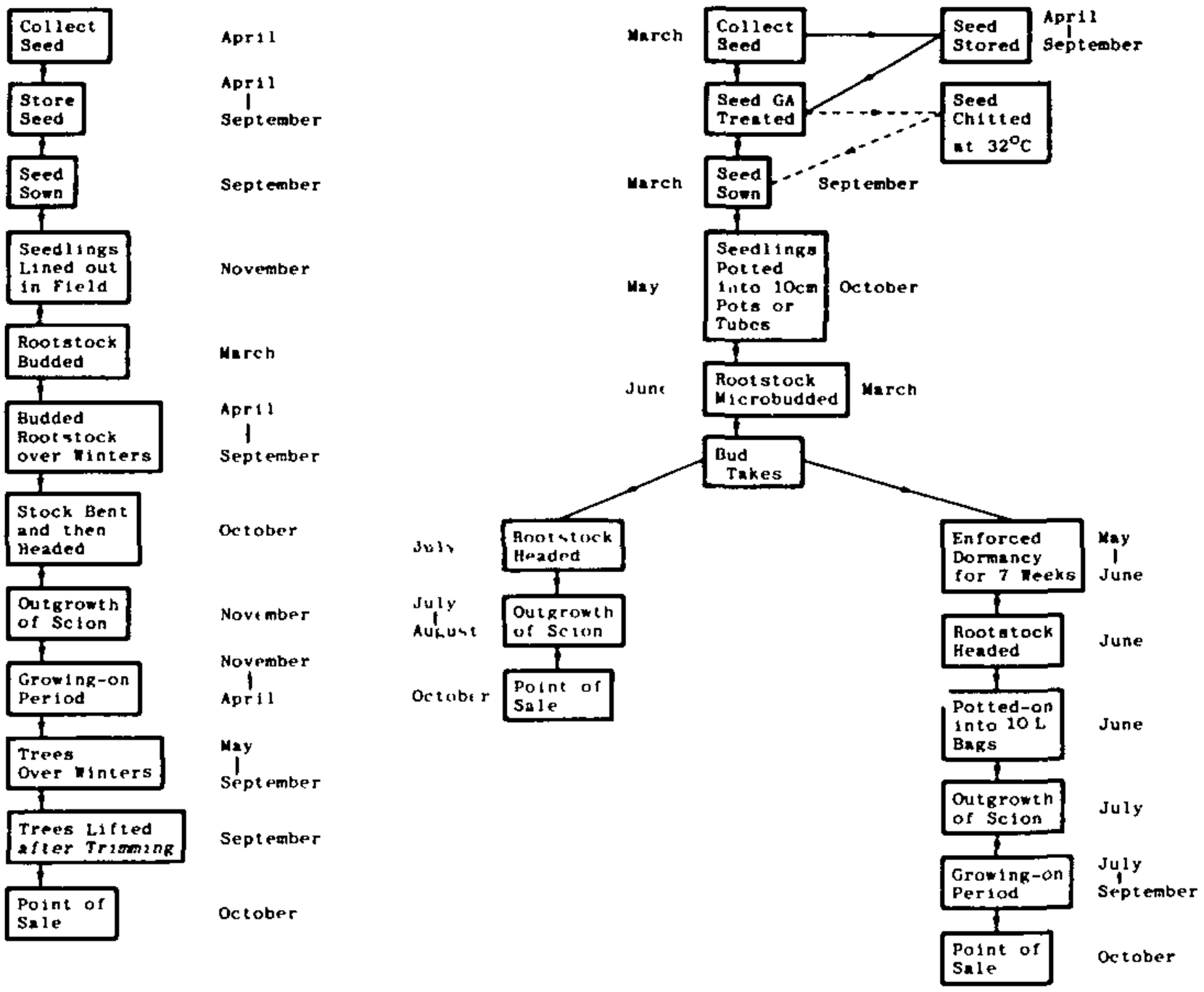

Figure 1. Comparison of three citrus propagation systems

can be heat-treated prior to germination if there is any risk of disease contamination. Another way to speed germination would be to chit the seed by keeping it moist at 32°C and sow at the onset of germination.

We sowed seeds in sterilized sand mixed with peat in "washing-up bowls" 35 × 30 cm with drainage holes. These containers hold 250 to 500 seeds and are 13 cm deep so they do not restrict root growth initially. Polystyrene grape boxes also would be suitable containers. At a minimum temperature of 25°C it took about two months for the plant to reach the transplanting stage. We did not observe any check in growth when the stocks were transplanted.

(b) **Growing-on the Rootstock**

(i) *Containers.* We used standard 10 cm plastic pots, but have tried other containers. A type sold in the USA for tree seedlings is a tapered plastic tube with three antispiral ribs on the inside (Figure 2). The largest of this type of tube is 215 mm long by 40 mm diameter at the top and holds 160 ml of medium (*cf.* the pots hold about ½ l). The standard Australian tube is unsuitable because the container must be large enough to take the stock to the size suitable for microbudding, that is 50 cm high with a stem diameter about 7 mm at 150 mm above the soil level.

Figure 2. Tapered plastic tube suitable for citrus rootstock production.

For System A the container must take the plant through to the planting-out stage. A tapered tube with a volume of at least 330 ml and a height of 250 mm would be best for System A.

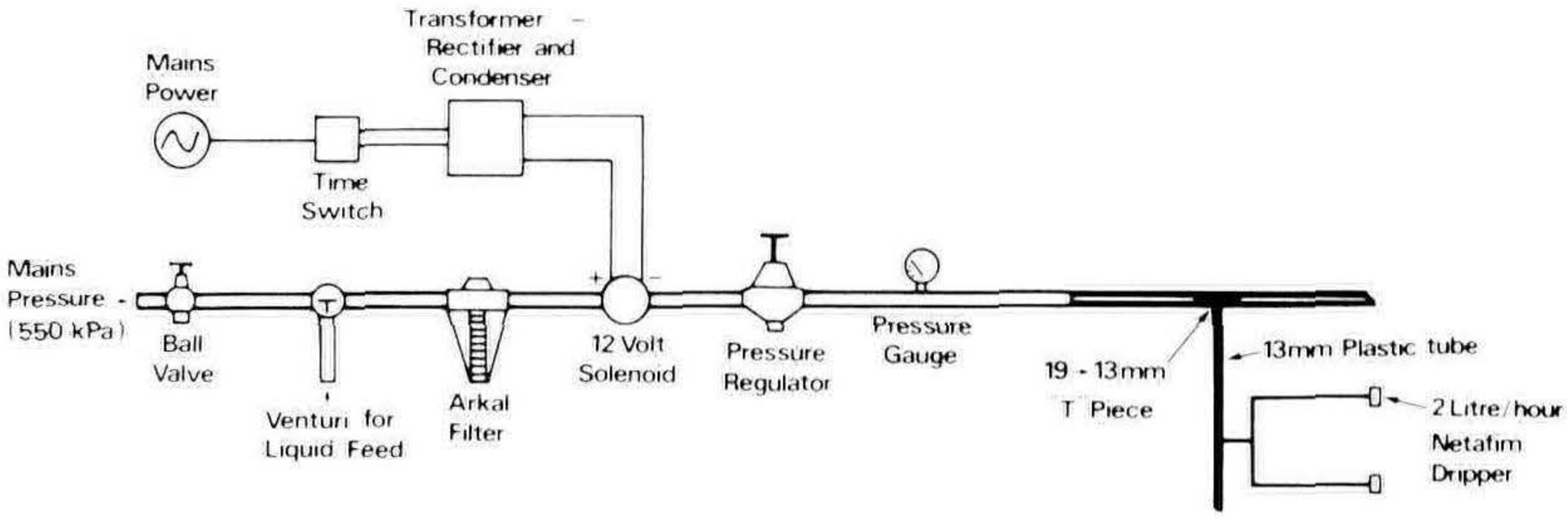

Figure 3. Diagram of the automatic watering system used in System B.

(ii) *Medium.* We used ⅓ loam, ⅓ sand, and ⅓ composted red gum sawdust. The pH was adjusted to 7. MagAmp slow-release fertilizer was added at the rate of 60 g per 10 l bag in system B. We had problems with this mixture — the pH fell rapidly at times and growth ceased, but this was easily corrected with additional lime. We suggest that a cheap, inert medium with liquid feeding might be better.

(iii) *Watering.* This was provided by individual pot drippers controlled automatically (Figure 3). In System B we hand watered up to the stage of potting on. Although we did not feed through the drippers we feel that the greatest advantage

of the dripper system is the ability to do this and therefore gain almost total control over the nutrition of the plant

(iv) *Growing Technique. Poncirus trifoliata* has a short-day photoperiodic response which stimulates leaf abscission and winter dormancy Dormancy was prevented by providing photoperiodic lighting to 18 hours and maintaining a minimum temperature of 15°C. Other citrus rootstocks. while not having this dormancy mechanism. are stimulated to better growth with extended photoperiod (12). Below 15°C the plant will become dormant because the critical daylength is dependent on night temperature. In System B we did not extend the photoperiod because the rootstock was grown during the summer months Maximum growth rate would be achieved if the night minimum was kept at 25°C. but we doubt if this would be economic unless it enabled two batches to be produced each year With System B we potted-on the budded rootstock into 10 liter bags after two months. although we now feel that the seedlings could go straight into bags

(c) **Budding.** This was done as soon as the stock was large enough to take a microbud at a minimum height of 15 cm (13) This was achievable 8 weeks from potting-on of the rootstock seedling in System A. In System B budding was done 4½ months from the first potting Plastic tape was used for tying in the bud. and was removed 12 days later because under greenhouse conditions there is the danger of the bud callusing over if the tape remains for too long. The bud take was at least 95% in all experiments.

(d) **Growing the Budded Stock.** Outgrowth of the "taken" bud is one of the major bottlenecks in the system A number of experiments were carried out to make the bud grow without the need for heading the stock (Table 1) None of the environmental or gibberellic acid treatments caused the buds to grow out quicker A similar experiment using ringing. bending and removal of leaves and apical buds was tried earlier and also failed (5) In System B we deliberately induced dormancy for 7 weeks by turning off the heat and leaving the ventilators open during winter (May and June). This was also economically advantageous as it saved considerable heating costs Upon recommencement of greenhouse heating the stocks were headed and uniform sprouting of the buds occurred We feel that a night temperature below 10°C is needed to predispose the bud to grow out because a period at 15/10°C did not achieve the same effect (Table 1) Perhaps treatment of the scion by defoliating prior to taking the budwood. or treatment of the buds with growth regulators such as cytokinins might achieve a more rapid outgrowth (11). With System A small plants were ready for planting out 8 to 9 months from com-

mencement. These are shown in Figure 4. In System B the greenhouse was evaporatively cooled, but we do not feel that the extra cost can be justified by a small increase in growth. Shading during mid-summer and ample ventilation are necessary to prevent excessively high temperatures, maybe requiring the use of fogging jets.

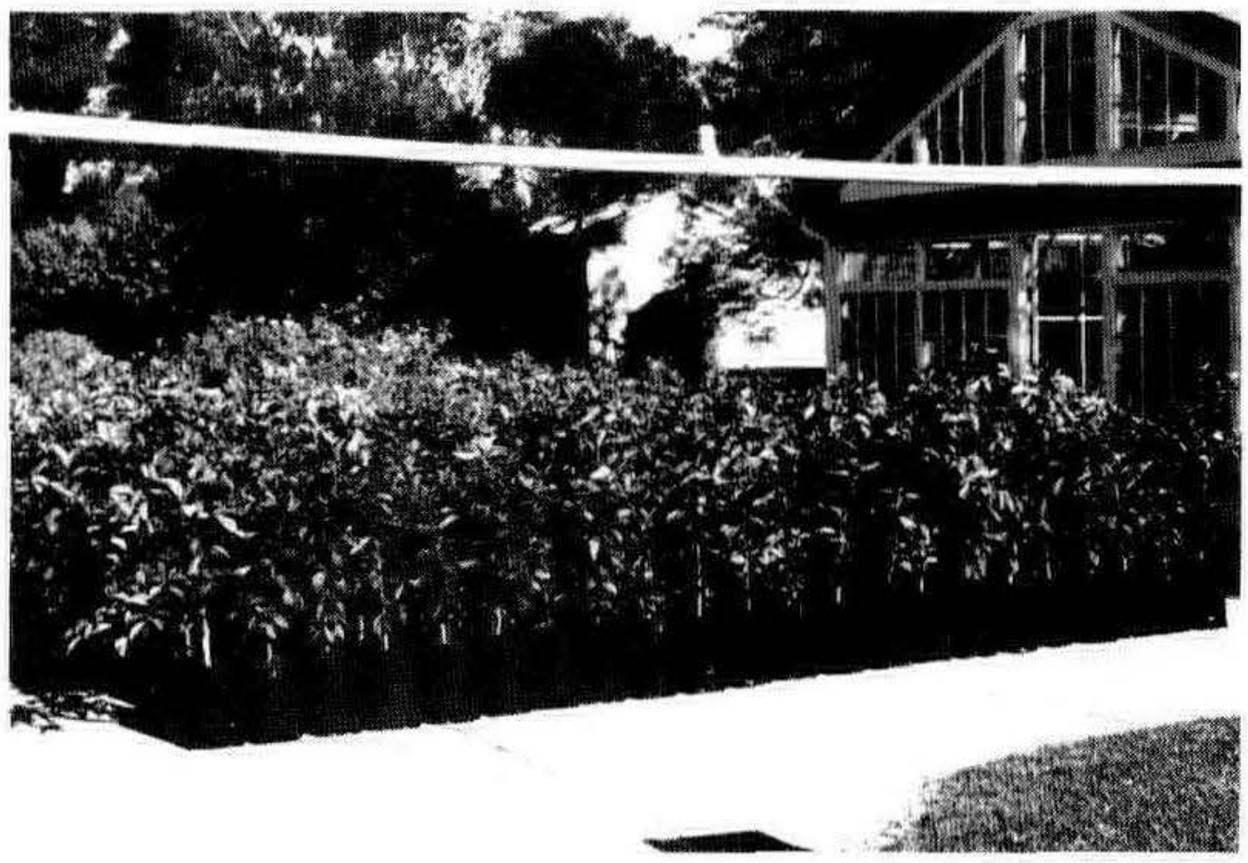

Figure 4. Finished citrus nursery plants in plastic bag containers propagated by System B, standing outside ready for sale.

Table 1. Details of treatments carried out on budded *Poncirus trifoliata* rootstocks to try and accelerate scion growth without the need for heading.

	Initial Treatments			
No.	day/night temp.	photoperiod	Following treatments	Further treatments
	°C	hr		
1	15/10	8	After 4 weeks to 27/22°C	After 4 months
2	15/10	16	with 8 hr photoperiod	foliage lightly trimmed
3	21/16	8		After 5 months, each
4	21/16	16		treatment split — (a) Plants dipped into 100 ppm GA (b) Not dipped
5	27/22	8	After 4 months to 18/13°C	
6	27/22	16	for 6 wks then to 27/22°C with 16 hr photoperiod	After 5 months lightly trimmed

ALTERNATIVE SYSTEMS

In Figure 1 our systems are described along with a few alternatives. There are also some fairly major changes that could be considered:

(a) **Production of Budded Stock in Tubes.** The rootstock could be budded in the tube and upon "take" of the bud could be sold at that stage. This would enable a very rapid turnaround of about 4 to 5 months. As mentioned in the Introduc-

tion, acceptance of such material would depend upon the use by the grower of a controlled irrigation technique where individual trees are watered and receive nutrients. Once the buds have started growth, tubes smaller than 10 cm would need spacing apart and would not be suitable for more advanced plants

(b) **Rootstocks Propagated from Cuttings.** There is some opposition to cuttings as it is believed they do not develop a normal root system, but studies on this have failed to note differences (3), or cuttings yielded better than seedlings (6). The main difficulty is obtaining large quantities of suitable cuttings at the right time. Rootstock material could be budded prior to rooting or afterwards (7). It would be much quicker to bud cuttings at the bench than to bud material in pots or in the field Citrus cuttings take about 6 weeks to root under mist at 30°C We estimate the use of rooted cuttings would save 6 to 8 weeks in our two systems.

(c) **Tip Grafting.** Here a small shoot or actively growing tip is cleft-grafted onto the rootstock, secured with tape or mastic and covered with a plastic envelope under plastic covers and shade (or in a mist propagator) until the graft has taken. It would save considerable time in growing because the stock would not have to be so large for budding, and there is little or no delay in growing out as with a bud. We estimate it would save some two months This technique has been described for use with sour orange rootstock which has a problem in that the bark does not always easily "slip", making budding difficult at times (9), and for other rootstocks (8) The disadvantages of this technique are that it is relatively slow to perform compared with budding, and that the right stage of the stock has to coincide with having suitable material for grafting Budwood trees might have to be pruned to get sufficient material of the right type available in time. Also it uses more budwood material than budding. We think it more profitable to improve the budding technique rather than to develop the micro-grafting method

(d) **Use of Inert Growing Media.** Rootstocks could be grown in rockwool cubes on capillary matting receiving nutrient solutions This would save on containers and make transplanting quicker and easier. Where containers are used with drip irrigation then an inert material (such as crushed scoria) could be used in place of compost and nutrients fed through the drip system

(e) **Use of Hydroponics.** In special circumstances citrus cuttings, rootstocks, or budded rootstocks could be grown using the nutrient film technique, and put into containers later on. We do not know how well such material would transplant

but this method has been mentioned for hardy nursery stock (4). With this technique it is cheap and simple to warm the root-zone and would enable a further improvement in growth rate. This method might be used in the production of disease-free material for export if such a market were created.

ADVANTAGES OF THE CONTAINER SYSTEM

1 The greatest advantage is the avoidance of pests and disease It is possible to propagate virus-free material under our system if required.
2. The time from ordering trees to planting is reduced considerably and it facilitates contract propagation and gives more flexibility to the system.
3. It enables a quicker turnover of stock.
4. It takes up less land.
5. The work, especially budding, is less arduous than in the field
6. Planting material could be produced much cheaper.
7. The container material is easier to plant out and does not receive a check in growth if adequately watered after planting.

DISADVANTAGES

1. Buyer Resistance to Containerised Material. In the Murrumbidgee Irrigation Area, citrus growers do not like using containerised citrus probably because of the use of furrow irrigation One hundred trees produced from system A were planted out in a field situation and did not grow well. This was apparently due to inadequate watering from furrows, and they were not able to use available soil moisture initially. This would have been less of a problem with trees produced in System B which were similar to presently available material, and had a large root volume As mentioned above, small containerized trees (as produced in System A) are most suitable for use where there is drip or micro sprinkler irrigation.
2. The capital cost of producing citrus trees in this way is high.

COST OF THE SYSTEM

We have costed out the two systems:

A, production of small trees in 10 cm tubes in 8 months, and

B, production of larger trees in 10 liter bags in 12 months.

We used a modern glasshouse with piped heat, but feel that the capital cost of this would be too high for this venture. Therefore, we have assumed the use of a 4 m × 20 m double-skinned plastic tunnel, with gas heating and automatic watering. The layout for the System B (10 liter bag) is shown in Figure 5. The tunnel would hold 1140 10 liter bags or 4560 10 cm pots.

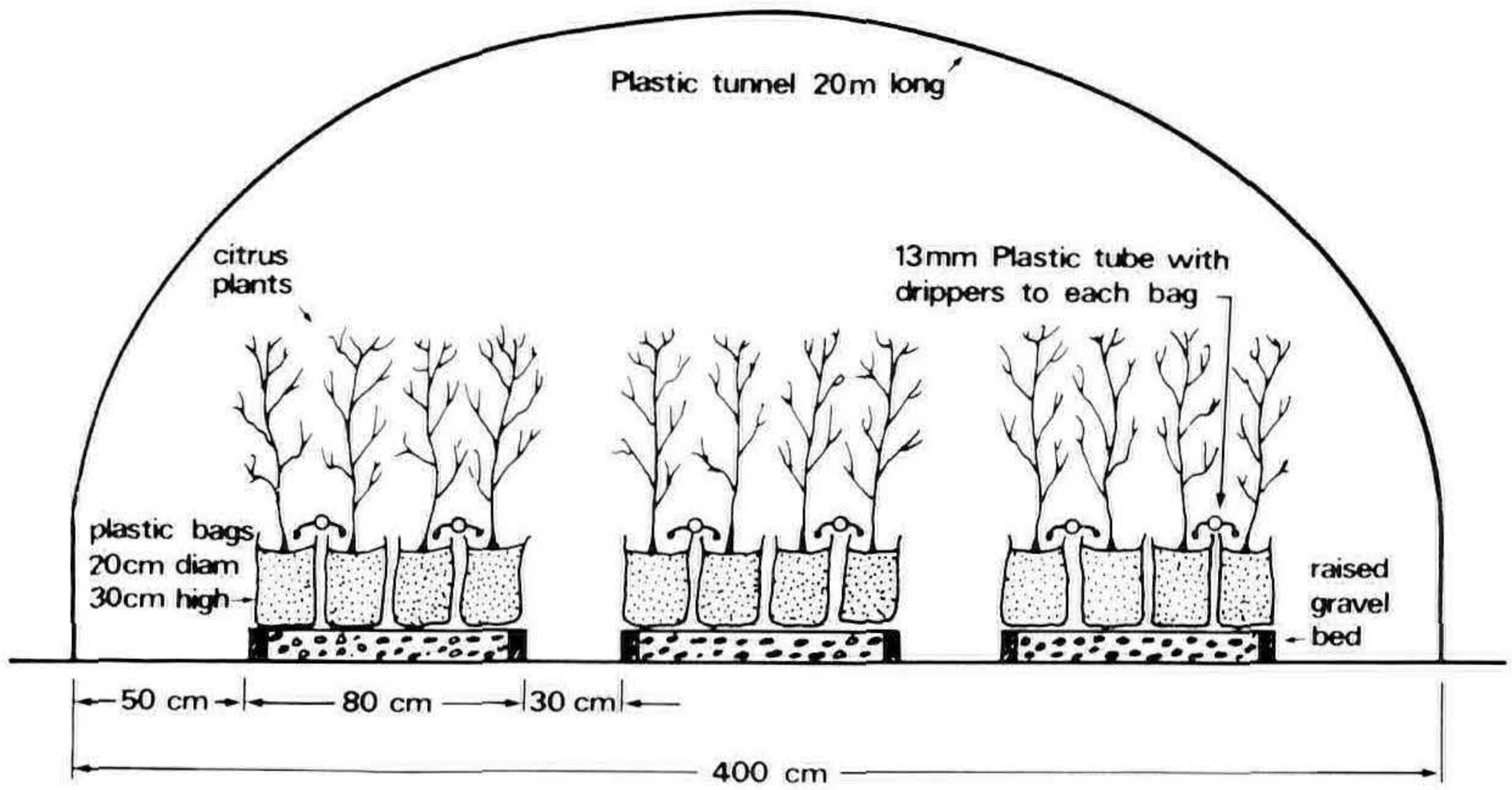

Figure 5. Layout of System B in a plastic tunnel.

The capital cost and depreciation is given in Table 2: depreciation is based on straight line depreciation over 5 years. The outer plastic cover would need to be replaced each year and the inner cover every other year. Indirect costs (Table 3) are based on 12½% interest and 10% land rent on the value of the land plus an estimate for rates.

Table 2. Investment costs of Setting up a Plastic Greenhouse for Citrus Propagation.

Item	Investment Total $	Investment per M² of bed $	Depreciation Total $	Depreciation per M² of bed $
Double-skin plastic greenhouse 4m × 20m	500	10.96	192	4.21
Site works and errection	100	2.19	20	0.44
Raised gravel beds	100	2.19	20	0.44
Gas heater with thermostat	600	13.16	120	2.63
Lights + time Switch + connecting costs, System A only	150	3.29	30	0.66
Irrigation system:				
System A, 4560 pots	2611	57.26	522	11.45
System B, 1140 pots	832	16.25	166	3.64
TOTAL SYSTEM A	4061	89.06	904	19.83
TOTAL SYSTEM B	2132	46.75	518	11.36

Table 3. Indirect Costs for Citrus Propagation Systems per 4m × 20m Plastic Greenhouse

Item	Annual Cost $	Cost per M^2 of bed $
Interest on investment at 12½% System A	495	10 86
System B	254	5.57
Interest on operating costs		
System A, 4560 units for 9 months	465	10 20
System B, 1140 units for 12 months	273	5 99
Land area utilized = 120m² Estimate for rent (10% value of $10,000/ha) plus rates	24	0 53
TOTAL System A	984	21 59
TOTAL System B	551	12 09

Table 4. *Direct Costs Involved in Propagating Citrus in Containers — per 1000 Units*

(a) Seedling Raising

ITEM	COST $
Seed (allow 50% wastage)	10 00
Gibberellic acid treatment	1 00
Containers (Allow 3 years use)	2 70
Medium (sand/peat)	4 00
Labour	3 00
Greenhouse heating to 25°C	2 16
TOTAL	22 86

(b) First Potting

ITEM	COST $ SYSTEM A	COST $ SYSTEM B
10 cm pot or tube (3 years use in B)	65	22
Medium	30	30
Labour	50	140
Greenhouse heating to 15°C	134	16
Greenhouse lighting	30	—
Fertiliser (liquid feed)	60	—
TOTAL	369	208

(c) Budding

ITEM	COST $
Buds	42
Labour	100
Tape	10
TOTAL	152

(d) Growing on (System B)

ITEM	COST $
10 liter plastic bags	150
Medium	300
Labour of potting-on	120
Fertiliser	30
Greenhouse heating (15°C)	386
TOTAL	986

Direct costs for each part of the system are given in Table 4. Labour was costed at $12 per hour and the estimates are based on how long it took us to do the various operations. Heating was calculated for Griffith on the average minimum temperature for each month, heating for the non-daylight hours only and on the use of L.P.G. It may therefore somewhat over-estimate the heating requirements.

Total cost calculations are in Table 5. They do not include a figure for overheads or for management costs The relatively lower cost per unit of system A is due to smaller containers so that four times the number of units occupy the same space. Indirect costs and depreciation account for 40% of the costs and there would be scope for savings in this area. For example, in System A, capillary bed watering would no doubt be more cost effective than drip irrigation. Simple gas burners could be used for heating saving about $500 but there would be less efficient use of gas without a thermostat. If the trees produced from System B sold at $2.80 each, it would give a sales:investment ratio of 1.42. We feel that one person could manage 10 such plastic tunnels with system B which would give approximately $30,300 worth of sales per employee. The profit would be 20% of capital costs.

Table 5. Total Costs Incurred in Propagating Citrus in Containers Excluding Overheads — per 1000 Units

SYSTEM A		
STAGE		*COST $*
Seedling raising		23
Potting-on stage and onwards		369
Budding		152
Indirect Costs		216
Depreciation		198
Allow 5% wastage		48
	TOTAL	1006
SYSTEM B		
STAGE		*COST $*
Seedling raising		23
First potting		208
Budding		152
Growing-on		986
Indirect costs		483
Depreciation		454
Allow 5% Wastage		115
	TOTAL	2421

CONCLUSIONS

1 Aceptable citrus planting material has been economically produced in one year and it has been shown possible to produce material in 8 months at a considerable cost saving.

2. We feel that there is considerable scope for development and improvement of containerized citrus tree production in such areas as.

   (a) A better container, i.e , one that is small enough to improve the density of plants, but not restrict growth. However, at a greater plant density than we achieved with 10 cm tubes, then a cheaper method of automatic watering would have to be used.

   (b) Perhaps the use of budded rootstock-cuttings rather than seedlings.

   (c) Some improvements to the potting medium, such as the use of inert materials

   (d) The initial growth of the bud after it has "taken" needs to be improved.

3. We would like to re-emphasize that developments in the nursery production of citrus requires the adoption of more modern techniques of citrus production in the field, especially closer spacings, and the use of controlled irrigation methods.

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EXPERIENCE WITH SHADE HOUSE CONSTRUCTION USING NEW KNITTED TYPE SHADE CLOTH

WELLS A. EDEN

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There are several different brands and qualities of shade cloth on the Australian market and I have used most of them over the years. It was in late 1978 that the newest type of knitted shade cloth came to my attention and I was quite impressed with its characteristics. These were mainly·

1. The ability of the cloth to be stretched tightly when being fixed to a structure, due to the fact that the fibres are claimed to not be affected by expansion or shrinkage, to any major degree, by weather changes.

2 The cloth which I used was black and was claimed to have a 2% ultra-violet inhibitor built-in (carbon black) which had shown in accelerated tests to lengthen the life span of the cloth by as much as 20%

3. Because of the knitted nature of the cloth it can be cut at random in any direction without the cloth laddering or coming unravelled along the edge

4 The cloth is available in either 6 or 12 foot widths, which gives added advantages on large construction.

5. The knitted pattern allows the effective use of fixing clips of various types without risk of pulling or fraying

In our first application, a retail display shadehouse, the new cloth was used on both the walls and roof of a wooden structure approximately 75′ long by 30′ wide (23 m × 9 m) One third of the roof was covered with 50%, another third with 70%, of the knitted shade cloth, and the remainder with 30% woven cloth. The reason for this was to give varying degrees of shade for the diverse range of plants on display

Knitted shade cloth (50%) was also used around the walls of the structure and, in all areas, was stretched as tight as possible before fixing down with timber battens on the roof and slotted hoop iron around the walls Where necessary, the knitted cloth was cut with a trimming knife around doorways

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and along edges of framework, and the material was not folded or reinforced in any way before being fixed by the batten or hoop iron. The woven 30% cloth was given the normal allowance for 5% shrinkage as suggested by the manufacturer, cut edges being avoided wherever possible, and it was fixed down with timber battens. The area in which our nursery is situated is extremely windy and, therefore, the shade cloth has been subjected to unusually rigorous conditions. This resulted in fatigue and tearing of the woven shade cloth in several places, whereas the knitted cloth has not torn or frayed at any point over a period of 2½ years. I do believe that the combination of the excessive wind and the loose application of the woven shade cloth was responsible for the premature fatigue of the material; however, on the other hand, the knitted cloth was not able to move to any degree in strong winds due to the tension in the fixing. The roof rafters are 3′ (0.9 m) apart for both materials and are fixed with continuous battens. The unsupported area of panel on the walls is 11′6″ (3.5 m) × 5′ (1 52 m), which is completely exposed to the full force of the wind. The knitted cloth has shown no sign of stretch or deterioration under these conditions

The growth of a wide range of plants under this shadecloth has been closely observed and has not shown any appreciable difference in performance under woven shade cloth

In early January, 1981, a much larger shadehouse of 190′ (58 m) × 110′ (33 5 m) was constructed with pipe frame, using 50% knitted shade cloth on both roof and walls To assist with tensioning of the shade cloth, the outer perimeter of the roof structure was braced with a continuous 15″ open web joist welded into the frame horizontally

The roof was constructed of 1″ I D structural steel pipe and the inner member of ¾″ I.D. pipe, with ⅜″ mild steel rod for web bracing

This type of construction allows tension to be applied to the cloth by cable to a tractor or four-wheel-drive vehicle The edges of the cloth were attached to the frame at 12″ centres with a new type of plastic clip having similar design to a nut and bolt with a large mushroom head, and a serrated locking strap for holding down to the pipe.

Internal edges of the shade cloth sheets were joined with flat butterfly plastic clips at 12″ intervals after tensioning.

The construction has proved very successful so far in the short time since it was finished. as it has withstood some very extreme storms and high winds without any sign of damage

There seems to be considerable controversy among the sales staff marketing the various types of cloth. with claims

and criticisms as to the quality and expected performance of the knitted shade cloth. There have been claims that the method of knitting creates sharp bends and tension on the yarn which will lead to early fatigue of the cloth and consequent breakdown of the fibre thread. However, my experience to date, although possibly a little premature, does not give me any indication of this claim being true The manufacturer claims that the product is made from high density polyethylene which, after ageing, exhibits more resiliency and less tendency towards brittleness of the fibre threads than does polypropylene from which some other shade cloths are made.

MASS PRODUCTION OF EUCALYPTUS SEEDLINGS BY DIRECT SOWING METHOD

FRANZ GROSSBECHLER

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INTRODUCTION

The tremendous growth rate of the city of Canberra during the sixties and early seventies brought an increased demand for inexpensive eucalyptus seedlings to be used in large landscaping and forward planting projects.

The time-honoured method in which seeds were sown in trays and the seedlings pricked off into another container tied up considerable labour and took six to nine months before the expensive seedlings were ready for planting. This prompted us to perfect a method of direct sowing into inexpensive throw-away polythene tubes packed into reusable wire baskets. Twenty-five tubes fit into a basket of 30 cm × 30 cm

Handling is reduced to a minimum by direct sowing into the tubes containing the growing medium By using a balanced soil and nutrient mix we are able to produce 47 species of eucalyptus, (Appendix A) grown to a saleable size in about three months. By using heated glasshouses for the five cold months we can produce four crops each year.

Container. The throw-away container is a thin, ultra-high-impact black polythene tube 200 × 50 × 50 mm with eight 25 *mm slits 20 mm from the base of the empty tube. The material* is 50 microns thick. Each tube costs approximately one cent and contains approximately 547 cm^3 of soil with an average weight of 705 g. when filled with moist soil.

Growing Medium. The medium is a modified U.C. (University of California) type mixture of 30 to 40% Australian

and criticisms as to the quality and expected performance of the knitted shade cloth. There have been claims that the method of knitting creates sharp bends and tension on the yarn which will lead to early fatigue of the cloth and consequent breakdown of the fibre thread. However, my experience to date, although possibly a little premature, does not give me any indication of this claim being true The manufacturer claims that the product is made from high density polyethylene which, after ageing, exhibits more resiliency and less tendency towards brittleness of the fibre threads than does polypropylene from which some other shade cloths are made.

MASS PRODUCTION OF EUCALYPTUS SEEDLINGS BY DIRECT SOWING METHOD

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INTRODUCTION

The tremendous growth rate of the city of Canberra during the sixties and early seventies brought an increased demand for inexpensive eucalyptus seedlings to be used in large landscaping and forward planting projects.

The time-honoured method in which seeds were sown in trays and the seedlings pricked off into another container tied up considerable labour and took six to nine months before the expensive seedlings were ready for planting. This prompted us to perfect a method of direct sowing into inexpensive throw-away polythene tubes packed into reusable wire baskets. Twenty-five tubes fit into a basket of 30 cm × 30 cm

Handling is reduced to a minimum by direct sowing into the tubes containing the growing medium By using a balanced soil and nutrient mix we are able to produce 47 species of eucalyptus, (Appendix A) grown to a saleable size in about three months. By using heated glasshouses for the five cold months we can produce four crops each year.

Container. The throw-away container is a thin, ultra-high-impact black polythene tube 200 × 50 × 50 mm with eight 25 *mm slits 20 mm from the base of the empty tube. The material* is 50 microns thick. Each tube costs approximately one cent and contains approximately 547 cm^3 of soil with an average weight of 705 g. when filled with moist soil.

Growing Medium. The medium is a modified U.C. (University of California) type mixture of 30 to 40% Australian

peat plus 60 to 70% coarse washed river sand Fertiliser is added to each m^3 of soil as follows:

Blood and bone	1,153 g
Calcium carbonate	789 g
Superphosphate	1,057 g
Potassium nitrate	102 g
Potassium sulphate	111 g

The sand, peat and fertiliser is mixed for one minute in a large industrial type concrete mixer and transferred to a portable 1 53m^3 capacity steam sterilising trolley. The trolleys are covered with a tarpaulin and steamed with aerated stem at 63°C for 20 minutes then cooled down by the injection of cold air, pH tests are carried out for each new batch of peat and the pH is adjusted to around 6.5 by increasing or decreasing the calcium carbonate added to the mixture.

Filling of Containers. To minimise handling cost and to reduce the possibility of contamination of soil with plant pathogens, the polythene bags are filled directly from the mobile, bench-high steam trolleys Filling is carried out with the aid of a tapered spout funnel and the filled bags are then stacked into wire baskets

Bulk Handling Baskets. These are constructed from galvanised A R C 2 5 cm × 2.5 cm grid, 2 mm gauge Weldmesh, 30 cm × 30 cm × 13 cm deep holding 25 filled black polythene bags The baskets are reusable and last up to four years

The baskets when filled with bags are transported to their final growing site, where they are stacked in rows of three wide for easy access for sowing, watering, and other maintenance work required To discourage roots from growing into the base, the baskets sit on 25 mm × 25 mm laths.

Seed Source. To ensure a reliable seed supply we collect our own. Seeds of species growing within a 300 km radius are collected from trees growing naturally in the wild Seeds of other species are purchased from seed merchants. As a rule we do not collect seeds from local planted species as there is always a danger of hybridisation. Once extracted, the seed is thoroughly dried and stored in glass bottles in a seed storeroom at a constant temperature of 20°C.

Sowing. Seeds are direct sown into the containers at their final site and are not handled again until dispatched for planting. Sowing is done by making a shallow thumb depression in the middle of the container in which a small quantity of seed

is placed by hand and covered up with sterile sand/perlite mixture.

Since eucalyptus seeds contain a large percentage of unfertilised ovules (called chaff) and the good seed is, in some species, indistinguishable from chaff, it is essential to place enough seeds in each container to get more than one seedling on germination Excess seedlings are cut off with a pair of scissors at the first leaf stage and only the strongest seedling remains.

Of the 47 species used only *E. dives* and *E niphophila* need cold stratification to break seed dormancy. In *E. pauciflora*, only old seed needs such treatment Germination takes place after 10 to 14 days.

During spring and summer, sowing is done in the open and the baskets are put on decomposed granite standing areas with rows of 25 mm × 25 mm timber laths to prevent plants rooting into the ground. No shading is necessary. Sowing during the hottest summer months to December and January is avoided, as shading may be required during the germination period.

During the winter months crops are raised in glasshouses under clear glass for maximum light. Night temperatures of 18°C and day temperature of about 25°C are provided

Watering. During the germination period the seedlings are lightly watered by hand with a fine rose spray once or twice a day depending on the day temperatures and evaporation rate. Once the seedlings have reached the one to two leaf stage, when the roots have penetrated deeper into the soil, watering is carried out by overhead sprinklers or by subirrigation if bays are provided. When grown in glasshouses, crops are hand-watered.

Follow Up Fertilising. The initial nutrients incorporated in the soil last only approximately six weeks, after which weekly applications of 0.1% liquid Aquasol are required or one application of dry broadcast of 10.9:8 at the rate of 12.5 g per basket or 0.5 g per tube.

Plants grown in glasshouses during winter are hardened off for a week in the open before going out into the field. A 30% shade cloth protection is provided for the hardening-off period None of the species have been frost-affected to date.

About three months from the time of sowing all medium to fast growing species have reached 30 to 50 cm in height and are suitable as planting stock for plantation and shelter belt planting Slow growing species might require an additional 14 days growing period before reaching the required planting height

Up to 150,000 eucalyptus seedlings are raised annually by this method with up to 20,000 or more plants of some species

An advantage of using this fairly large size tube is that plants not required immediately may be held for up to 12 months in the nursery. Growth can be checked by withholding fertiliser and, once applied again, growth resumes immediately, apparently without any undesirable effect

Pests and Diseases. Diseases are rare and only powdery mildew and *Botrytis cinerea* have occasionally been found on seedlings when grown under low light in glasshouses in winter, or during long wet spells during spring or summer. Effective control is achieved with TMTD and Karathane.

Pests are more prevalent, particularly sap-sucking psilids and the painted apple moth (*Orgyia anartoides*). These are controlled with application of Malathion or Carbaryl when the pests appear.

This method of direct sowing into containers is not restricted to eucalyptus but is also used for other native genera, such as *Acacia*, *Banksia*, *Hakea*, *Melaleuca*, *Callistemon*, exotic species such as *Quercus*, *Ulmus*, *Pyracantha*, *Picea*, *Liquidambar* and *Pinus*, just to mention a few In general, any species in which good germination is expected are propagated by this method, but in larger containers if larger plants are desired.

Appendix A. Eucalyptus Species Grown by the Direct Sowing Method

E acaciaeformis
E aggregata
E albens
E alpina
E andreana (E elata)
E blakelyi
E bridgesiana
E camphora
E cinerea
E coccifera
E crenulata
E dives
E glaucescens
E globulus subsp bicostata
E goniocalyx
E gregsoniana
E kybeanensis
E leucoxylon
E linearis
E macarthurii
E macrorhyncha
E maidenii
E mannifera subsp maculosa
E melliodora
E moorei
E nicholii
E niphophila
E nitens
E nortonii
E olsonii
E ovata
E parvifolia
E pauciflora
E perriniana
E polyanthemos
E pulverulenta
E radiata
E risdonii
E rodwayi (E aggregata)
E rosii
E rubida
E scoparia
E sideroxylon
E sieberi
E stellulata
E subcrenulata
E viminalis

HYGIENE IN THE NURSERY

NEV HIGGS

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Hygiene is one of the most important parts of plant production. It is so easy for us to pick up the phone and order chemicals to cure our ills in the nursery, but I am sure it is much better and cheaper to resolve this before it starts. That is, to look toward prevention rather than cure This of course falls into basic areas — Why — and — How.

The question of why we should be concerned with plant hygiene is really the first and most important area that any propagator should be concerned with. Without a proper understanding of its necessity by both management and staff, no hygienic programs can be successfully introduced. The key words for this area which relate to the overall topic, are *education* and *awareness*.

A good example of the futility of one without the other, happened recently in the nursery. A young lad was taken on just after he had attended a Horticultural Refresher course, a good part of which did emphasize various aspects of hygiene. On this particular day, he had been walking through several sections, over both concrete paths and some soil areas. In seeking further information about a particular job, he walked up to his supervisor, and while asking about the job, put one of his boots up on a low bench that had just been sterilized ready to receive a new batch of African violets. He had some education which is a first must, but he had fallen down in its application.

In most cases in a nursery, hygiene falls down through:

1 A lack of understanding why, which is education.

2. Thoughtlessness, which is continuing awareness.

3. Straight-out laziness.

In each of these, management can be just as much at fault as the staff. For a commercial grower, the number one reason why we must give hygiene first place in our culture practises, is, when its all said and done, a dollars reason. What might initially appear to be a waste of time and money in establishing a good hygienic system will, in the long term, save many thousands of dollars. For what must never be forgotten is that although poor hygiene can cost a nursery dearly when large losses are incurred, there is a much more important and far reaching loss and effect. That is, when diseased plants, whether the disease is obvious or suppressed, are sold to the con-

sumer. For where this happens, a retail and general consumer backlash can develop that no only affects the original supplier but also hurts other innocent growers and the trade as a whole.

This is one of the most important points of education. For only when this is fully realised and appreciated, can the actual implementation of a hygienic system begin. And then, when we break any good system down and analyse it, its only common sense anyway.

Education then must start with management, the implementation and enforcing of hygienic practices then becoming a continuing daily aspect of good management. Thoughtlessness or a lack of awareness by staff, although in part their own fault, generally always comes back to the management or supervisors.

Straight out laziness is a common problem, that only a firm hand will correct. Cutting corners is a variation of this, again done by both management and staff, which, if done when a full hygiene programme has been in hand, completely wastes all effort, time, and money spent on that programme to that point of time, and into the future. There are many examples of cutting corners that could be quoted, but probably the most prevalent ones would be when excessive quantities of cuttings or plants are programmed for a day, when one is running short on supplying a specific quantity that one does not feel he can afford to fall down on, and when cramming occurs. When problems do arise in a crop that is for general sale, or pre-sold, or being promoted, keeping in mind the long term and far reaching effect that diseased plants can have when moved into retail, one must be frank and take the bull by the horns, clean up, suffering the loss as the only responsible action one can take.

I will now consider the second aspect of how this is achieved.

As always hygiene must start with the mother or stock plants Too often these are left in areas less accessible for easy maintenance Also, there are often slip-ups in controlling excessive growth, which reduces ventilation and penetration of preventive disease controls, and becomes a perfect breeding ground for disease. Method of watering is also very important, with many diseases being spread by water splash. So when cuttings are taken off stock plants, it is always very important to take them well above ground level, or above the water splash line. Trickle irrigation in preference to overhead irrigation is an obvious means of preventing these sort of problems, when in a roofed house situation.

On taking the cuttings, the next most important aspect has to be observed. It is one that we all have fallen down on at some stage, and that is, the continuous sterilization of our cutting tools Whether they be knives, blades, secateurs, scissors or whatever, they should always be at least doubled up on, with the spare one soaking in a sterilant solution, with only a small number of cuttings being taken with a tool, before replacing it with a sterilised tool. By changing over at regular intervals, the transmission of any disease from one to the next is greatly minimised, overcoming a problem that has been very evident in a variety of plants grown throughout Australia in the last 12 to 18 months

Of course it is very easy for anyone to talk about how things should be. So what if we are getting diseases through our cutting batches, or even if it is only being manifested later on in the adult plant stage. This is where records become a very important part of hygiene and disease control. Where there is a problem, each small batch of stock plants, or better still, every stock plant should be numbered, and the cuttings coming off each numbered batch, also identified. This batch number must be carried right through to adult plants, if that is when the disease is manifesting itself, so that when the disease does show up, those original mother or stock plants can be identified and removed.

Even generally, accurate concise records are a must if trends such as lowering percentage strikes, etc , are to be picked up. Yes, there is a lot more effort involved, but when we do find a drop off we must take stock of ourselves and our systems, and clean up and straighten up Lets face it, we are only human. Many will always say it is expensive but really, as I have personally found, the results always exceed the cost

We next come to the propagation working areas, especially the benches. These must be regularly washed down with a sterilant. Once a day even is of no real practical advantage. It should be done between each batch of plants during the course of the day, so as to effectively reduce any carry over of disease.

It follows, of course, in any good hygienic system, that no contact with the floor or possible contaminated objects or areas is made with any items used directly or indirectly with plant propagation and production in general. All items used must be guaranteed clean or sterilized.

Several points that come to mind that are often overlooked are water supply and contamination through dust and water drip.

Clean water is essential for good plant management. Even

with most town water supplies, it is often necessary to use filtration systems to take out algae and other organisms. This can be achieved through a series of special microfilters or sand filters. Also, separately or in conjunction with, chlorination injection can be used to assist in control.

Contamination through dust being sucked in through fan ventilation systems, and then settling on plants, is also a very important aspect too often neglected when problems arise Ventilation duct systems can hold quite a residue of contaminated dust that can be dispersed over a greater period of time.

Contamination from condensation taking place, and water dripping from the roof and purlins, can often be a factor in disease spread as well. Control for these is much more difficult, extra ventilation being one of the few means of overcoming condensation.

It is always amazing how quickly disease can spread from such contamination points, wiping out big areas if daily checks, which should be a normal part of good management, are not made, and immediate remedial steps undertaken.

OPEN GROUND VS. CONTAINER-GROWN CITRUS

GARY R. EYLES

A.T. Eyles & Sons Citrus Nursery
Kenthurst, New South Wales

"You'll never change an old field grower to growing in containers."

I have heard that comment made on any number of occasions It is difficult to change from something you know well and which, in our case, has been a successful practice for over 60 years. This paper is a brief description of how we have begun the change to container growing of citrus.

For many years citrus in the Sydney area has been grown in the field to a stage of one full season's growth after budding. They are then pruned back significantly and dug bare-root They are sold to orchardists or retailers, in the latter case they need to be placed in a "heeling in" bed, or grown-on in containers for another season and then sold as an "advanced" or three-year-old tree.

A T Eyles and Son were and still are involved in growing the tree to the two-year-old stage in the field. It is now felt, however, that a tree could be grown in a container in two years that would compete favourably with the three-year-old tree containerised after being transplanted from the field.

The system being developed for container-growing differs little from previous practice in the field.

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The system being developed for container-growing differs little from previous practice in the field.

For cultivating field citrus, rootstocks were grown in a seed-bed, dug in early spring and planted out in rows. These would then be grown on and autumn-budded. The following spring they are cut down, trained and grown on the following season. The next spring they are dug out and sold bare-rooted — that is, two years after planting out from the seed-bed.

For container growing, rootstocks from the seed-bed are still used Experiments have been made this year with some rootstocks grown in seven-inch "root-trainers" inside a poly-house. The advantage here is the minimal disturbance to the root system in transplanting.

Rootstocks planted in the "root-trainers" have shown good growth but seed germination was very poor; this aspect will need improvement before poly-house propagation can provide a reliable alternative to the seed-bed

The bare-rooted rootstocks from the seed-bed transplanted to containers up to date have had their tap roots cut and have been pruned back. They are planted in 15 litre bags in spring. The nursery work schedule is such that it is more efficient to have filled and positioned the bags some time previously Originally the bags were filled by hand, lately a front end loader has been used

Budded in autumn, the rootstocks are cut down in spring, grown and trained into trees and sold starting the end of the following summer. All trees are staked and topped at about 15 inches from the soil level. Four or five branches are kept to form the head of the tree, as was the case with field-grown trees.

Container-grown trees begin to grow after the winter dormancy more quickly than field trees. This may account for the overall accelerated growth rate of container trees compared to field trees. Container trees have been topped this past year in mid-spring, at least a month earlier than their counterparts in the field. By late summer there is a good head on container trees which is left untouched, whereas the growth on field trees is cut back to ensure their survival

Containerisation seems to promote a greater production of fibrous roots than field growth, and this good root system need not be disturbed when the tree is transplanted

Fertilization of the tree varies with the two methods of growing In the field a complete fertilizer along with organic fertilizer are used Slow-release fertilizer was never used. Containerisation requires great care in the use of any feed that released immediately.

Slow-release fertilizer with its even supply of nutrients is ideal, and has the added benefit of one application lasting several months An organic feed is employed, primarily to act as a mulch on the surface of the container

Watering is done by overhead sprinklers which, while watering the plants sufficiently, does have some disadvantages. The space between the rows of containers and the foliage they develop before sale means that the majority of the water is wasted. Sprinklers in the field water the whole bed area evenly so in that situation sprinklers are appropriate. A drip system is to be given a trial and the results compared with the overhead sprinkler operation. While water consumption should be much less it remains to be seen if the drip system can provide sufficient moisture to carry nutrients through the soil in the container.

Weed control in the containers has proven to be much less of a problem than open-field cultivation. The great care required in the application of chemical weedicides, the necessity for several applications, combined with hand weeding which was the practice in the field, has been replaced by the application of a knock-down weedicide to the containers prior to planting to eradicate any weeds growing in the soil mix, followed by hand weeding if necessary.

Containerisation has many advantages over field growing of citrus during the growth stages, and for plant management. A major factor in favour of field-grown trees remains however. As transport costs continue to escalate it is important to take acocunt of the ease and cheapness of transporting bare-rooted trees. Packed in rice straw and moistened, 100 per carton, free of the bulk and weight of container and soil, field-grown trees last for at least two weeks unattended, and have been successfully transplanted after four weeks when shipments have been held up by industrial action.

It seems that transport considerations aside, the advantages of the container-grown tree do outweigh those of the bare rooted product,

1) little disturbance of the root system on transplanting,

2) no need for pruning,

3) no need to search out arable land for cultivation,

4) easier maintenance with fertilization and weeding

The results obtained from container-based propagation so far justify the prediction that a two-year-old container citrus tree can compete adequately with those grown in open ground to be "grown on" in a container for a third year

THE INFLUENCE OF AUXINS AND MINERALS ON ROOT MORPHOGENESIS OF *EUCALYPTUS FICIFOLIA* F. MUELL *IN VITRO*

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Abstract. When several auxins were tested individually in the rooting medium of seedling cultures of *Eucalyptus ficifolia* distinct differences were found in root morphology and were linked to auxin structure Auxins having a phenolic oxygen between the aromatic ring and the side chain induced callus formation, whereas auxins without this oxygen promoted the development of a good root system Within this last category, however, different auxins gave rise to distinct root systems

Several nutrient groups were also tested in a rooting medium containing indole-3-butyric acid (IBA) as the only auxin and there was an interaction between the nutrients and IBA

INTRODUCTION

Morphogenesis, the origin of form, is a little understood phenomenon, which even recent advances in biochemical techniques and increased knowledge at the molecular and genetic levels, have failed to explain. Ultimately, an understanding of morphogenesis must involve a synthesis of all the individual details of plant function but at this level too, there are still large gaps in our knowledge, and much basic research is required.

The tissue culture system provides a unique opportunity for studying many aspects of plant growth and development under well-defined conditions In particular it should be exploited much further in studying the effect of various growth substances on morphology In recent years, there has been considerable research into plant cell cultures and concomitant genetic manipulation. The progress made, in terms of being able to achieve an end product, i.e. a whole plant from a single cell, has been disappointingly slow, and there is an increasing realization that a better understanding of plant developmental biology, through basic tissue culture study, is vital to the success of applied levels of research (4)

In this paper, a small aspect of plant development — the differentiation of roots at a macroscopic level — is discussed. The study is not definitive, it serves to emphasise the importance of cooperation between workers in the areas of plant physiology and biochemistry

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The work described here, follows on from a project commenced in 1976 designed to devise a suitable tissue culture method for the propagation of *E. ficifolia*. The basic principle applied to the initial research was that founded upon the Broad Spectrum experiment (5,10). The objective was to find a particular combination of the interacting categories and concentrations for use as a basal medium, suitable to achieve a particular response, e.g. callus, multiplication, rooting. Experimentation was then done to define specific constituents in the basal medium which were important to the achievement of the desired response.

The research on seedling cultured material was in its final stages, when, in large experiments with individual growth factors (6,8), the significance of riboflavin, especially in relation to the rooting response of cultures, was first discovered under light incubation. The presence of riboflavin in the culture medium, led to the development of a root system in which there were one to three, occasionally more, long, subsurface roots with short or no laterals, callus development at the base of the cultures was minimal. In comparison, absence of riboflavin led to the development of a root system in which there were many short roots and teratomas, associated with fairly heavy callusing, there was a tendency for the roots to grow close to, or on, the surface of the medium. Under dark incubation, the presence of riboflavin had no effect. Subsequent experimentation (15) to determine which constituents of the medium were affecting the rooting response, showed that riboflavin and indole-3-butyric acid (IBA), were linked in a distinct riboflavin-induced change in root morphology, in the light.

When activated by visible light, riboflavin gains a high oxidising potential, and reduced riboflavin, resulting from the oxidation of organic substances, can be readily re-oxidised by oxygen (12), thus having a role analogous to the one it plays in respiration. It has long been known that riboflavin can sensitize the degradation of indole-3-acetic acid (IAA) (1,11,12,13,14). It has also been reported to sensitize the degradation of 2-4-dichlorophenoxyacetic acid (2,4-D) (3), and α-naphthaleneacetic acid (α-NAA) (16), and it would thus seem reasonable to assume that a similar degradation was occurring with IBA

The results of the experiment to determine which constituents of the culture medium were affecting the rooting response, suggested two interesting avenues for further experimentation. a) to examine the effect of riboflavin together with other auxins, on root formation, b) to examine the interaction between riboflavin, IBA, and minerals on root formation.

MATERIALS AND METHODS

Plant material. The methods used to initiate and develop seedling cultures, have been described previously (2,6,7,9). The seedlings were repeatedly subcultured at approximately two month intervals over a four year period on the multiplication medium (6). Cultures were maintained in a Sherer growth cabinet (25 ± 2°C, 12 h photoperiod supplied by Powertube cool white fluorescent lights of approximately 20 $\mu Em^{-2}s^{-1}$). They were grown in UC30P polycarbonate tubes fitted with polypropylene screw-on lids, and containing 10 ml of medium, sterilized at 121°C and 104 kPa, for 20 min

Experimental media: The constituents of the rooting medium are given in Table 1. Deletions and additions to this medium were made according to the nature of individual experiments.

Experimental media were prepared in subdued light, and stored no longer than 24 h prior to use, in darkness. Explants, which consisted of 1 cm long shoot tips with several nodes, were transferred from the multiplication medium to the experimental media in a darkened room, with a small point light source, to illuminate the working area. Such precautions prevented the breakdown of riboflavin and any light-stimulated reactions between riboflavin and other constituents of the media.

(i) Auxin experiment.

The basal medium was that described in Table 1, except that various auxins were substituted for IBA. The auxin treatments were as follows*:

No auxins, six auxins (IAA, IBA, α-NAA, β-NOA, pCPA, 2,4-D), each at 5 μM. These are the components of the auxin category of the Broad Spectrum (BS) experiment; 5 μM of the following auxins tested individually, IBA, IAA, pCPA, 2,4-D, β-NOA, α-NAA, β-NAA, IPropA, IPyrA, 2,4,5-T.

Each of these auxins was tested in the presence and absence of 10 μM riboflavin, thus giving a total of 12 × 2 = 24 treatments Ten replicates of each treatment were incubated in the dark, and ten were given a 24 h exposure to light of approximately 110 $\mu Em^{-2}s^{-1}$, supplied by 40 W Sieray white fluorescent lights These replicates were then transferred to dark incubation. The cultures were examined after a total incubation period of 34 days.

* The following abbreviations, not already defined were used β-NOA — β-naphthoxyacetic acid, pCPA — p-chlorophenoxy-acetic acid, IPropA — indole-3-propionic acid, IPyrA — indole-3-pyruvic acid, 2,4,5-T — 2,4,5-trichlorophenoxyacetic acid

(ii) IBA/Mineral experiment

The basal medium was that described in Table 1; except that macro- and micronutrients were tested in the groups indicated in Table 1 as follows:

No macro- and micronutrients; Groups 1-5; Group 1; Group 2; Group 3; Group 4; Group 5.

Each of the mineral groupings was tested in the presence and absence of 5 μM IBA and 10 μM riboflavin, thus giving a total of $7 \times 2 \times 2 = 28$ treatments. There were ten replicates and all cultures were given a 24 h exposure to light before dark incubation. The cultures were examined after a total incubation period of 34 days.

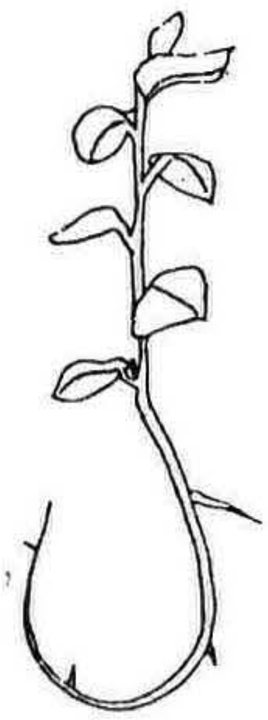
RESULTS

(i) Auxin experiment

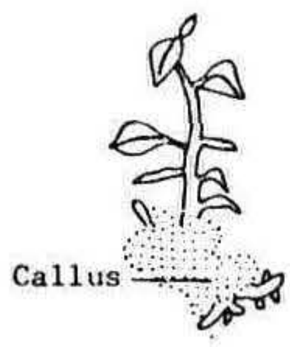
The effects of the individual auxin treatments, in the absence of riboflavin, in the light and the dark, are represented in Figure 1. In the absence of auxins, the percentage of explants forming roots was low (approximately 50%), and the root system was characterized by the appearance of one or two long roots with some lateral development; there was little or no callus; β-NAA, α-NAA, IPropA and IPyrA generally, encouraged 100% rooting of explants and the root system consisted of two or three long roots with fairly extensive lateral development.

All explants on a medium containing IBA, produced a root system consisting of many short roots, with extensive lateral development and a tendency for abundant root hairs, where roots had not penetrated the medium; IAA also caused a rather "stunted" root system to develop (in 100% of explants), but lateral development was minimal. It is interesting to note the difference in the root systems formed by IBA, IAA and IPropA. These three homologous auxins differ only in the number of CH_2 groups in the side chain and yet produced three distinct responses.

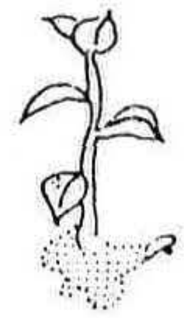
In the case of 2,4-D, 2,4,5-T, pCPA, β-NOA and the six BS auxins, 100% of explants produced a mass of basal, nodular callus, which occasionally developed teratomas (root-like extrusions) The addition of riboflavin to the medium had no effect on cultures incubated in the dark. However, with the exposure to light, cultures containing pCPA, β-NOA, β-NAA, α-NAA, IBA, IAA, IPropA, or IPyrA, produced a root system identical with that formed on cultures in a medium without any auxins; i.e. these auxins appeared to be inactivated in the presence of riboflavin in the light The riboflavin/light interaction caused a reduction in callus in cultures on a medium

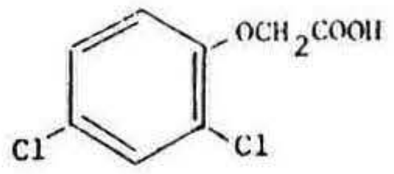


NO AUXINS

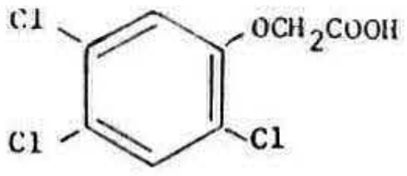


SIX BS AUXINS





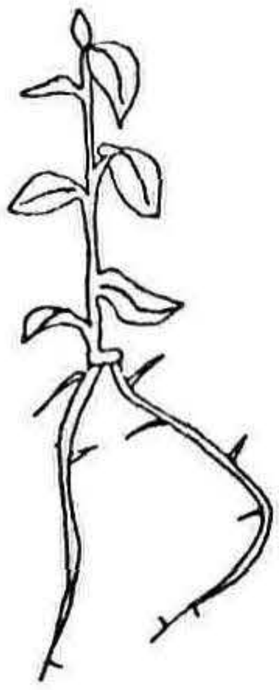
2,4-D



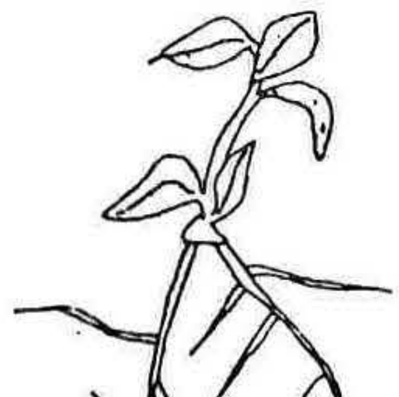
2,4,5-T

pCPA

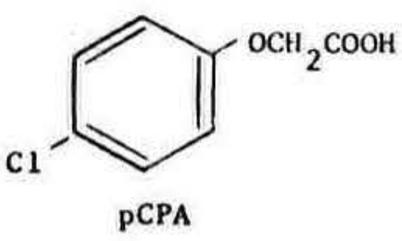
β-NOA



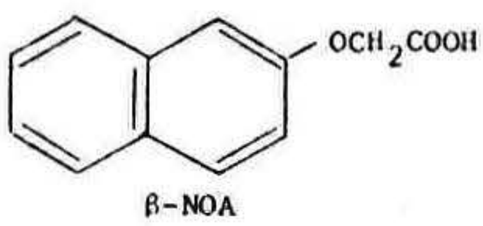
β-NAA



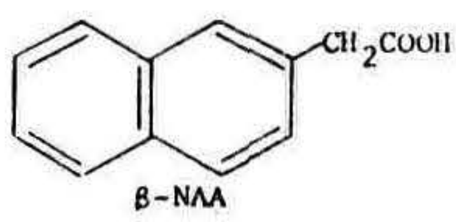
α-NAA



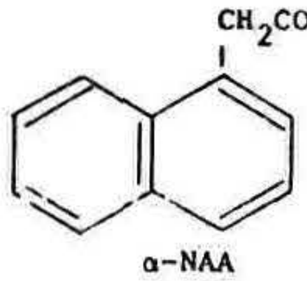
IBA



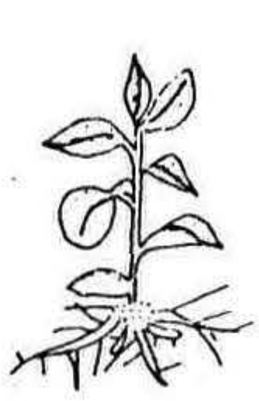
IAA



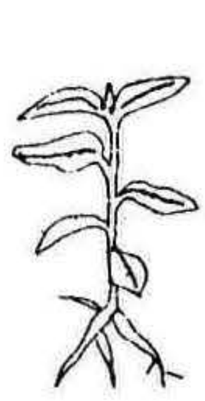
IPropA



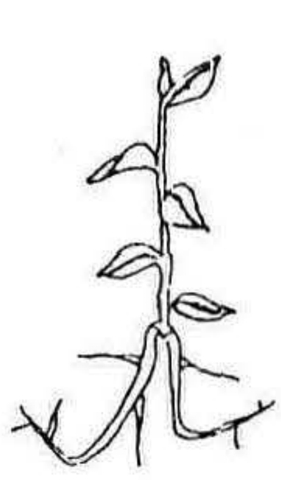
α-NAA



IBA



IAA



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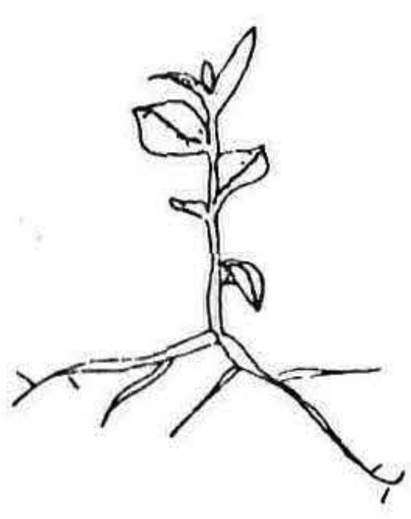
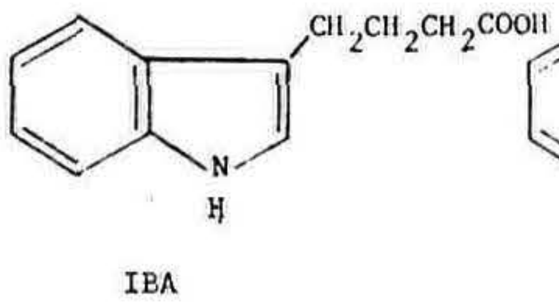


IPyrA



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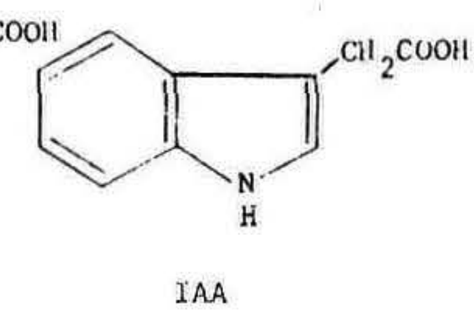
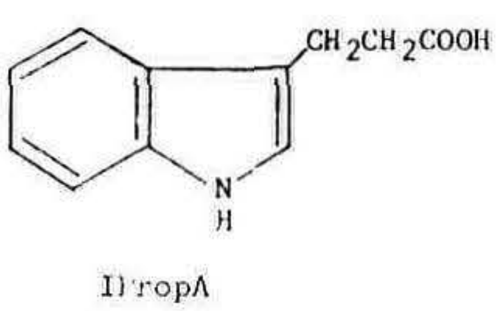


IAA



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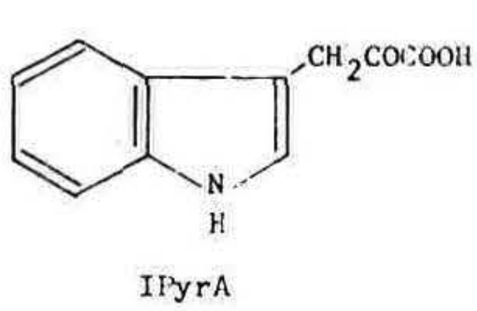

IPyrA

Figure 1. The effect of individual auxins in the rooting medium on root morphology of seedling shoot tip cultures. These results were obtained in the light and in the dark when riboflavin was excluded from the medium. The six BS auxins are IBA, IAA, α-NOA, pCPA and 2,4-D.

containing 2,4-D, and short, thick roots were formed. Explants on media containing 2,4,5-T or the six BS auxins were unaffected by the presence of riboflavin in the light.

The most obvious point emerging from the experiment in terms of the effects of individual auxins, is that auxins containing a phenolic oxygen cause the formation of heavy callus and few or no roots This point is brought home dramatically in the comparison of the effects of β-NONA and β-NAA; there are two entirely different responses in the explants and yet the only difference between the auxins is in the oxygen link.

It would be interesting to test α-NOA which differs from α-NAA only in having a phenolic oxygen If the conclusion about structure and plant response holds true, one would expect the α-NOA to give a similar response to β-NOA.

(ii) IBA/Mineral experiment

The effects of individual treatments in the absence of riboflavin, are represented in Figure 2. It can be seen that in the absence of minerals and auxins, explants produced a root system identical to that described in the Auxin experiment for explants on the treatment without auxins, i.e. one or two long roots with some lateral development and little or no callus. Interestingly, this root system type appeared in all the mineral treatments where IBA was excluded from the medium (either in the presence or absence of riboflavin), or where IBA and riboflavin were present together, i.e. by themselves, individual nutrients did not affect morphogenesis.

In the presence of IBA, there were distinct morphogenetic responses to individual nutrients Explants on media containing no minerals, NaH_2PO_4, or KCl + $CaCl_2$, produced similar root systems, i.e. short, thick roots with fairly well developed laterals, with NH_4NO_3 + $MgSO_4$ present in the medium, explants produced a mass of very short roots — almost teratomas, $FeSO_4$ + Na_2EDTA, led to the formation of two or three long roots covered in a mass of very short laterals, and the remaining micronutrients (Group 4), gave a similar response although lateral development was not as pronounced.

DISCUSSION

The aims of the two experiments were to look at the effects of the riboflavin/light/auxin interaction on root morphogenesis and to this end, it has been shown that riboflavin caused inactivation of all the auxins tested, with the exception of 2,4,5-T and, to some extent, 2,4-D It is interesting that the two other callus promoting auxins, pCPA and β-NOA, were inactivated by riboflavin; the reasons for this difference need to be sought at the biochemical level. The incidental but more

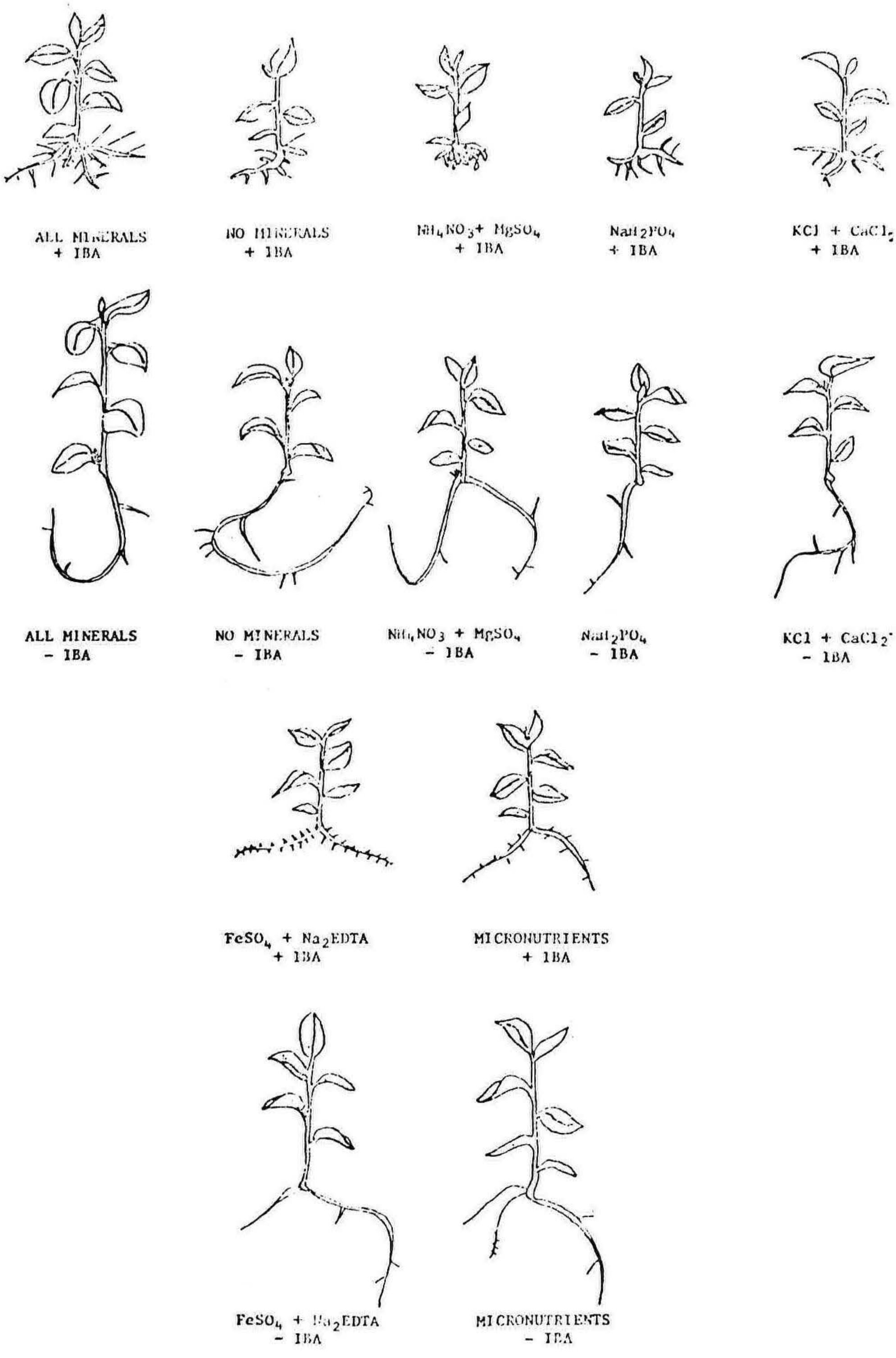

Figure 2. The effect of various nutrients in the rooting medium on root morphology of seedling shoot tip cultures, in the presence and absence of IBA. All minerals refers to the macro- and micronutrients described in Table 1.

interesting results of the experiments showed firstly that there is strong evidence for an auxin structure/plant response relationship, and secondly that specific nutrients and auxin interact to influence morphogenesis.

The way in which auxins act in the plant is still not fully understood. IAA is probably the major natural plant auxin and Thimann and Koepfli (19) were the first to suggest that IAA was the root-forming hormone. Synthetic auxins have been used for the induction of roots on cuttings, since they appear to be more stable in the plant than IAA, IBA and α-NAA, particularly, are commonly used in horticultural practice. The morphology of roots formed by the different auxins has not been widely noted. Pearse (18) found, in a variety of fruit tree cuttings, that IBA gave a finely-branched fibrous root system, while α-NAA gave thick, fleshy roots with few branches. Van Overbeek (20) noted that auxins generally promoted a compact root system composed of many short roots, whilst there were a few long roots when rooting was "left to nature". Certainly this latter point has been illustrated in the experiments described here

Connections between auxin structure and root morphology have not been widely reported. Kaethner (17) postulated that the hormonal activity of auxins was due to the ability of the bound ligand to undergo a simultaneous conformational change or re-orientation with its receptor. This theory may account for the observed differences between auxins, and other groups such as cytokinins, but it does not account for any differences in response elicited by different auxins.

Table 1. Composition of the culture medium for the induction of roots in seedling cultures of *Eucalyptus ficifolia*. (The nutrients are combined from 5 pre-stock solutions (5) and these groupings are shown)

Macronutrients (mM)	NH_4NO_3 (5), $MgSO_4$ (0.5)	— Group 1
	NaH_2PO_4 (1)	— Group 2
	KCl (1 9), $CaCl_2$ (1)	— Group 3
Micronutrients (μM)	H_3BO_3 (150), $MnSO_4$ (100), $ZnSO_4$ (40), $CuSO_4$ (1 5), Na_2MoO_4	— Group 4
	$FeSO_4$ (100), Na_2EDTA (100)	— Group 5
Auxins (μM)	IBA (5)	
Growth Factors (μM)	± Riboflavin (10)	
Main Carbon Source (mM)	Sucrose (120)	
Agar (g/l)	'Fluka' (9)	

The pH of all culture media was adjusted to 5 5 with 1M NaOH prior to autoclaving

Similar problems are encountered when considering the nutrient story and explanations for the interaction of IBA with individual groups of nutrients, are disappointingly elusive. One could speculate that concentration gradients created within the root cells, play some part

The work reported here has raised many questions for further research. The problem is to select an approach which will give interpretable and useful results. Structure-activity or hormone-nutrient studies are not likely to give answers on the mechanism of auxins in the initial biochemical event leading to root formation because the assay of root formation is too far removed biochemically from this event However, studies of this type are likely to produce results which are highly specific and useful for the plant propagator.

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THE INFLUENCE OF PLANT HORMONES AND GROWTH FACTORS ON GROWTH OF ERIOSTEMON AUSTRALASIUS PERS. IN TISSUE CULTURE

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Abstract. Following standard disinfestation treatments, cultures of apical and axillary buds of *Eriostemon australasius* Pers can be initiated on a simple minerals-sucrose-agar medium, i e , MZZ [ZM] and rapid multiplication can be induced in cultures transfered to medium — $[MH_{Fe}]Z$ $BAP_{31\ 6\mu M}$ $[H_{4+R}M]$ Apically-dominant growth can be induced on transfer of cultures to medium — $[MH_{Fe}]M$ KINETIN $_{10\mu M}$ $[H_{4+R}M]$, and roots can be induced to form on some cultures on medium — $[MH_{Fe}]$ $NAA_{31\ 6\mu M}$ $BAP_{0\ 0316\mu M}[M_{ALL\text{-}R}M]$

Only BAP and PBA were able to induce adventitious bud formation and these cytokinins had, in common, a benzyl ring as a substituent in the N^6 position

Interactions of auxins, cytokinins, riboflavin and other growth factors in producing various growth forms in culture are discussed

INTRODUCTION

The research done by Lilien-Kipnis and de Fossard (unpublished results) was primarily aimed at finding methods for the clonal propagation of *Eriostemon australasius* Pers. It succeeded in developing a high multiplication rate, but only one experiment was done on root induction (Lilien-Kipnis and de Fossard, unpublished results). Of great interest was the induc-

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tion of numerous adventitious buds on the leaves and stems of cultures and the interaction of cytokinins, auxin and riboflavin to produce strikingly different growth forms. This paper discusses the continuation of this work and includes not only the successful rooting and establishment of tissue-cultured *E. australasius* in soil but also additional research into the role of specific cytokinins in adventitious bud formation.

Much research has attempted to define the role of various cytokinins. For high cytokinin activity, the compound must have an intact adenine nucleus and a moderately sized N^6 substituent (11). The saturation level of the substituent also influences activity (10,11). The cellular pathway for cytokinin action is unknown. An association, described in this paper, between chemical structure of substituents and morphogenetic events might lead to new insights into the initial reactions of cytokinins in the plant.

Riboflavin, a vitamin which has been used only rarely in tissue culture, had striking effects with cultures of *Eucalyptus ficifolia* F. Muell (2,3,8,9) and also with cultures of *E. australasius*. It has been suggested that riboflavin acts by sensitizing the photo-oxidation of auxin (6,4) and enzymes (5). This paper describes experiments with riboflavin, auxins and other growth factors.

MATERIALS AND METHODS

Media (Table 1) were adjusted to a pH of 5.5 and were solidified with 9g Fluka agar per litre. Hot liquid media were dispensed in 10 ml aliquots into 8 × 2.5 cm polycarbonate tubes and then autoclaved for 20 minutes. Cultures were incubated in controlled-environment chambers with a 16 hr light/8 hr dark photoperiod at 25 ± 3°C for six weeks. Data were collected either by direct measurement or using a 1-10 scoring system and these were analysed using appropriate statistical methods. Controls were used in all experiments and there were 10 replicates of each treatment.

Initiation and Multiplication. Cultures, initiated 12 months earlier by Lilien Kinis and subcultured at approximately two-month intervals, were used. The multiplication medium developed at the end of this initial work was Medium A, i.e., $[MH_{Fe}]MH[HM]$ (Table 2) and this was subsequently modified to Medium B, i.e., $[MH_{Fe}]\ MH[H_{4+R}M]$ (Table 2), by the elimination of certain growth factors.

The experiments were based on the Broad Spectrum approach (1) and the chemical compositions of various categories of constituents used to prepare the different media cited in this paper are described in Table 1.

Table 1. Composition of minerals, auxins, cytokinins and growth factor categories used to make media described in Table 2.

Constituents of Medium	Chemicals (Concentration)	
Minerals — $[MH_{Fe}]$		
Macronutrients [mM]	NH_4NO_3(10),KNO_3(10), $MgSO_4$ (1 5)	NaH_2PO_4(1),$CaCl_2$(2),
Micronutrients (μM)	H_3BO_3(50),$MnSO_4$(50), Na_2MoO_4 (0 1);$CoCl_2$ Na_2EDTA (100),Na_2SO_4	$ZnSO_4$(20),$CuSO_4$(0 1), (0 5),KI (2 5),$FeSO_4$(100), (650)
Auxins — M (μM)	IAA (1), IBA(1), NAA(1), NOA(1), CPA(1), 2,4-D(1)	
Cytokinins -H (μM)	Kinetin (10), BAP (10)	
Sucrose -M (mM)	Sucrose (60)	

	Growth Factors Code		
Chemicals (μM)	H	H_{4+R}	M_{ALL-R}
Inositol	600	600	300
Nicotinic Acid	40	40	20
Pyridoxine HCl	6	6	3
Thiamine HCl	40	40	2
Biotin	1	—	0 2
D-Ca-Pantothenate	5	—	1
Riboflavin	10	10	—
Ascorbic Acid	10	—	1
Choline Chloride	10	—	1
L-Cysteine HCl	120	—	60
Glycine	50	—	5

Experiments with Cytokinins. Cytokinins were tested using Medium C, i.e., $[MH_{Fe}]M^*[H_{4+R}M]$ (Table 2) as a basal medium. The mineral, auxin, growth factor and carbon source constituents were held constant while the cytokinin constituents were varied. The effects of the following individual cytokinins (μM) were compared with the effects of 10 μM BAP and 10 μM Kinetin together with (Kinetin (10), BAP (10), IPA (10), Zeatin (10) and PBA (10). This was to determine the effect of these cytokinins on growth habit.

These cytokinins were also tested, using the same basal medium, over a range of concentrations. This was to determine the cytokinin concentration which produced the maximum number of adventitious buds. The concentrations used were (μM): 1.0, 3 16, 10, 31.6 and 100, i.e., 10^{-6}M, $10^{-5\,5}$M, 10^{-5} M, $10^{-4\,5}$M and 10^{-4}M. Controls of zero cytokinins were used in both experiments.

The effects of auxins, cytokinins and riboflavin were examined using the basal medium, $[MH_{Fe}]^*$ $^*[^*M]$, Medium D (Table 2). Here the mineral constituents and main carbon source were held constant while the auxin, cytokinin and riboflavin constituents were varied. The cytokinins (μM) tested were: Kinetin (10), BAP (10), IPA (10), Zeatin (10), PBA (10) and a zero cytokinin control. Auxins (μM) were either present as:

IAA (1), IBA (1), NAA (1), NOA (1), pCPA (1), and 2,4-D (1) or absent. Riboflavin was either present at a concentration of 10 μM or absent.

Table 2. Combinations of Constituents Used to Make Different Media

Constituents of Medium	Medium Code A	B	C	D	E	F	G	H
Minerals [MH^{Fe}]	✓	✓	✓	✓	✓	✓	✓	✓
Auxins M	✓	✓	✓	—	—	—	—	✓
Other	—	—	—	*	*	—	NAA 31 6μM	—
Cytokinins H	✓	✓	—	—	—	—	—	—
Other	—	—	*	*	—	BAP 31 6μM	BAP 0 0316μM	Kinetin 10μM
Growth Factors H_{ALL}	✓	—	—	—	—	—	—	—
H_{4+R}	—	✓	✓	—	—	✓	—	✓
M_{ALL-R}	—	—	—	—	✓	—	✓	—
Sucrose M	✓	✓	✓	✓	✓	✓	✓	✓
Agar 9g/l	✓	✓	✓	✓	✓	✓	✓	✓

Medium Code	Broad Spectrum Code
A	$[MH^{Fe}]$ MH [HM]
B	$[MH^{Fe}]$ MH $[H^{4+R}M]$
C	$[MH^{Fe}]$ M^{*} $[H^{4+R}M]$
D	$[MH^{Fe}]$ ** [*M]
E	$[MH^{Fe}]$ * $[M^{ALL-R}M]$
F	$[MH^{Fe}]$ $ZBAP^{31\ 6\mu M}$ $[H^{4+R}M]$
G	$[MH^{Fe}]$ $NAA^{31\ 6\mu M}$ $BAP^{0\ 016\mu M}$ $[M^{ALL-R}M]$
H	$[MH^{Fe}]$ M Kinetin $^{10\mu M}[H^{4+R}M]$

Experiments to Develop a Rooting Medium. Attempts to induce root formation were made first with individual auxins using the basal medium $[MH_{Fe}]^{*}Z[M_{ALL-R}M]$, Medium E (Table 2) that is a cytokinin free medium containing the medium concentration of all growth factors except riboflavin. The following auxins were tested individually at 6μM and 10μM (Lilien-Kipnis and de Fossard, unpublished results). IAA, IBA, NAA, NOA, pCPA, 2,4-D.

Later a rooting experiment with Medium E, i.e., $[MH_{Fe}]^{*}Z$-$[M_{ALL-R}M]$ tested a range of concentrations of NAA in combination with a range of concentrations of BAP and Kinetin. NAA was tested at (μM). 0 1, 1.0, 3 16, 10, 31.6 and 100, i.e., 10^{-7}M, 10^{-6}M, $10^{-5\ 5}$M, 10^{-5}M, $10^{-4\ 5}$M and 10^{-4}M respectively. BAP and Kinetin were tested individually at (μM). 0.1, 0.0316 and 0.01, i.e., 10^{-7}M, $10^{-7\ 5}$M, 10^{-8}M.

RESULTS

Growth Habit. Adventitious buds formed in cultures with

See Appendix I for definition of abbreviations

either BAP or PBA present in the medium BAP, PBA and Kinetin stimulated the growth of axillary buds (Figure 1). The optimal concentration of BAP and PBA for adventitious bud formation was 31.6μM. The stimulation of axillary bud growth by BAP and PBA increased with increase in concentration however it decreased with increased kinetin concentration over the range tested. When no cytokinins were present the growth was apically dominant

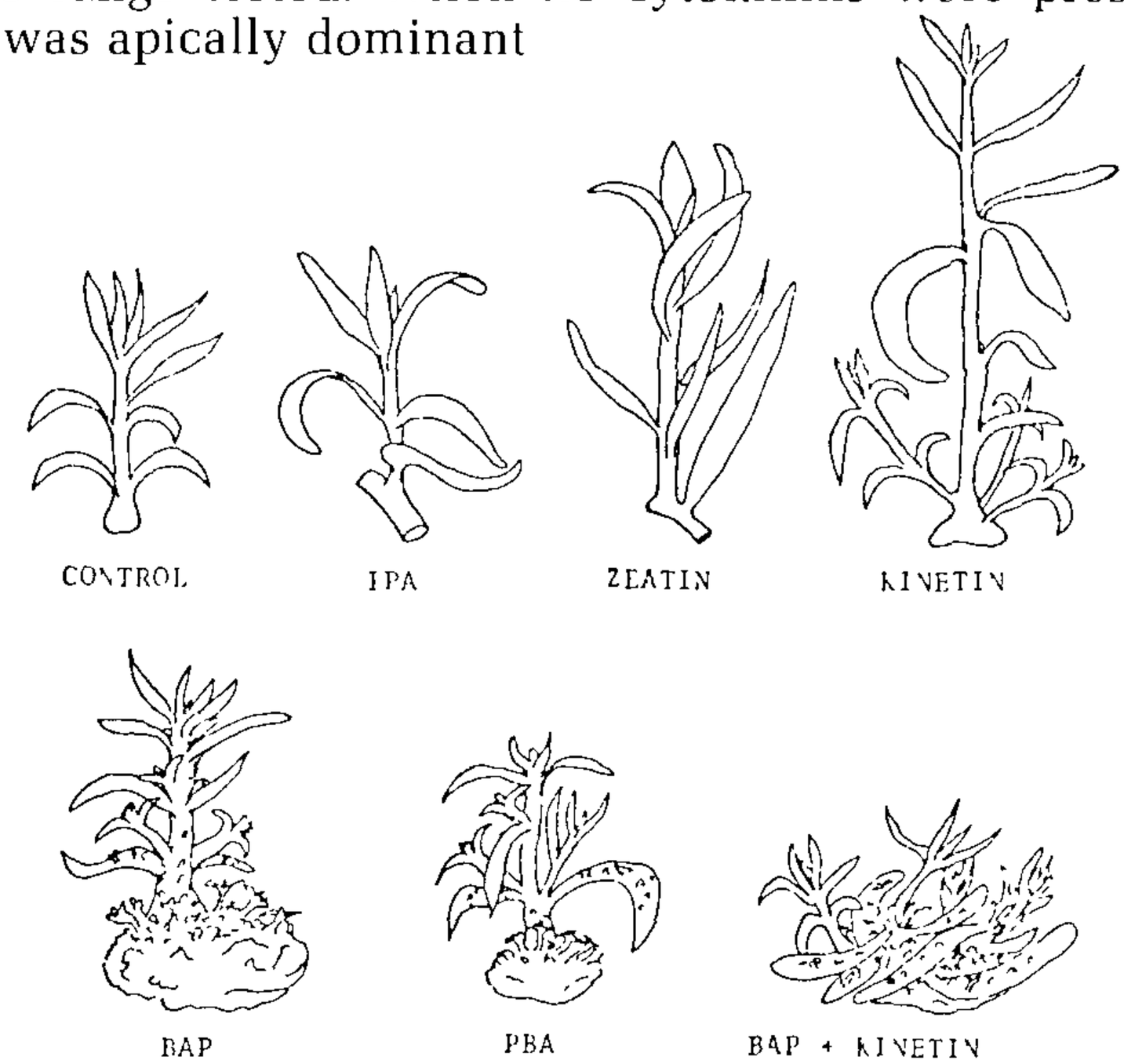


Figure 1. The response of cultures to the various cytokinins (all at 10μM) as shown by adventitious bud formation and growth habit

The presence of auxins in the media inhibited apically dominant growth in the case of cytokinin-free media and it inhibited adventitious and axillary bud development in the case of media containing either BAP or PBA. The addition of 10μM riboflavin to auxin-containing media appeared to nullify this inhibitory auxin-effect. These responses are shown on Table 3.

Table 3. Interactions of auxins, cytokinins and riboflavin on the growth habit of *E australasius* cultures, basal medium was [MH[MH^{Fe}]**[*M]

			Cytokinins
Auxins	Riboflavin	Zero	10μM BAP or PBA
Zero	Zero	Apically dominant growth	Adventitious and axillary bud development
	10μM	Apically dominant growth	Adventitious and axillary bud development
M	Zero	No growth	No growth
	10μM	Apically dominant growth	Adventitious and axillary bud development

Rooting Medium. In the experiment testing various auxins at two levels only one root formed where the culture medium contained 10μM NAA. In the following experiment the medium inducing most roots contained 31.6μM NAA and 0.0316μM BAP; this gave 40% (6/15) rooted cultures (Medium G, Table 2). The rooted cultures were successfully transferred to soil by first placing the culture tubes in a shaded glasshouse followed by the removal of their lids. Two days later rooted cultures were washed free of medium and placed in 5 cm diameter tubes containing a moist peat-sand (1.1) mixture. A plastic hood was placed over the plants and, when new roots had formed, the plants were gradually hardened by exposure to less humid air. This procedure was adapted from that used by Gorst et al. (7) with *Grevillea*.

DISCUSSION

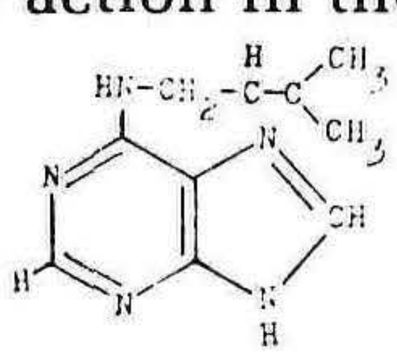
Propagation System. Medium F, i.e., $[MH_{Fe}]Z\ BAP_{31\ 6\mu M}$ $[H_{4+R}M]$ (Table 2) was found to be a good rapid multiplication medium with up to 200 adventitious and axillary buds forming over a 6-week incubation period. Usually 50 of these buds were sufficiently developed for transfer to the rooting medium G, i.e , $[MH_{Fe}]NAA_{31\ 6\mu M}BAP_{0\ 0316\mu M}$ $[M_{ALL-R}M]$ (Table 2). The remaining 150 may be intermediately transferred to Medium H, i.e., $[MH_{Fe}]$M Kinetin $_{10\mu M}[H_{4+R}M]$ (Table 2) to induce apically dominant development. However, due to the abundant supply of material formed by this system this extra step would not normally warrant its expense.

The rooting medium was successful in 40% of cultures. This figure is low compared to other tissue culture rooting systems; however it is greater than the 5% success rate using *in vivo* systems over the same period and plant material is abundant *in vitro*.

Cytokinins. As can be seen in Figure 2 the two cytokinins, BAP and PBA, that induced adventitious buds are structurally related. Skoog and Armstrong (10) found that high levels of unsaturation in the substituent, which is the benzyl ring of BAP and PBA, produce high activity. Therefore this greater unsaturation level compared with the other cytokinins tested may be responsible for their activity. However none of the other cytokinins induced adventitious bud formation, even in high concentrations.

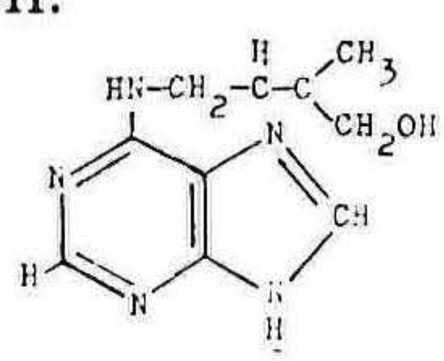
This suggests two other alternatives. One is that the other cytokinins did not enter the plant tissue or were rapidly broken down. Kinetin, however, did induce the development of axillary shoots showing that it was not completely broken down.

Another possibility is that a specific molecular structure is required at one of the steps that leads towards adventitious bud formation and that BAP and PBA satisfy this requirement. In this supposition, these compounds and others closely related to them may be suitable for experiments to determine their point of action in the cell.



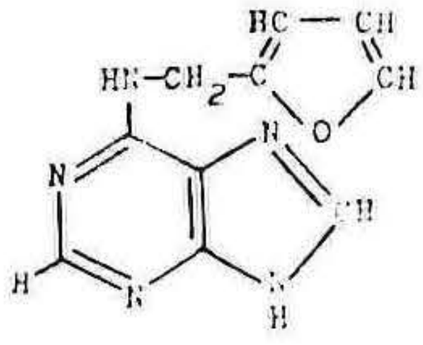
N^6 - isopentenyl amino purine

IPA



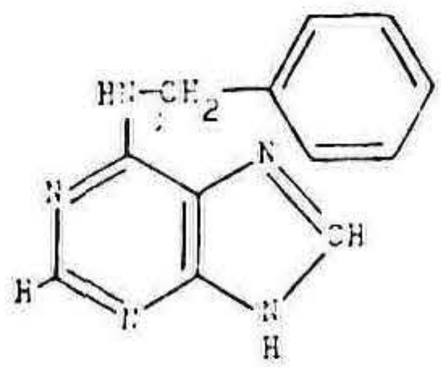
6-(4-Hydroxy-3-methylbut-2enyl)-amino purine

ZEATIN



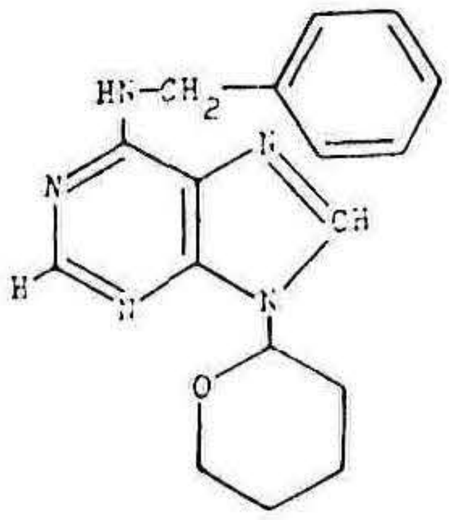
6-Furfuryl amino purine

KINETIN



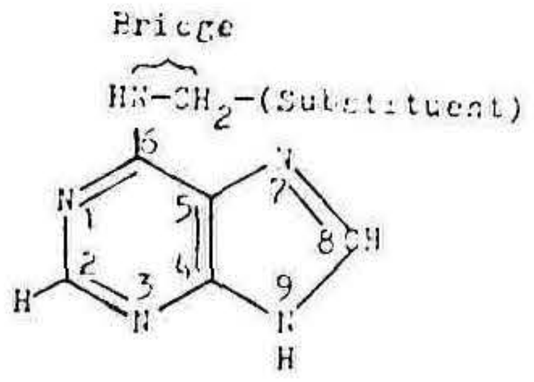
N^6-Benzyl amino purine

BAP



6-(benzylamino)-9-(2-tetra hydro-pyranyl)-9H-purine

PBA



Basic Arrangement and Numbering System for substituted adenines

Figure 2. The Structural Formulae For The Five Cytokinins Used.

Interaction Between Auxins, Cytokinins and Riboflavin on Growth Habit. In the absence of cytokinins, growth was apically dominant but in the presence of either BAP or PBA adventitious and axillary buds developed. Auxins inhibited both apically dominant growth in the cytokinin-free media and the development of adventitious and axillary buds in the case of media with either BAP or PBA. The addition of 10μM riboflavin to auxin-containing media appeared to nullify the inhibitory auxin effect.

Lilien-Kipnis and de Fossard (unpublished results) also tested the interaction between riboflavin and cytokinin but used different growth factors (Table 4).

Table 4. Interactions of riboflavin and cytokinins on growth of *E. australasius*; basal medium was [MH^{Fe}] M * [$H^{ALL-R}M$]; note that all four media had all growth factors (except riboflavin); these growth factors were at the high concentration.

	Cytokinins	
Riboflavin	Zero	High
Zero	Growth	No growth
10μM	No growth	Growth

In the presence of cytokinins on a medium containing auxins, growth is dependent on the addition of 10μM riboflavin to the medium — this result is depicted in both Tables 3 and 4. However, in the absence of cytokinins on a medium containing auxins, different responses to riboflavin were elicited in the separate experiments summarised in Tables 3 and 4. In Table 3, riboflavin induced growth of cultures on auxin-containing, cytokinin-free media, whereas in Table 4 riboflavin addition inhibited growth. Thus it would appear that one or more of the growth factors used in the Table 4 experiment induced growth in the absence of riboflavin but not in its presence. In contrast (Table 3) in the absence of these growth factors, riboflavin can induce growth These puzzling results indicate the need for further systematic work to unravel the active substances in these interactions.

APPENDIX 1. Full names of auxin and cytokinin compounds used in experiments and explanation of symbols

Auxins IAA (Indoleacetic acid), IBA (Indolebutyric acid), NAA (α-naphthaleneacetic acid), NOA (2-Naphthoxyacetic acid), pCPA (*para-chlorophenoxyacetic acid*), 2,4-D (2,4-dichlorophenoxyacetic acid)

Cytokinins BAP (N^6-benzyl amino purine), KINETIN (6-furfuryl amino purine), PBA (6(benzylamino)-9-(2 tetra hydropyranyl)-9H-purine), IPA (N^6 isopentenyl amino purine), ZEATIN (6-(4-hydroxy-3-methylbut-2-enyl) amino purine)

Symbols

Z Represents zero concentration, i e , this constituent is absent

* Represents the use of a number of compounds, i e , this constituent is changed for different treatments

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LITHODORAS

TERRY HATCH

Joy Plants
RD #2, Pukekohe East

Lithodoras are hardy sub-shrubs, from southern and western Europe and Morocco. The finest of all the species is *Lithodora diffusa* (*Lithospermum diffusum*), one of the most brilliant and widely grown of the genus. It is of a wirey sub-shrubby habit, a strong, rapid trailer, covering itself in early summer with heads of intense, pure, deep blue flowers.

The two cultivars grown in New Zealand and many other parts of the world are Heavenly Blue and Grace Ward However, sometimes they are hard to propagate in any numbers and to form into well-grown bushy plants.

I have been growing these plants for many years, trying to find an easy way to mass-produced this spectacular rock plant and, like many others who have tried before, never managing to get a good strike The cuttings often rot when under mist or only send out few thin roots with bottom heat. Semi-hardwood cuttings have never made such progress so I tried very small, soft tips. These seemed to be the best although not all of them rooted

I evolved a method of growing stock plants in large bags then putting them under a nova roof house after the first flush of flowers finished I trim back all flowering shoots and give a light feeding of urea to promote very soft growth. When the plants have made 3 cm. of growth the cuttings are taken and the three bottom leaves removed, then the cuttings are dipped in No 1 rooting powder and stuck into trays of pumice, given a good watering, placed in the nova house and covered with clear plastic — no bottom heat

They are watered after about 3 to 4 days and by 10 days many cuttings have rooted. As soon as the whole tray of cuttings has rooted, in 14 to 20 days, they are put outside to harden off before potting in a bark-pumice mix. I try to put them outside on a dull or rainy day. Most years I get 100 percent strike, with later batches giving 85 to 90 percent as the weather gets cooler and the cuttings become firmer.

Growing them this way produces very strong roots. The potted plants are put outside to grow on over winter, although our first batch is often sold in the autumn without flowers.

RHODODENDRON PROPAGATION

DENIS HUGHES

Blue Mountain Nurseries
Tapanui, West Otago

Our nursery is located 20 miles from the nearest rail head, 60 miles from the nearest airport, 100 miles from our main market of any size. Since the loss of our local rail link three years ago some changes have had to be made in our nursery production. In the past it was easy to take our tractors and trailers to the local rail station and consign flower budded plants to the garden centres. Now, without this convenience, we have to do this transporting ourselves. (We find the local trucking firms have no plant sense and our product can arrive in very poor shape when left to them.) With this in mind we have moved away from the production of full-size plants to liners, which are taken to other growing nurseries nearer the population areas This has also meant a greater interest in new cultivars. These have to be bulked up from very small numbers which may have been imported from other countries, or from friends or acquaintances of single pieces from newly named and registered plants. To achieve this we maintain a quantity of *Rhododendron* 'Cunningham's White' for either grafting or chip budding some of this very limited material onto By doing this we can gain two to three years. Occasionally we saw down a plant of an old obsolete cultivar and green graft on it one of the newer more outstanding cultivars and, in this way, we can have remarkably vigorous growth which gives us a large bush from which we can take a large number of cuttings in three years.

GRAFTING

We only use this method for a special purpose, as mentioned previously, or where an already popular cultivar is difficult to produce from cuttings, e.g. *Rhododendron* Loderi Grex. Propagation from cutting-grafts onto *Rhododendron* 'Cunningham's White' is a more efficient use of propagation space giving 50 percent more plants from a given area of mist bench. In *R. yakusimanum* we find that we can gain a year's growth by using cutting-grafts. Once again we think this to be worthwhile for such a popular plant When making cutting-grafts it is possible to remove all buds from the stock while wounding. This avoids one of the big disadvantages of grafted rhododendron, which often sucker.

CUTTINGS

Having mentioned some of the lesser used methods of

rhododendron production I must stress that cuttings represent over 90 percent of our production and we favour this method wherever possible Our propagation houses (12′ × 50′) are designed with benches containing 4″ of fine sand in which are imbedded ½″ hot water heating pipes spaced 6″ apart. The thermostat is set to give a bottom heat temperature of 70°F at the base of the cutting. On these benches are placed the trays of cuttings. The misting is controlled through an Aquatron mist unit coupled to a weaner, which is the electronic leaf type. We adjust as near as possible to give a short quick burst of mist to maintain a coating of water on the leaves but have as little run-off as possible.

The cuttings are collected mainly from stock plants growing in a lathhouse while the dew is still on the leaves. They are placed in plastic bags in a coolstore until required. We prefer only to collect the cuttings required for that day; however, we do store some cuttings up to 14 days without apparent damage. The type of cuttings we prefer are half ripe and still feel rubbery in the hand. Most clones are at this stage in New Zealand sometime from January to March (late summer). Like most things in horticulture there are exceptions and we find that cuttings of some of the old hardy hybrids, e.g. *R.* 'Fastuosum Flore Pleno' root best when much harder, as in April or even May.

The cutting are made 3″ long with three leaves, often shortened back so that they do not overlap when inserted in the cutting trays. The basal 1″ is given a heavy wound into the cambium layer on one side. At this stage the cutting is placed in a suspension of Captan and left to drain before being dipped to the full length of the wound in a rooting hormone. The rooting powder consists of 1.5 percent IBA + 2½ percent Benlate and 2½ percent Captan in talc. The cuttings are then inserted in trays and placed in the propagation house. We prefer to have, if possible, only one cultivar per tray as this helps to prevent mixing; also all the cuttings then root at the same rate. The cutting mix consists of 50 percent sphagnum peat moss and 50 percent sand of similar particle size.

To keep aeration high we handle the trays carefully so that the mix stays soft and fluffy. While the trays are under the mist we drench fortnightly, alternating between Captan and Benlate. At this time care is taken to remove any dead or decaying leaves from the propagation house as they appear. After six weeks for quick-rooting types and six months for the most stubborn we harden them off by placing the trays in an unheated glasshouse. The cool treatment should continue for about six to eight weeks at about 40°F but never down to freezing. After this, the rooted cuttings are ready to be potted

on. Should time not be available at this stage we water the rooted cuttings weekly with MaxiCrop. This prevents the plants from starving while they wait for cuttings of the other cultivars to catch up with them. In this way we can pot most at the one time, or send most of their order out to other nurseries.

The plants we retain for ourselves are potted into 4" p or P.B. 1½ and, at first, are in a 50 percent shaded plastic tunnel house but later, as they settle in, the plastic is removed and they grow the remainder of the summer in a 50 percent Sarlon shade cloth tunnel.

In the autumn the well-established plants are planted in raised beds in a lathhouse where they remain for two growing seasons. As they grow through the following summer the terminal buds are removed as soon as they are large enough but have not begun to harden. By doing this the plants continue to grow and become very bushy. By growing a few of these larger plants we can monitor our propagation techniques and sometimes obtain a few extra cuttings from clones we are short of.

LEAF-BUD CUTTINGS

When very short of propagation material leaf-bud cuttings may be used. These are particularly successful when dealing with easy-to-root clones, which have large buds, e.g. *R.* 'Anna Rose Whitney'. Care must be taken when making and dealing with these since, if the hormone is placed too near the bud, problems may be encountered by good roots developing but the bud will not break. Also the large leaves have to be carefully supported, otherwise they may fall against each other and so begin to decay.

SEED

Seed is used for the production of selected strains which flower quickly from seed, e.g. *R. racemosum* 'Forrest's Dwarf', or which are usually used as a foliage plant, e.g. *R. macaebeanum*. It is important to select the seed carefully or a very variable crop can result.

The seed is sown on a chopped spagnum moss veneer on potting soil during August. When the cotyledons are fully developed the seedlings are pricked off and established under mist for the first week and then weaned and kept in a shaded glasshouse for eight weeks By this time the weather has warmed sufficiently and the seedlings are large enough to go into a 50 percent shaded tunnel where they remain for the remainder of the growing season. Deciduous azaleas are treated in the same manner and have proved very popular when hand pollinated seed has been used.

THE ROLE AND WORK OF THE NEW ZEALAND NURSERY RESEARCH CENTRE

M. RICHARDS

Massey University
Palmerston North

The New Zealand Nursery Research Centre was established in 1975 as a joint venture between New Zealand Nurserymans' Association and Massey University. It owes its origins to a belief, held by the nursery industry, that it would benefit from research into industry problems, carried out in an organization accountable to the industry. This objective was secured by establishing a Research Centre, with an Advisory Committee, to whom the Director is responsible. The Advisory Committee determines policy, and directs the pattern of the research programme.

The role of the Centre can be seen as seeking to investigate problems affecting the nursery industry; these may be known problems, or problems which have not yet been recognized as such. To carry out its work the Centre may enter into co-operative research with other people or organizations, rather than attempt to do all of the work itself. In general it avoids becoming involved in work being undertaken elsewhere, except where it feels that a very different approach to a problem may yield useful results.

Because of its need to service the whole spectrum of the nursery industry, its work covers a very wide field, and this has influenced the way in which the programme has been developed.

The quality of plants produced is only as good as the material from which they are propagated, and the provision of propagating stock of High Health quality has been one of the major areas of work. This has led to the development of High Health clones of *Daphne* and *Nandina* currently being bulked up by licensed propagators. Much valuable experience has been gained from this programme, and current work is being aimed at extending this programme into other crop areas. Other work in the plant health field has involved the testing of new agricultural chemicals against specific disease problems.

In the field of plant propagation a major area of work has been in the study of propagating deciduous ornamentals by hardwood cuttings, using a modified heated-bin technique. This work has subsequently been extended to cover the propagation of deciduous fruit trees by the same methods. One important aspect of the hardwood cutting technique is the production of suitable cutting material and work is continuing

in this matter Work has also been carried out with leafy cuttings, including such areas as cutting selection and size, chemical treatments, cutting environments, and nutrition. This work has yielded a great deal of information which is now starting to appear as a unified picture.

One problem in all cutting propagation is the importance of securing juvenile shoots as a cutting source; we are currently involved in techniques for developing juvenile shoots in trees without the need for heavy pruning. This may be important in selection of improved forms of plants from matured seedlings growing in gardens

We have also been involved in developing techniques which can be used to reduce the time required to produce plants from budding. Using the chip budding technique, budding in late winter onto freshly-rooted cuttings can produce a saleable plant in one year. To do this it was necessary to have a rootstock with high nutrient reserves; this is more important than the size of the root system on the stock. There has been a flow-on effect from this, which has emphasized the importance of nutrient reserves in transplanting and subsequent growth of cutting-grown plants.

From its inception the Centre has been deeply involved in the problem of growing plants in containers. Our work has encompassed studies of the restraints imposed by the container, container design, the physical and chemical requirements of the growing medium, and water practices. These studies have developed a picture of these factors as an integrated system, which forms the basis of an improved system of growing plants. Of special importance has been the recent work on fertilizer placement as opposed to mixing the nutrients through the growing medium. Fertilizer placement offers new opportunities in precise growing techniques and an easy means of variation in standard media to suit individual plant needs.

Another area where the Centre has been particularly active is co-operative work in the field of market research. Several market research studies have been carried out through the University's Market Research Centre and more are under way. These are giving us a much better picture of the market place in which the industry's products must be sold.

I have touched very briefly on the major areas of the work of the Centre, details of which are available from the Annual Reports; it seems appropriate that I should look briefly into the future.

In the field of plant health there will be an increasing need for High Health propagating material and we are current-

ly planning to extend our work on ornamental plants.

In the field of plant propagation there will be increased interest in propagation from cuttings, and parallel to this, much greater interest in clonal selection programmes. Similarly we will need to develop a much better understanding of what constitutes a high quality transplant and devise ways of producing such plants. This will involve much of our present understanding of container production.

What may create problems is the extension of research work results into industry. The nursery industry has a well developed respect for tradition. The real worth of the Nursery Research Centre may well depend on the extent to which it can convince the industry that change may sometimes be necessary and even advantageous.

MICROPROPAGATION OF ZANTEDESCHIA HYBRIDS

DANIEL COHEN

Plant Physiology Division, DSIR,
Palmerston North

Several nurserymen in New Zealand have been breeding *Zantedeschia* hybrids for a number of years. The golden Calla lily, *Z. elliottiana* has been crossed with the pink *Z. rehmannii*. The progency have been back-crossed to *Z. elliottiana* and re-selected resulting in many potentially useful hybrids. These range in size from plants similar to *Z. elliottiana* to small miniatures about 30 cm high. Colour of foliage is either spotted or plain green. The spathe is either narrow and pointed like *Z. rehmannii* or the more rounded form of *Z. elliottiana* with all stages between. Spathe colour ranges from yellow to orange, red, pink and bronze. Some clones produce few flowers, others many. Selected large flowered clones might be useful for cut flower production whilst some of the miniatures might be suitable for pot plants. There is potential for export of cut flowers or rhizomes of selected clones.

However, in order to test the market for these selections, rapid propagation methods are needed. Traditional propagation would involve cutting the tuberous rhizome into sections each year resulting in only 10 to 20 fold increase per year. Soft rots caused by the bacterium *Erwinia aroideae* enter wound areas and can cause severe losses unless the rhizomes have been washed, dried, and stored on well-aerated trays before division.

There are numerous published examples of micropropaga-

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There are numerous published examples of micropropaga-

tion methods for plants belonging to genera of the family Araceae such as: *Anthurium*, *Caladium*, *Dieffenbachia*, *Monstera*, *Philodendron*, *Scindapsus*, *Spathiphyllum* and *Syngonium*. However, no work appears to have been done with *Zantedeschia*. Any procedures developed for *Zantesdeschia* would need to be simple and inexpensive because large numbers of plants would be needed for field planting.

In an ideal micropropagation system, culture initiation should be simple and multiplication rates high. For speed of handling in the multiplication stage the explants should preferably consist of a group of buds rather than single shoots. Rooting of shoots should be carried out under non-sterile conditions or, if this is not possible, the rooting percentage *in vitro* should be high and the plantlets should be able to be transferred readily to the greenhouse.

Initiation of cultures. Hybrid *Zantedeschia* plants are winter dormant and the rhizomes can be lifted and allowed to dry. If stored at 20°C, dormancy is lost after several months, buds begin to swell and eventually flower primordia develop.

Buds can be dissected either during the dormant phase, or as the buds begin to swell. The rhizome is first washed thoroughly to remove surface dirt and a section of the rhizome with a bud is removed with a sharp knife. This section is dipped into 95% ethanol and flamed twice. The buds can then be dissected under a stereomicroscope taking care that contaminants are not transferred from the outer parts of the bud to the inner portion. Two procedures for dissection have been used successfully, either slicing the bud horizontally until the apical tissue is reached or removing the bud scales to expose a small shoot tip. Using either procedure, a small piece of tissue containing the apical bud and some rhizome tissue (2-4 mm long) is cut out. In some clones the apical bud is considerably depressed below the surface of the rhizome making dissection by the second method more difficult.

The culture media used are shown in Table 1. For culture initiation and multiplication the medium contains benzyladenine at 3 mg/1. The sterilised medium is poured into standard plastic disposable petri plates using 25 ml/plate. The plates can be sealed with strips of 'Glad wrap.' Four to six dissected buds can be placed on each plate without danger of cross-contamination provided buds are checked after 3 days. At that time fungal contaminants can usually be detected before they have sporulated. Apparently clean buds can be removed and indexed for slow growing bacteria using an impression test on nutrient agar. We use Standard Methods Agar (SMA). The bud to be indexed is pressed against the SMA plate and is then

replaced onto a fresh culture plate with 3 mg/1 BA. Both the bud and the impression position are numbered and the SMA plate is incubated at 28° for 4-7 days The impression test is a very simple and effective method for detecting bacterial contaminants. Our success rate in the establishment of axenic bud cultures has varied between 20 and 60% depending on clone and the time of storage of the rhizome. Rhizomes which are stored in dry conditions and have commenced bud movement usually have less contamination.

Table 1. *Zantedeschia* micropropagation medium

Murashige and Skoog mineral medium supplemented as follows	
myoinositol	100 mg/l
thiamin HCl	0 4 mg/l
sucrose	30 g/l
benzyladenine (BA) (the concentration is varied for each stage	
Initiation and multiplication	3 mg/l
Shoot elongation	0 3 mg/l
Rooting	0 1 mg/l
Davis agar	6 g/l
pH	5 8

Shoot multiplication. On the initiation medium buds expand rapidly and in many cases proliferation occurs from axillary buds on the side of the explant. Proliferation can be enhanced by splitting the main bud longitudinally after about 3 weeks Both halves are replaced on the same medium. A proliferating bud mass develops consisting of small highly compressed buds. This mass can be cut into sections and replated onto the same medium indefinitely. In the clone used for the development of these procedures the proliferation rate was approximately five-fold per month, but clones do vary considerably in growth rate.

Shoot elongation. The effect of BA at 3 mg/1 in the proliferation medium is inhibitory to root development. Even when sections of the bud tissue are transferred to a rooting medium, root development is slow and erratic. It is desirable to condition the bud masses by transfer to a medium containing BA reduced to 0.3 mg/l for one or more subcultures.

On this elongation medium individual buds expand but usually one or two buds become dominant. In order to obtain maximum benefit from this stage the explants should be smaller than used for proliferation, containing about 5 buds. The buds which expand in 4 weeks can be individually removed for rooting and small buds can be returned to the elongation medium for a further month. We continue to use petri plates for the shoot elongation stage.

Rooting. Attempts to root clumps of shoots from proliferation medium directly into potting mix were unsuccessful, very

few roots formed and the shoot masses eventually died After about 3 weeks cultures on shoot elongation medium begin to develop roots. It was found that individual shoots rooted easily if placed in small 100 ml jars containing 25 mls of a medium with 0.1 mg/1 BA. Approximately 15 shoots are placed in each jar which is covered with a sheet of high density thin polyethylene film (Tissuethene, Trigon Plastics, Auckland. This film is 10 microns thick and can be autoclaved between paper sheets).

Rooting usually occurs within two weeks and after a further two weeks the leaf sheath has grown to about 30-50 mm. The plantlets are easy to handle at this stage and can be transferred directly to a potting mix in the greenhouse. If rooted cultures cannot be transferred to potting mix after 4 weeks they can be stored at 4°C for at least 2 months without any detrimental effect on subsequent establishment in potting mix

Shoot clumps transferred to rooting medium also produce roots but it is difficult to separate these shoots at the planting stage without damage and not all shoots develop roots.

Light intensity. We grow our *Zantedeschia* cultures at a lower level of light than most other cultures. A light intensity of 7-10 μEinsteins/m^2/sec (approx. 350-500 lux) is achieved by indirect fluorescent lighting. At the shoot elongation stage this results in shoots with the leaf laminar unexpanded. If the light level is raised to 40 μ Einsteins/m^2/sec the leaves unroll. These plants are more difficult to handle on subculture and subsequent transfer to potting mix.

Transfer to potting mix. Rooted shoots are rinsed to remove agar, planted into a free-draining soil-less potting mix and placed directly into a shaded greenhouse with excellent establishment The leaves unroll and new leaves develop. After about 2-3 months the tuberous rhizome is visible and this continues to grow for a further 3 or 4 months. After about 6 months, if the plants are allowed to dry out the small rhizomes can be collected. These rhizomes measure about 1 cm in diameter They are initially dormant but this dormancy is lost if the rhizomes are stored in dry conditions for 2 months at 20°C.

Transfer to the field. Although we have no direct experience of this essential stage, a few observations can be made. Small rhizomes, grown in the greenhouse, have been replanted into pots and develop well as pot plants. These rhizomes could have been planted into open ground. If the rhizomes are dipped into gibberellic acid (GA_3) at 40 ppm before planting, growth is stimulated.

We have also observed that disturbance of plants by repotting once the rhizome has formed, leads to premature senescence. It would obviously be undesirable for plants to become dormant on transfer to the field. We are therefore experimenting to determine the stages at which plants can be safely transplanted.

There appear to be several possible methods for handling large numbers of plants for field transfer:

1. The plants could be grown for one complete growth cycle in either trays or beds in the greenhouse. About 60 plants can be grown in a standard propagating tray. The small rhizomes can then be lifted, graded and replanted in the field in the spring.
2. The plants could be established in cell-packs in the greenhouse, so that after hardening outside, they could be transplanted with minimal disturbance to the root system.
3. The plants could be established in seedling trays and, after hardening outside, an attempt could be made to transplant into the field. This could be done approximately 4-6 weeks after transfer from culture before any visible rhizome development.
4. The plants could be transferred directly into the field in the spring. If they were planted in beds covered with a low polythene tunnel with a layer of heavy shade cloth, the plants might establish satisfactorily.

Flowering of the rhizomes. A treatment of the rhizomes with GA_3 at 40 ppm will stimulate vegetative growth of very small rhizomes and flowering in larger rhizomes. We have been able to flower rhizomes, 2 cm diameter, in pots in the greenhouse. The whole rhizomes were dipped into a solution of GA_3, drained and planted. Flowers developed two months later on the treated but not on the untreated rhizomes.

CULTIVATION AND PROPAGATION OF INSECTIVOROUS PLANTS

KEVIN GARNETT

Christchurch Botanic Gardens, Christchurch

Insectivorous plants are, of course, divided into many different genera which are distributed throughout the world.

I will endeavour to show you the differences within the different genera, as well as the propagation and cultural details of these particular plants.

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SARRACENIA (Pitcher Plant)

Description. The leaf is moulded into a long, upright, funnel-shaped tube which is surmounted at its rear by a lid-like but immobile structure which is usually termed the hood. There is a variety of colour present on the funnel. In *S. leucophylla* the upper pitcher and hood are pure white nettled with dark red. In *S. minor* and *S. psittacina* their pitchers have white translucent windows or false exists which are very prominent.

Along with the attractive funnel the *Sarracenia* possess an attractive nodding solitary flower, from which large globular terminal buds on tall upright stems are produced. These are about 7.5cm in diameter and consist of five petal-like sepals under which hang the five rather longer true petals which hang over the pistil. The whole structure resembles an inverted umbrella. The colour of the petals can range from pale pink to crimson, while the sepals are often of a deeper shade.

The Trap. The interior of the pitcher is divided down its length into several distinct zones with rather different functions.

The surface of the lid is scattered with nectar glands which prime function is to attract the insects to the funnel. Interspersed between these glands there are short, sharp, downward-pointing hairs. About one or two inches down the funnel there is a glossy waxy surface which presents no foothold to insects. Scattered on this are microscopic glands which produce secreting juices containing digestive enzymes.

In the lower zone of the tube, the sides are lined with long, sharp, downward-pointing hairs and the attraction of strongly scented nectar brings the insects lower down and with the hairs and that of the narrowing funnel there is usually no escape.

Insects trapped in this way are flies, ants, bees, wasps, etc.

Culture. Container size can vary with size and type of plant. They should always be potted in spring or early summer when in full growth.

The mix can vary. We have found just pure spaghnum moss with weekly liquid feedings has produced large healthy plants, although mixes of three parts spaghnum moss, three parts peat, and one part of sand; *OR* six parts spaghnum moss, two parts perlite, and one part of sand, have been used with good results.

Sarracenia do best in fairly strong light, but need to be lightly shaded against direct sun. They should be grown in a cool greenhouse where temperatures should range from 10° to

15°C. Plants can be grown outdoors where similar temperatures are experienced

The plants should not be allowed to form thick clumps. To prevent this they should be divided every two or three years. Sarracenias usually die down after the growing season in summer and have a resting period of several months over winter. The pitchers in most species die from the top downwards and, when the whole leaf is dead, it should be carefully removed from the base

Hygiene plays an important part in successfully growing any insectivorous plant, removing any dead or dying material periodically, keeping the pots free from slime, and generally allowing free air movement around the plant to prevent mildew, etc., from developing

Propagation. Usually carried out in spring, either by division or by the sowing of seed.

1 *Division* — Split the rhizome with a sharp knife when the plant is starting to make young growth. Each division should have several roots attached and the lengths should be between half and one inch long. These sections should be potted into a sarracenia mix with the top of the rhizome just being exposed. The pot should then be placed in a water tray away from direct sunlight, and shoots usually appear two weeks to a month after potting.

2. *Seed* — Seed always has to be fresh for good germination, and should be sown directly onto spaghnum moss, or equal parts of spaghnum moss and peat can be used. Seed should not be covered, the pan being placed in a water tray with, if possible, humidity and bottom heat being applied. Germination can take anything up to six to eight weeks and, as soon as seedlings can be handled, they should be pricked out into very small pots or tubes

DROSERA (Sundew)

Description. In this particular plant the upper surface of the leafblade is thickly covered with tentacles, which is pinkish in colour and is crowned by drops of clear colourless liquid which tends to glisten in the sun, hence the common name of sundew

In this genus there are over 90 recognised species scattered over the world, many being found in Australia They are usually growing in the wild in poor, acid soils, usually in bogs.

The species differ in size and habit between one another,

some being ⅛″ long, some 2′ (60cm) long The roots of this plant can be tuberous, fleshy or fibrous depending on the species involved

The tentacles which catch the prey are held outwards so they are exposed to the smallest insect. These tentacles consist of gland tipped stalks which are egg-shaped in appearance. They have dual functions. Firstly they secrete the sticky liquid which catches the prey. Secondly they produce the enzymes like peroxidase acid, phosphatase, esterase and protease, which have been found amongst others in the liquid, and which help to dissolve the skeleton of their victims.

It is not known what attracts small insects to the leaf. It has been suggested that it could be the bright drops of sticky liquid which may suggest nectar or that there is a scent which is procuded to attract them.

General Cultivation. This can differ greatly depending upon what species is encountered, but most require a large amount of light, but should be shaded from direct sunlight to prevent scorching of foliage

Like sarracenias, we have grown droseras very successfully in straight spaghnum moss with weekly liquid feeding in the summer months and in between periods keeping the moss moist

Propagation. This can be achieved by sowing seed, by leaf cuttings, or by root cuttings, although the two latter methods sometimes can destroy the plant.

Sowing seed is one of the best ways to increase numbers of plants. sowing directly onto spaghnum moss without covering the fine seed. They should then be placed into a humid atmosphere being maintained at around 21°C. and kept moist at all times. We use a propagating pit which has an air-tight lid on it with heating cables placed in sand at the bottom, onto which the pan is placed.

Germination can take up to eight weeks, when the seedlings large enough to handle are pricked out into pots with about 10 plants per container.

Leaf cuttings. One should select healthy leaves of reasonable size and cut them off with a sharp knife with a small part of petiole attached Lay the leaves, tenacle side uppermost, *flat* on the spaghnum surface. Then sieve a layer of fine spaghnum moss over top of the leaf, pressing the moss down into contact with this, allowing small areas of the leaf to be exposed. After about one month. buds should start forming at the base of the tentacles and, when large enough to be handled, potted up.

Root cuttings. The method used is same as for leaf cut-

tings, removing pieces of healthy root and placing them onto moist spaghnum moss, over which a layer of fine moss is sieved. Subsequent handling is the same as for leaf cuttings.

DIONAEA MUSCIPULA (Venus Fly Trap)

The foliage of this plant is in a rosette produced from a shoot unbranching rhizome which is clothed with the succulent bases of the petioles of previous leaves. The leafblade is in the form of the twin-lobed trap borne on a petiole which is often flat and usually wedge shaped, widening towards its end. Flowering takes place in early summer.

The Trap. This is made up of two lobes upon which are attached to a continuation of a spine. The upper surface of each lobe is dished, along which are some 15 to 20 prong-like teeth, upon when closed interlock

Inside the trap there are several trigger hairs which are the mechanism that springs the trap Most of the upper surface is scattered with microscopic glands and, in particular, there is a narrow band of glands which secrete nectar, so attracting the insects to the trap. Other glands that are present are used for the digestion of the prey.

Insects usually have to brush against the trigger hairs twice to activate the trap, and this has been seen perhaps as a safety mechanism against accidental closure, e.g. wind, etc. After the insect has activated the trap, the prey is held in place by the interlocking jaws until a second phase starts, that of narrowing and flattening of the two lobes against the insect's body. Then digestive juices are released form the upper surface glands digesting the insect's body except the wings, etc.

General Cultivation. We have found the best way of growing the Venus flytrap is to place several plants in a large 30cm bucket with just straight spaghnum moss in the container with weekly liquid feedings. Other mixes that have been used are one part peat moss and one part sand, or just peat moss alone.

Keep the mix moist at all times and grow the plants in a well-lighted position although away from direct sunlight; during winter reduce water to avoid rotting.

Propagation. This is mainly done by sowing seed straight onto spaghnum moss with a light covering of fine spaghnum moss over the top. A mixture of peat and spaghnum has also been used by us with success. Keep in a moist, humid, position with temperatures, if possible, maintained around 20°C. Seedlings should be pricked out as soon as possible into small pots, after which they should be potted up together when large enough.

Leaf cuttings also can be used as another means of propagating this plant although, by far, seed is the best and most convenient way.

NEPENTHES (Pitcher plant)

These plants are basically climbing in nature and grow in damp humid places, as in tropical jungles, etc., but in some other places they grow along the ground and over low shrubs, etc They are able to climb through the use of tendrils which can be seen growing from the tips of the long flat leaves, as these attach themselves to supporting vegetation.

The Trap. Usually produced in summer, it starts with a swelling at the end of the tendril of a recently formed leaf. This grows fairly rapidly, the tendril hanging down due to its increased weight As the flat bud approaches maturity it is suddenly inflated with air, the pitcher starts to obtain striking markings. After a few days the lid opens and in the bottom can be seen fluid which has been secreted after inflation.

The pitcher attracts its prey by producing nectar-secreting glands which liberally cover its inner surface. Just inside the pitcher are downward-pointing hairs, from which there is, about ⅓ down the pitcher, a glaucous waxy area offering very little footing to the insect. The remainder of the pitcher consists of a smooth, glassy, glandular surface fitted with microscopic glands which secrete digestive fluid found in the bottom of the pitcher and also absorbs the foods resulting from the digestive process.

General Cultivation. Temperatures ranging from 15 to 21°C seem to be best although many plants thrive above and below these settings. The plants require a high level of humidity, from 70 to 90% should be maintained at all times.

A mix which we have found good is one part leafmould, plus one part chopped spaghnum moss, although there are many similar ingredients that could be used. We also base feed and foliar feed weekly; the plants generally should be kept moist at all times.

Propagation is by seed or by cuttings.

Seed can be handled as previously suggested for the Sarracenias.

Cuttings are best taken in spring or summer, the length being from 6 to 8″ long (15-20cm). These can be dipped into a fungicide to help prevent rotting. Cuttings should be placed into a propagating pit with bottom heat of 21°C provided, and should be treated with hormone powder. High humidity during the rooting period should be maintained by frequent syr-

inging After several weeks a well-rooted plant develops which can be potted.

DARLINGTONIA CALIFORNICA (Cobra Lily)

Commonly called the cobra lily, this plant has an expanded hood and forked tongue, resembling a striking cobra. The pitchers may reach 30″ (75cm) in height, the tube widens gradually upwards, bending at the top where it is inflated to form the dome-like hood. The roof of the dome is heavily spotted with windows, and inside the pitcher is scattered with small nectar glands. Also found in the pitcher are stiff pointed hairs which are directed backwards towards the tube. The remainder of the tube is clothed with long, thin down-pointing hairs. No digestive enzymes appear to be secreted by *Darlingtonia*, but water is produced from the walls which is found at the bottom of a pitcher An insect is attracted into the dome by the nectar glands and starts feeding. When its time to leave, the insect flies to the most lighted portion of the dome which is the false windows on the roof and is thereby trapped and finally falls into the watery liquid at the bottom of the pitcher. Then with the aid of bacterial action the insect's body is slowly broken down into a nutritive solution which is finally absorbed into the plant.

General Cultivation. This plant is usually grown in pure spaghnum moss in about a 15cm pot size The plant should be protected from hot direct sun by the use of shade cloth, etc. and, in particular, the roots of the plant must be kept constantly cool, especially in the summer. The average temperature which seems best for these plants is from 12 to 15°C.

Propagation. The best method is by potting up offshoots from the rhizome, although it can also be propagated by seed. First the seed should be soaked in water until all have sunk to the bottom of the container. The seed should be sown on spaghnum moss with a fine covering over top of fine spaghnum moss Until germination has taken place the seed should be kept cool and away from direct heat, etc. Plants should be potted up as soon as they can be handled.

PINGUICULA (Butterwort)

There are 48 known species in this genus. All are fibrous-rooted perennials. In summer they develop flat rosettes of blunt oblong or elliptical leaves They are greasy to the touch, due to the droplets of sticky substance borne by the numerous stalked glands which cover the surface.

There are two kinds of glands on the leaf surface. The primary function of the stalked sticky gland is to catch and

detain prey, but also plays a secondary role in digestion. The other kind is similar to the stalked gland but is ¼ the size, and is seated in a slight depression. Both these glands produce enzymes which rapidly reduce and dissolve the soft parts of the insect The resulting nutritive fluid is absorbed into the plant's system.

General Cultivation. All Pinguiculas are retarded by root disturbance and should never be repotted while in summer growth. They require good light, but must be shaded from direct sun. The plants are best grown several to a pot to make a more compact unit. These, like all the other insectivorous plants, require frequent watering in the summer but with reduced water in the winter.

Propagation. This is done by seed sown in mid-winter in a pan with a mix of equal parts of peat and sand. The seed is placed on top and not covered. The pan should then be placed in a tray of water. After germination, the seedlings should be pricked out into their permanent pots, grouping several into a pot.

CEPHALOTUS

This plant possesses two types of leaves, the non-carnivorous foliage leaves and the pitcher leaves, which are borne in a rosette.

The Trap. This resembles a moccasin slipper in shape. It has a sideless heel having been curved over to form the lid. The belly is short and tubby, curving forwards towards the base. A curious feature of the internal structure of the trap is the thick wide collar below the rim which overhangs the well. This is covered with many nectar glands. The sides of the well are also glossily surfaced. In its upper part are numerous digestive glands.

General Cultivation. Again we have had good results growing these in straight spaghnum moss with weekly liquid feedings. Another mix which is used is two parts moss, one part leafmould, one part perlite, and one part sand. The pots can be placed in trays of water with regular watering throughout the summer. Plants should be shaded from the hot, direct summer sun.

Propagation. This is mainly achieved by division of the clumps. Root cuttings can also be taken from thick roots ½ to 1" (1.3 to 2.5cm) long, cut with a sharp knife. Use a mixture of two parts sand to one part peat moss. Lay cuttings flat, covering with 3mm of compost.

Leaf cuttings can also be taken, where the entire leaf is removed with the base (6mm) inserted into a bed of live

spaghnum. Keep moist until rooting takes place and pot as normal.

PROPAGATION AND CULTURE OF BROMELIADS

ALAN G. JOLLIFFE
Christchurch Botanic Gardens, Christchurch

The bromeliad family (*Bromeliaceae*) is exclusive to the New World — the Americas. Comprising 60 genera and about 1400 species they can be found growing wild in the southern United States, Central America, South America, and various outlying islands. Distribution is through 80° of latitude. Plants are subject to a variety of climatic conditions. Occurring north and south of the equator means plants receive rainfall at different times of the year. This results in widely different life patterns.

Bromeliad habitats range from purely tropical areas to mountain altitudes of 4000m, from sea shore to densely forested areas, and from inland areas to the southern ocean islands.

Climate variation throughout the distribution area has forced the bromeliads to adapt in many ways. Bromeliads have been very versatile in the adaptions.

The world's most well known bromeliad is the pineapple (*Ananas*), which is grown intensively in Hawaii, Australia, and the Phillipines, and exported over the world.

Growth Forms. Bromeliads are either epiphytic or terrestial. The epiphytic plants are found in a variety of climatic areas, not just the jungle. An example is *Tillandsia usneoides*, or Spanish moss, which grows luxuriently on trees in the southern U.S.A., giving an almost ghostly appearance.

Terrestial plants occur in most climatic zones growing in scrub, desert or jungle, marshes, rocks, or beaches.

Sizes of species vary - some Tillandsias are under 50mm in height and *Aechmea conifera* has leaves 3.5m long. Both are epiphytic. Other species have been recorded being 10m high, 2.5m in diameter or with 3m branching inflorescences.

The leaves are always arranged spirally and each genus tends to exhibit a particular type of leaf shape. Leaf shape influences the shape of the plant. Some are bulbose (bulb shaped), some others may be grass-like, moss-like or comprised of spreading rosettes. Leaf colour varies and leaves may be green, mottled, banded or reticulated.

Some bromeliads, mainly epiphytic ones, are the only plants that must have water in their growing centres to sur-

spaghnum. Keep moist until rooting takes place and pot as normal.

PROPAGATION AND CULTURE OF BROMELIADS

ALAN G. JOLLIFFE
Christchurch Botanic Gardens, Christchurch

The bromeliad family (*Bromeliaceae*) is exclusive to the New World — the Americas. Comprising 60 genera and about 1400 species they can be found growing wild in the southern United States, Central America, South America, and various outlying islands. Distribution is through 80° of latitude. Plants are subject to a variety of climatic conditions. Occurring north and south of the equator means plants receive rainfall at different times of the year. This results in widely different life patterns.

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Some bromeliads, mainly epiphytic ones, are the only plants that must have water in their growing centres to sur-

vive. Since there are no permanent water pools in the jungle, nature has provided these plants with a leaf arrangement to serve as reservoirs. Large volumes of water can be held. Even in a small potted plant a litre of water could easily be held. In nature a wide variety of fauna has specialised to live with the bromeliads — insects of many types, frogs and snakes.

Inflorescences and Flowers. Bromeliad rosettes end their growth with the formation of a terminal flower spike. Each rosette only produces one branched or unbranched inflorescence. (There are some exceptions.) The time it takes for an inflorescence to develop may be a few weeks to several months or over 12 months. Not only do these plants flower but also the last few rosette leaves or scape bracts on many species change colour. The bract colours present a great variety.

The flowers are typical monocotyledonous, with all whorls being of three parts. Blooms may last from a few hours to several days. The size of the inflorescence determines the flowering period as the individual flowers open over a period of time as each becomes mature.

Roots. In general the roots of bromeliads do not play the same role as do roots of other plants Epiphytic species have very hard roots which attach themselves to their foundation by excreting a rubber-like substance.

The large terrestial bromeliads, such as *Puya*, have strong root systems to anchor themselves and absorb nutrients.

Nutrient Uptake. Terrestial plants with strong root systems absorb nutrients in the same way as other plants.

Epiphytic plants have developed trichomes which appear all over the leaves. Some species have many more than others which is directly related to their habitat. The trichome consists of two parts, a shield and water absorption cells. It is through the trichomes that water and nutrients are absorbed.

Culture. With over 1400 species of bromeliads of varied size scattered over such a wide climatic range, cultivation is difficult to describe, but by grouping species with similar climatic requirements, or only specializing in one group, many bromeliads can easily be grown.

A common mistake in New Zealand is to assume that all bromeliads must be grown in a glasshouse or similar structure. This is nonsense. New Zealand has a climate which varies almost as much as the climatic range of the bromeliad. In New Zealand there are many climatic areas, each with its good and bad points.

One important feature of New Zealand is its microclimates — an example is the north side of houses under the eaves

where, especially in the South Island, it is dry and hot with no frost all year round Other microclimates under trees, in borders, on slopes, or near water can all be found. What does this mean for bromeliads? It means you can grow them outside if you choose the right area for the right plant.

A garden in Wellington features epiphytic and terrestial bromeliads in an area of native bush all growing very well. My own garden in Christchurch features at least six species, one of which is almost in flower now (late spring). Puyas are featured in several borders in the Christchurch Botanic Gardens and they flower regularly. Do not underestimate our New Zealand climate Some experimentation gives interesting results.

Generally, however, most collections are grown in pots or wired onto logs in glasshouses. A glasshouse provides protection from the elements and allows the plants to be grown to perfection — no tattered leaves, insect damage, or the like A minimum temperature of 18 to 22°C during the growing season with ample humidity provides good conditions. Bromeliads do best with plenty of light but too much direct sunlight can damage the leaves.

Plant knowledge is very important in the cultivation of bromeliads A person needs to know —

1. The plant's correct name — very important in this large family.
2 Its natural habitat and climatic conditions.
3 Whether it is epiphytic or terrestial.
4 Whether or not it has a vigorous root system
5. Any cultural requirements from the literature.

The answers to these questions will determine its treatment and eventual placement. Most can be pot-grown, even the epiphytic ones, but they must be potted firmly. There is a tendency today to grow bromelaids and other plants in more natural conditions. Many growers provide epiphytic plants with logs, fern trunks or similar to grow on

Species having smaller plants and smaller root systems need only a small pot 75mm to 125mm, but larger species require up to a 200mm pot. The stronger rooted species require larger pots. It is necessary to provide a firm but well-drained soil mixture. Potting of plants is generally done in late spring

Mounting plants on logs or branches is simply carried out Place some sphagnum moss where plant is to be mounted, position the plant and firmly wire it on. Wire is a little more invisible but a plastic product could easily be substituted.

The "branches" in the Christchurch Botanic Gardens for public display are actually a pipe and No. 8 wire structure, surrounded by 13mm chicken wire filled with sphagnum moss It won't rot or fall down and allows for easy mounting and good root holding.

Nutrients are given to display material via a liquid feeding programme. Commercial preparations are used.

Bromeliads do not tolerate lime. Lime is excreted from the plants through the leaves and left as a deposit on the outside of the leaves

Flowering of plants is normally left to nature, the plants producing flowers when conditions are right. Some, such as *Billbergia nutans*, are very free flowering. Flowers have been induced commercially using carbide solutions, ethylene gas, or naphthelene acetic acid.

In collections of plants, flowering is always the crowning success of growing these plants. In commerce, flowering could mean quicker sales It depends on your operation. Seed is formed in either dry capsules or in attractive berries.

Propagation. There are obviously two methods of propagation. Sexual — or by seed, and asexual — from vegetative material.

Seed is often collected in the wild and sent or sold to the horticultural industry — be it a botanic garden or nursery. Seed from a known origin is more likely to be true to name and provide a good line of plants. Seed collected from a collection of plants — such as a botanic gardens collection or nursery stock — is more likely to be of hybrid origin, because many bromeliads are self sterile This latter seed should be sown with caution.

Obtaining nursery stock from seed is time-consuming, taking from 3 to 5 years, and up to 30 years to obtain flowering size plants.

(a) *Atmospheric Tillandsias*

Seed is best sown on a brush seed bed. A bundle of conifer branchlets tied together to make a cylindrical mass about 40mm thick. Seed is sown on and through this and sprayed with water. The seed sits tightly on the twigs and soon this can be dipped in a can of water. As the young plants grow they can be transferred to "permanent" mounts. When growing spray with a complete fertiliser every month.

(b) *Other Bromeliads*

Fresh seed is the best and will give fast germina-

tion. Sow in pots or trays on a 50:50 mixture of peat and sand. Other specialist mixtures are used.

Do not cover the seeds as they germinate only in light conditions — remember many are epiphytic.

Pricking-out follows as soon as a few leaves have grown. Potting-on can be done when plants are of reasonable size. Depending upon how well each species responds to being potted, epiphytic bromeliads can be grown in pots. If they are not doing well, then transfer them to a mounting structure - logs, tree ferns, or even a display epiphyte tree.

In the Christchurch Botanic Gardens the epiphytic tree display features many plants. In fact the "tree" — that pipe and wire structure — is divided into sections, e.g. a moist tropical section, and a drier more temperate section.

The range of species, and collecting seed in various collections, has resulted in a large number of hybrids. Many have been named. Care is needed in obtaining and sowing seed Resultant plants should be checked for hybridism. Rouging of plants should be undertaken to remove inferior quality plants.

Vegetative Propagation. Although mature plants bloom once and die they produce offsets or "pups" which can be used for propagation. Only with poor conditions should you actually kill a plant. There are, of course, a few exceptions.

Offsets are produced about flowering time and, as the mother plant is dying (after flowering), the offsets obtain nutrition from the mother plant. They grow very quickly.

Offsets appear or develop in several ways — some at the base of the inflorescence, in the axils of basal rosette leaves, from adventitious offsets, and offsets from the inflorescence (*Ananas*). In all cases offset propogation is a quick method of producing mature plants quickly. A well-cared-for plant could be mature enough to bloom in 12 months.

Offsets are removed with a sharp knife at the point of attachment. Timing of the removal is important. If offsets are removed too soon then they will take longer to reach maturity. But early removal may mean the plant will produce more offsets. The longer it is attached, the better quality of offshoot. Again, depending upon the species, the size of the offset depends on the treatment. Offsets with a good root system can be potted up and treated as young plants. Those with few or no roots can be placed in a propagating mist pit with bottom heat for three weeks. A medium of sphagnum moss is quite suc-

cessful. Some hardier species do not need mist. The "tanks" of funnel shaped bromeliads must be filled with water.

SUMMARY

The large number of bromeliad species (over 1400 from 60 genera) and their wide growing adaption to various climatic areas and growing situations makes it very difficult to give an authoritative account on the culture and propagation of these plants. To add to this list of species are the many hundreds of hybrids that have been raised. This is only an introduction to this wide and interesting group of plants. Bromeliads are easily cared for and should be grown more by the horticultural industry.

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NEW DEVELOPMENTS IN SPRAY APPLICATION TECHNOLOGY

J. MABER

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ABSTRACT. The basic principles of controlled droplet application (CDA) spraying and electrostatic spraying are reviewed, with particular reference to how these techniques can increase the efficiency of spray application

The introduction of these techniques and their acceptance in New Zealand is discussed

1. INTRODUCTION

The sole reason for applying pesticides (including herbicides) is to protect crop yield potential. To do this, one must transmit an appropriate quantity of active ingredient to a population of specific targets such that the organism or weed endangering the yield may collect it and be killed.

Whilst present spray application techniques may, on the whole, be effective they are inefficient. New developments in spray application techniques are directed at improving this efficiency, whilst maintaining or improving effectiveness.

This paper reviews two of the most important of these new techniques; controlled droplet application (CDA) spraying and electrostatic spraying. There is, however, one other develop-

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This paper reviews two of the most important of these new techniques; controlled droplet application (CDA) spraying and electrostatic spraying. There is, however, one other develop-

ment which, although technically cannot be described as spray application, is important. Much of the inefficiency in present spray application techniques can be attributed to drift of spray droplets out of the target area. The development of herbicides such as Glyphosate has given rise to equipment which applies the chemical directly to the target plant — there is no spray drift because there are no spray droplets. Instead the chemical is wiped onto the plant — complete coverage is not necessary because the chemical is translocated throughout the plant. The example is interesting because the application technique and appropriate equipment followed on from the development of the chemical. It also illustrates the importance of chemical mode of action and formulation in relation to the equipment being used to apply the chemical.

One result of the "weed-wiping" technique and of CDA and electrostatic spraying is greatly reduced application rates — both total volume and chemical rate. With CDA spraying, the achievement of reduced rates involves the use of smaller sized droplets to maintain coverage. This conflicts with the need to control drift and has, to some extent, led to the next step — the need to give a definite guidance to the spray droplets in their travel from nozzle to target. Electrostatic charging of the spray droplets provides such guidance.

What follows is a review of the important concepts in CDA spraying and the developments taking place in the electrostatic charging of spray droplets. The introduction of these techniques in New Zealand is also discussed.

2. CONTROLLED DROPLET APPLICATION (CDA)

A logical extension of the ULV (Ultra Low Volume) concept, the objective of which is to apply the minimum volume compatible with achieving economic control, is CDA spraying. CDA emphasises not only the importance of applying the correct size of droplets for a given target, but also the uniformity of droplet size, to optimise use of the minimum volume and dose to achieve effective control.

There are four important aspects of CDA spraying:

2.1 **The Target.** Precise definition of the target is vital if pesticides are to be used more efficiently. In horticulture for example, the target for insecticides and fungicides has been regarded as the crop itself, with no regard for where the pest might be in that crop. Also, insecticide applications may be more effective if applied in the evening, when conditions are more stable, and many pest species are more active. The importance of understanding the target was perhaps best illustrated by Himel and Moore (4). By using the fluorescent parti-

cle droplet sizing technique, he showed that droplets collected (impacting on) insects were never bigger than 50 μm (1000 μm = 1 mm). In contrast, over 99 percent of the spray volume commonly used was in droplets bigger than this.

2.2 **Droplet Size.** From work by Himel and others, it is clear that maximum control of a pest, with minimum use of chemical and minimum contamination of the environment, can be achieved when droplets of optimum size are used. If droplets much larger than the optimum are used, the amount of chemical wasted rapidly increases — a droplet of 200 μm has a volume 1 000 x greater than a 20 μm droplet.

Optimum droplet size will vary with different targets. It is possible to choose droplets small enough to follow the airflow around an obstacle such as a stem, yet large enough to impact on insects resting on it.

Larger droplets ($>$ 250 μm) are needed when settling of droplets onto horizontal surfaces with minimum downwind drift is required. Drift is accentuated when sprays are used under hot, dry convective conditions, because of the rapid decrease in droplet size due to evaporation. The smaller the initial droplet size, the more rapid the further decrease in size from evaporation, so with droplets smaller than 100 μm, oil based formulations should be used.

CDA spraying also implies a limited droplet size range. The volume median diameter (VMD) is defined as the drop diameter having half the volume of the spray in smaller drops, and half the volume in larger drops. The number median diameter (NMD) is defined as the drop diameter which divides the total number of drops into two equal groups, half (by number) the drops being smaller than then NMD, and half larger.

If all the droplets in the spray volume were exactly the same size, then:

$$\text{VMD} = \text{NMD},$$
$$\text{or VMD/NMD} = 1.$$

The closer the VMD/NMD ratio is to one, the more uniform the droplet size range. Ideally, for CDA the VMD/NMD ratio should be less than 1.4 (when sampling droplets on magnesium oxide coated slides) (10).

2.3 **Droplet Density.** The required number of drops/unit area will vary depending on the mobility of the pest, the characteristic of the active ingredient, and redistribution of the active ingredient over the target.

The theoretical droplet density obtained if uniform sized droplets were distributed evenly over a flat surface is given in Table 1.

Table 1: Theoretical droplet density when spraying 1 litre evenly over 1 Ha

Droplet Diameter (μm)	No of Droplets/cm^2
10	19,099
20	2,387
50	153
100	19
200	2 4
400	0 298

2.4 **Spray Concentration.** The basic measurement of acute toxicity of a chemical is the Lethal Dose, or LD. The dosage, in mg of active ingredient per kg of body weight of the test organism (mg/kg) which kills 50 percent of those organisms is described as the LD_{50} If the LD_{50} contained in a single droplet can be determined, the concentration of the spray required in controlled droplet application can also be calculated. When a high proportion of the spray reaches the target, a reduction in the total dosage compared with recommended dosages per unit of ground area may be possible. The application of 1 kg/ha is equivalent to 100 nanograms/mm^2 (1 nanogram = 10^{-9} gm). The lethal dose for some insects may be as little as 1.0 nanogram of certain insecticides, so in some circumstances, there could be 100 times overkill.

3. THE PRODUCTION OF NARROW DROPLET SPECTRA

One of the most promising methods of controlling size of droplets within fairly narrow limits is by using centrifugal force and various spinning discs, cups and cages have been designed. With spinning discs, the three most important parameters (apart from disc shape), are:

(i) Disc diameter

(ii) Disc rotational speed

(iii) Flow rate onto disc.

Liquid is fed near the centre of a rotating surface so that centrifugal force spreads the liquid to the edge at or near which the droplets are formed. Three methods of droplet formation, for increasing liquid flow rates, have been defined.

These are:

(i) Single droplets leave directly from the nozzle at low flow rates.

(ii) Liquid leaves the nozzle in the form of long curved threads or ligaments which break down into droplets.

(iii) At still greater flow rates, liquid leaves the nozzle in the form of a sheet which disintegrates — fragments of the sheet break up into ligaments and subsequently droplets. Sheet formation occurs when the

rotating surface is flooded; droplet formation is similar to that of hydraulic nozzles, and a wide range of droplet sizes is produced.

For VMD/NMD ratios of 1.4 or less, the total liquid flow rate onto a rotating surface should be such that droplet formation is by methods (i) or (ii) above. If larger flow rates are required for a given disc speed and diameter, a stack of discs can be used.

The other main type of rotary atomiser is the spinning cage. With this, the liquid is introduced through a central hollow spindle, then via a deflector, onto a rotating gauze, which completes the final atomization. The speed of rotation determines droplet size. The droplet spectra produced by rotating cage atomisers is not as narrow as that produced by spinning discs, with VMD/NMD ratios typically around 3.0.

As the name implies, CDA spraying emphasises the importance of the individual spray droplet. CDA sprayers are machines which exhibit a degree of control over both the droplet size and size range produced. Some equipment, notably the hand held spinning disc applicators, are intended to be used as drift sprayers. That is, use is made of prevailing winds to carry the pesticide (normally a fungicide or insecticide) to the target. This is a very important concept, as this type of sprayer produces a narrow size range of small droplets ($<100\mu m$) and if the correct procedure is not followed in their use, results will be poor. It is the promise of more positive control of the spray droplets in directing them to the target which makes electrostatic spraying attractive.

4. ELECTROSTATIC SPRAYING

As droplet size becomes smaller, deposition of these droplets by inertial or gravitational forces alone becomes more uncertain and they are prone to air borne drift. Droplet charging and electrostatic deposition technology has been proposed and investigated by a number of workers as a possible means of reducing drift and improving depostion (2,8). Figure 1 illustrates the effect of electrical propulsion.

The particles to be deposited are given a unipolar charge, q, as they leave the spray nozzle. The charge acquired by the particles is of the same polarity as the electrode, so that they are then electrically propelled away from it immediately they acquire charge. The force of propulsion, F_e, on each particle is qE, where E is the electric field strength. In some cases, the electrode may form an integral part of the spray nozzle.

Both electrostatic considerations, and efficient liquid use for adequate target coverage at low application rates dictates

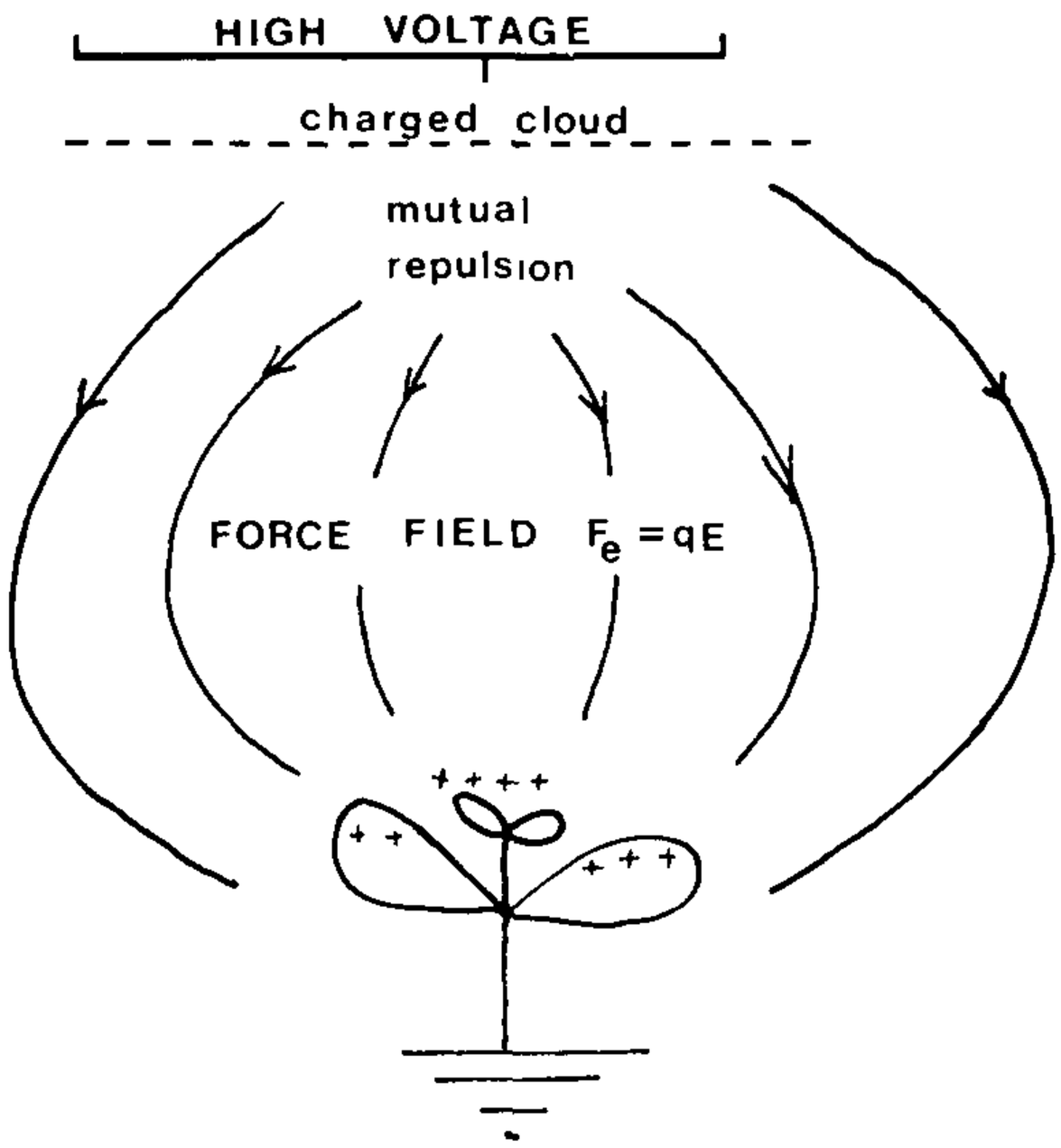

Figure 1: When particles are charged and ejected into a powerful electrical field, they experience a force F_e in the direction of the field

using droplets with diameters generally under 50 μm (7). Since the electrostatic charge resides on the particle surface, the electrostatic forces are proportional to the square of the diameter. The smaller the droplet, the greater the charge/mass ratio, and the greater the electrical force acting on the droplet.

One could expect more even deposition of spray droplets because of the mutual repulsion that occurs between like charged particles. Also, the travel path of droplets from nozzle to target will tend to follow the curved electrical flux lines

Table 2. A summary of the three main lines of work in the development of commercially available electrostatic sprayers

	Law	Arnold	Coffee
Droplet Production	Air Shear	Centrifugal	Electrodynamic
Droplet Charging	Induction	Ion Injection	Electrodynamic
Droplet Size (VMD)	30 - 50 μm	30 - 250 μm (adjustable)	40 - 200 μm (adjustable)
Application Rate	5 - 15 l/ha	0 5 - 20 l/ha	<1 5 l/ha
Formulation	Water Based	Oil and Water Based	Oil Based
Energy Requirement	750 w	7 - 10 w	0 1 w
Moving Parts	Compressor	Motor/Spinning Disc	None

that envelop the earthed target, rather than the straight line of sight (Figure 1). This would tend to give better coverage on the underside of leaves.

The principles of electrostatics are not new, but it is the development of suitable high voltage generators that largely has given impetus to the commercial exploitation of these principles. There are presently three main development areas being worked on, and these are summarised in Table 2 (1,3,7).

Comparisons of charged droplets with uncharged droplets drift sprayed onto cotton showed up to nine times greater recovery from the charged spray (2).

5. NEW PESTICIDE APPLICATION TECHNIQUES IN NEW ZEALAND

With the dramatic increase in horticulture over recent years, there has been a corresponding increase in awareness of the need for more efficient spray applications. The establishment of new crops such as kiwifruit, with their strict quality and chemical residue standards, places stringent requirements on spray application techniques. The success of CDA techniques in other cropping situations has led to the development of a CDA/airblast sprayer for kiwifruit. The first full field trials of this machine are being carried out by the Agricultural Engineering Institute this season. The treatments include the full Ministry of Agriculture and Fisheries export schedule spray programme, except that the active ingredient will be applied in a total of approximately 60l/ha instead of the usual 2,250 l/ha. A second treatment involves applying half the recommended of active ingredient again at an approximate total application rate of 60 l/ha. The machine, illustrated in Figure 2, uses spinning disc rotary atomisers with a modified plumbing and agitation system to handle the greatly increased liquid concentrations (almost all of the chemicals used in the kiwifruit spray programme are wettable power formulations).

A second example of the interest in greater application efficiency is the importation into New Zealand of the first commercially available electrostatic sprayer. The machine, a low volume airblast sprayer with a radial flow fan, uses air shear atomisers, with induction charging of the droplets.

In an evaluation of this sprayer, Inculet et al. (5) showed that, by using electrostatically charged liquid pesticide droplets, one can achieve a substantially enhanced leaf coverage in an orchard. They found a markedly improved deposition in the upper tree canopy with better uniformity of deposition.

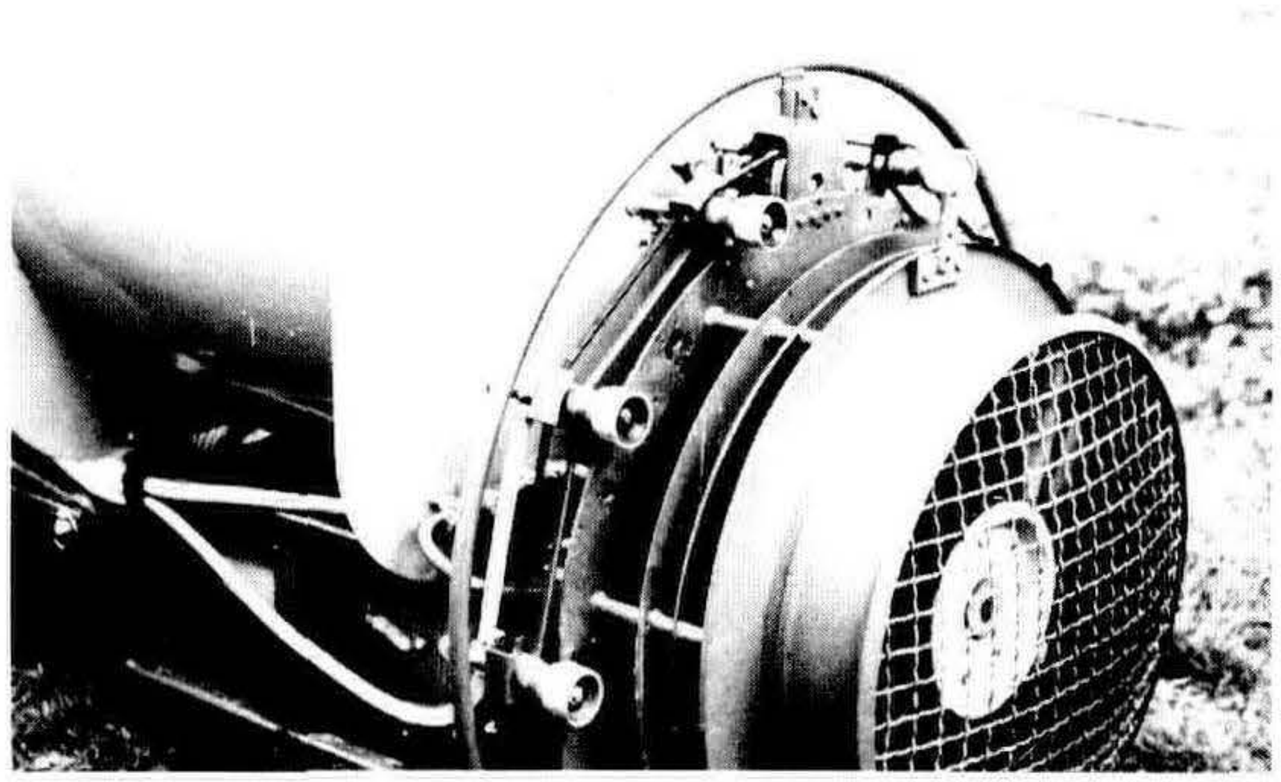

Figure 2: The CDA/Airblast sprayer being developed for kiwifruit, by the NZ Agricultural Engineering Institute.

6. SUMMARY AND CONCLUSIONS

The new techniques in spray application are exciting and offer real promise of greatly reduced total application rates and chemical rates. The path to achieving these objectives is not without potholes however. The underlying principles of CDA spraying have been set out clearly in many publications (e.g. 9); and reports of successful trial work demonstrating the advantages of the technique continue to be published. The drift spraying technique demands perhaps a greater operator understanding for success. He must, for example, learn to use the prevailing wind to direct the spray to the target. A number of parallel developments must occur for the successful implementation of the CDA technique. For example, the availability of suitably formulated chemicals currently lags behind the availability of application equipment. Again, widespread implementation of electrostatic spraying is unlikely within the next five years as there are many aspects still needing work — for example, drought stress on a target plant adversely affecting the deposition process by reducing the plant's ability to transfer charge (6).

While these developments are exciting it is perhaps appropriate to observe that to a large extent current spraying techniques and equipment used in New Zealand are effective. To make the most immediate impact in improving efficiency, the value of correct calibration and use of existing equipment should not be lost sight of.

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GRAFTING NUT TREES IN A COLD CLIMATE

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Ashburton, South Island

Until five years ago, grafted walnut trees could not be bought in New Zealand No nurseryman could offer them, yet in California alone, there are 200,000 acres of grafted walnuts in orchards, and we were told again and again that they were all grafted outside and there was no special trick about achieving good results.

The breakthrough came when we realised that the limiting factor was our low average temperature, thanks to our equitable maritime climate. Walnuts need a temperature of around 80°F for a period of three weeks to make a strong graft union and as you know, we seldom have a spell of weather as hot as this — thank heavens! California has a Mediterranean climate with moderate winters and very hot summers in the interior valleys, as does southern France where walnuts are grafted in the field as a matter of course. However, walnuts have the ability to callus in winter even though dormant and our grafting methods are based on this.

We like to use two-year-old black walnut (*Juglans nigra*) as the rootstock, it will grow a metre a year in the garden, but we need to do work on choosing more suitable rootstocks. *Juglans hindsii* is a possibility, as is the Manregian strain of the

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GRAFTING NUT TREES IN A COLD CLIMATE

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Until five years ago, grafted walnut trees could not be bought in New Zealand No nurseryman could offer them, yet in California alone, there are 200,000 acres of grafted walnuts in orchards, and we were told again and again that they were all grafted outside and there was no special trick about achieving good results.

The breakthrough came when we realised that the limiting factor was our low average temperature, thanks to our equitable maritime climate. Walnuts need a temperature of around 80°F for a period of three weeks to make a strong graft union and as you know, we seldom have a spell of weather as hot as this — thank heavens! California has a Mediterranean climate with moderate winters and very hot summers in the interior valleys, as does southern France where walnuts are grafted in the field as a matter of course. However, walnuts have the ability to callus in winter even though dormant and our grafting methods are based on this.

We like to use two-year-old black walnut (*Juglans nigra*) as the rootstock, it will grow a metre a year in the garden, but we need to do work on choosing more suitable rootstocks. *Juglans hindsii* is a possibility, as is the Manregian strain of the

common English walnut (*Juglans regia*). The latter is used but little in the States. I have some seedling trees out on the farm, but it will be some years before they start bearing.

We have had many problems getting good scion wood. New Zealand has a large disease-free seedling resource of walnuts and we spent some years tracking down the best trees. They were generally oldish with consequent short annual shoots growth, difficult to graft. Whenever possible, we persuaded the tree's owners to cut a limb to force vigorous new growth for the next year.

We are now at the stage of being able to take good vigorous wood off trees we grafted some years ago, which makes grafting easier if less exciting. This scionwood must be taken when the wood is dormant, but is can be stored for several months in a refrigerator at around 35°F. The ends of the sticks should be waxed to preserve their moisture and they should be wrapped in damp newspaper and then stored in a plastic bag. For safety's sake the damping should be done with a weak solution of fungicide.

I generally start my grafting in late winter (August) but other, more skillful propagators, start anytime after the leaves have fallen off. (Maybe they are just lucky.) I dig out my stock and bring them ınto the workshop, generally on a Saturday afternoon when the farm work is up-to-date.

If you have good quality scionwood, the type of graft you use doesn't seem to matter. An ordinary whip or tongue graft works well The trouble with walnut scion wood is that it is often very pithy, particularly if the wood is from an old tree. I have generally used the special graft developed at East Malling, England, for pithy wood. It ıs a double graft, giving a lot of cut surfaces and it fits tightly together even before being bound with budding tape. Personally, I think it is worth the extra time involved.

It is most important to use lots of fungicide. I dip the scion in a fungicide solution and dip the top end of the stock as well. If this is neglected, the grafted trees will soon be covered with mould in the hot box.

Once grafted, the trees are packed into a container of some description. I use old worm drench containers, but anything will do; then the roots are covered with sphagnum moss, sawdust, or pumice. This material is to keep the roots damp and a solution of fungicide is best to use. The correct degree of dampness is when all the water has been squeeze out by hand.

The whole container is then covered with a plastic bag which is tied onto the container. The result is that you get a microclimate which seems to be just right for the graft union.

Then the containers go into the hot box. This can be any shape or size. Its function is to provide a temperature inside itself of around 80°F. I use an enclosed bar heater attached to one end of the box. It should not be on the bottom as this will stimulate the roots into growth. I think it is important to have a small fan operating in the box to even out the temperature everywhere in the box. Without it, you will get quite a range of differing temperatures in various parts of the box. That's all there is to it. Just wait for three weeks and keep your fingers crossed. You should get better than 75% success.

When you take the trees out, they should be kept in a shaded area for at least a week till the leave green up. Leaving them in the sun will kill them. Some of the trees will not break dormancy and these I place out in the garden for a year. The others are potted up and planted in their final position as soon as the danger of late frosts is over. The sooner they are in the field the better.

The hot box method works but so did Stephenson's Rocket, and already we see members of the New Zealand Tree Crops Association improving on the method. Basically they are heeling the grafted trees into sawdust and then running a heating cable on either side of the actual graft, with all that area being well covered with straw for insulation This means that the main part of the tree will not be heated and consequently will not break out of dormancy till the season beckons. By next year we should have this system streamlined.

Grafts of hazel nuts (filberts), (*Corylus avellana*) need a temperature of around 70°F for good callusing and all my remarks about walnuts are relevant. I have grafted them outside but it is not very successful.

Chestnuts (*Castanea sativa*) can be grafted outside more easily than either walnuts or hazels They graft well in the hot box, requiring only a couple of weeks inside I favour tip grafting and have had good success even with wood not much thicker than a match

Tip grafting in the field has worked well. Our local nursery finds that side grafting is vastly better than splice grafting, and I aim to have a go at it.

Budding in the autumn is not successful. One of our members budded a thousand seedlings last season and only got six to take.

New Zealand has, a last, a large scale seedling resource of sweet chestnuts *which is totally disease-free.* In Japan, which imports a large tonnage of the nuts every year, the average life of a chestnut tree is only 15 years because of the disease and insect problems.

We have found some first rate chestnuts, mainly in the North Island; they are now recognised by the Government as an official export crop and we are all set to go.

ACCEPTANCE OF GLASS SUBSTITUTES IN GREENHOUSE CLADDING AND DESIGN

B.E. SINCLAIR

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Here in New Zealand, isolated as we are from the major horticultural areas of the world, new techniques and developments gain acceptance only slowly. New materials for the greenhouse skin are no exception. In recent times, other work (1) has covered the characteristics and operating costs of the alternatives. The aim of this paper is to comment on the current useage of these materials and their applications on the basis of information gleaned from greenhouse builders and growers themselves.

There are certain overlying considerations when choosing a covering and design:

1. The initial outlay.
2. The heat conservation properties of the total structure.
3. Repairs and maintenance, including re-cladding.

To put this another way, the operating costs of the proposed design per unit of area are a major deciding factor. This figure must, however, be balanced against any change in the yield or growth characteristics of the crop in a new environment. The necessity for and the cost of implementing any change in management practice under new conditions must also be considered.

Discussions with greenhouse builders indicate demand in the following areas:

1. Glass in single or multiple span remains popular with the preference being for aluminium construction for low maintenance. The higher cost of aluminium structures as compared with wood means that this is not always feasible. This type of structure appeals to growers of high light-demanding crops, in particular, winter production of vegetables.
2. Non-rigid plastics of the polyvinyl chloride (PVC) and ethyl vinyl acetate (EVA) types pioneered the plastic

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2. Non-rigid plastics of the polyvinyl chloride (PVC) and ethyl vinyl acetate (EVA) types pioneered the plastic

alternative. Their comparatively low capital cost and their flexibility in useage are major attributes. When two sheets are combined as a double film, separated by a layer of air, thermal efficiency is greatly improved. These films are being used with increased frequency in large-scale permanent operations.

3 Rigid plastics in current use in New Zealand are of two main types—

(a) Corrugated sheets of fibreglass reinforced acrylic plastic laminated with poly vinyl fluoride.

(b) Double skinned polycarbonate reinforced with plastic ribs

The main reasons underlying the grower's decision to use these products are the potential heat savings over glass, the strength and lightness of the sheet for easy handling, and their properties of light diffusion which renders the use of shading unnecessary for some crops even in mid-summer.

A strong feeling is evident even amongst those growers using these materials that the risks associated with producing a crop under a glass alternative are higher. This reasoning is on the basis of.

1. Inflammable nature of most of these products.
2. Structural deterioration, particularly of the non-rigid plastics, may place the entire crop at increased risk under wind or snow loadings.
3. Shortage of proven data on the weathering of coverings with respect to light transmission and structural deterioration.

Nurserymen and cut flower growers use a greater ratio of plastic to glass than other growers in general. The complexity of the situation and the range of alternatives offered makes it difficult to be sure that the best choice is made. As these materials gain acceptance, let's hope that the research for good practical information to help the grower rationalize his decision continues.

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RE-ESTABLISHING PLANTLETS FROM TISSUE CULTURE: A REVIEW

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Abstract. The literature pertinent to the re-establishment of tissue-cultured plants *in vivo* is reviewed The difficulties associated with survival and growth of tissue cultured plants after transplantation are attributed to the poor control of water loss from the plants and their necessity to switch from heterotrophic to photoautotrophic nutrition Aspects discussed include the possibility of transplanting directly from stage II shoot proliferation cultures and rooting *in vivo*, the importance of stage III culturing for preconditioning plants prior to transplantation, the optimum sizes of propagules and substrate preferences for transplantation, stress reduction, disease prevention, and the importance of humidity, temperature and light levels during transplantation The relative merits of numerous approaches to transplantation by various workers for many species are discussed Suggestions of areas in which further work is urgently required are given, along with some recommendations and general guidelines for the re-establishment of tissue cultured plants *in vivo*

INTRODUCTION

Plant tissue culture has become very important in horticulture for the rapid clonal propagation of plants (53-57). In recent years this technique for plant propagation has surpassed the mere stage of laboratory research and resulted in the establishment of many laboratories throughout the world to mass produce a wide variety of plants (especially ornamentals) on a commercial scale. Although there has been considerable research to optimize the nutrient medium and culture conditions for numerous plant species/cultivars, there has been a general lack of research examining problems associated with the re-establishment of tissue-cultured plants *in vivo*. This is unfortunate because the ultimate success of plant tissue culture as a commercial means of plant propagation depends on the ability to transfer plants out of culture on a large scale, at low cost, and with a high survival rate.

In this paper we review the literature relevant to the transfer of plants from tissue culture. Our intentions are to identify those areas in which further research is urgently required for the commercial exploitation of plant tissue culture and to provide some suggestions and general guidelines for the large scale re-establishment of tissue cultured plants *in vivo*.

PROBLEMS ASSOCIATED WITH TRANSPLANTING FROM TISSUE CULTURE

A sound knowledge of general nursery propagation meth-

ods is very important when attempting transplantation from tissue culture. However, it should be realised that plant propagation via plant tissue culture differs from conventional nursery practice in several key aspects, an understanding of which is necessary to maximise survival rates when re-establishing cultured plants *in vivo*. The plantlets used in tissue culture are usually much smaller and held in more precisely controlled environments than nursery seedlings or cuttings. Furthermore, the plantlets are cultured under aseptic conditions on nutrient media containing exogenous sugars and plant growth regulators. A third key aspect, especially relevant to transplanting, is that in tissue culture plantlets are grown in very high humidities, about 100 percent.

Due to the very precise conditions under which plantlets are cultured *in vitro*, carefully controlled hardening-off procedures are necessary for survival when transplanting from tissue culture. Even when supposedly gradual hardening-off procedures are carefully followed, poor survival rates are frequently reported.

Tissue cultured plants are difficult to transplant for two main reasons; firstly, their heterotrophic mode of nutrition and secondly, their poor control of water loss.

The plantlets used in tissue culture are very small and their growth requires an exogenous sugar (usually 2 to 3% sucrose) in the culture medium. Although the plantlets may appear "fully functional" physiologically, they are unlikely to be actively photosynthesizing — simply because it is unnecessary. Even if chlorophyll is present in the leaves, it is probable that the enzymes responsible for photosynthesis are inactive or absent. The transition from the heterotrophic state to the photoautotrophic state during the transplantation of *Brassica oleracea* Botrytis group plantlets from tissue culture has been studied by Grout and associates (30,31) They found that in culture there were very low levels of photosynthesis (estimated through the activity of the Hill reaction, $^{14}CO_2$ uptake and net CO_2 exchange in light and dark), despite the green appearance of the plantlets (although chlorophyll levels were also low). Active growth in culture was therefore dependant on the exogenously supplied carbon source. When such plants are transplanted, there is an immediate necessity for the regenerated plants to assume a fully photoautotrophic nutrition Even seven days after transplantation of *B. oleracea* Botrytis group plants from tissue culture, there was still no net CO_2 uptake (ie: CO_2 released in respiration was greater than that taken up by photosynthesis) (30). A net uptake of CO_2 was not achieved by these plants until 14 days after transplantation, at which stage they had become fully photoautotrophic and could sus-

tain normal growth. Therefore, poor development of the photosynthetic system in tissue culture may be a major factor causing newly transplanted plants to be vulnerable to any form of environmental stress.

There have been several investigations examining the problems associated with the water relations of plantlets on their transfer from tissue culture. The leaves of tissue-cultured *Prunus insititia* plants have smaller palisade cells, larger intercellular spaces and lower stomatal frequencies compared with transplanted plants (13). Such leaf anatomy is characteristic of leaves grown in high relative humidities and is also more sensitive to water stress (24). In tissue-cultured plants, poor vascular connections between the shoots and roots may reduce water conduction. Such morphological abnormalities have been reported in tissue cultured *Brassica oleracea* var. *botrytis* plantlets, where no water transfer from roots to shoots could be detected (29).

Scanning electron microscopy studies have revealed a considerable reduction or absence of epicuticular waxes on the leaves of plantlets produced in culture compared with greenhouse grown plants (28,29,31). There was an increase in the density of structured epicuticular waxes occurring in response to a gradual decrease in humidity during the hardening-off process. For *Brassica oleracea* Botrytis group this was also associated with an increase in both the weight of epicuticular waxes and the water contact angle, and a decrease in the rates of water loss from plant tissues (28,29,31). Because the wax component of cuticles determines the rate and extent of water diffusion through the cuticle (48), the extreme susceptibility of tissue-cultured plants to wilting on transplantation was initially attributed to a severe reduction during culture in epicuticular wax formation and possibly a deficiency of wax within the cuticle (28,29,31). However, more recent evidence suggests that this may be due to stomatal as well as cuticular phenomena.

A considerably higher rate of water loss from excised leaves of tissue-cultured plants than plants transferred to a greenhouse has been demonstrated in *Malus domestica* (12), *Prunus insititia* (13) and *Solanum laciniatum* (18). In these experiments, the tissue-cultured leaves lost more than 50 percent on their moisture content within 30 minutes for *P. insititia* and 70 minutes for *S. laciniatum*, compared with 90 and 140 minutes respectively for transplanted leaves. Electrolyte leakage and ethylene/ethane analyses have indicated cell injury in *P. insititia* leaves at 50 percent water loss (42). The rates of water loss and stomatal closure have been examined in excised leaves of *M. domestica* plants during acclimatization from culture to the greenhouse (12). The results demonstrated

that the high rates of water loss from tissue-cultured leaves are attributable to slow stomatal responses. With five days acclimatization at 30 to 40 percent relative humidity, these leaves had regained normal stomatal functioning. Microscopic examination of detached *S. lacinatum* leaves (initially fully turgid) over a 16 h period, demonstrated that leaves of transplanted plants had closed all of their stomata within 30 minutes of detachment, whereas half of the stomata from tissue-cultured leaves were widely open after 16 hours (18). Measurements of water loss from *P. insititia* leaves with either the adaxial, abaxial, both or neither surfaces coated with silicon rubber have clearly shown that the water loss occurs solely through the abaxial surface (25). All the stomata on these leaves are located on this surface (12).

Therefore, it appears that the rapid wilting of tissue-cultured leaves immediately after transplantation can be attributed to the inability of their stomata to close, rather than reductions in wax components of leaf cuticles. This is because the leaf cuticles are primarily effective in controlling water loss only after stomatal closure. Nevertheless, later acclimatization involving cuticular development is no doubt important once the stomata are fully functional, and is probably essential before transplanting plants from a greenhouse into the field. The reason why tissue-cultured plantlets have inactive stomata and poor cuticular development remains to be shown. This probably relates, to some extent, to the culture environment (especially the very high humidity in culture vessels); however, the culture medium (particularly the plant growth regulator component) may also have an important influence. Once such casual factors are clearly understood, then possible treatments to help avoid the wilting response during transplantation can be examined.

The problems associated with transplantation from tissue culture may be alleviated to some extent during the final stages of tissue culture as discussed later in this paper.

TRANSPLANTATION FROM STAGE II CULTURES

Four important stages of plant tissue culture have been defined by Murashige (53,56) for use in plant propagation:

Stage I — establishing an axenic culture,
Stage II — the multiplication of propagules,
Stage III — the preparation of propagules for transfer to soil and
Stage IV — the re-establishment in soil.

Although propagules of some cultivars from stage II have been directly transplanted out of tissue culture, difficulties are fre-

quently encountered with some cultivars and may be overcome by a preparatory step (stage III) just prior to transplantation.

Transplantation from stage II cultures involves the rooting of individual shoots after their removal from tissue culture, i.e.: treating them as micro-softwood cuttings. In fact, shoots from *Vaccinium ashei* cultures have proved to be easier to root than conventional softwood cuttings (46). A distinct advantage of such early transplantation for commercial plant propagation is that it by-passes the need for stage III culturing. Cost analyses for propagating plants via tissue culture indicate that labour comprises over 65% of the total tissue culture production costs and that stage III requires a considerable labour input for subculturing with usually no increase in the number of propagules (6,5,22). Substantial savings per unit plant produced from tissue culture have been calculated for *Begonia rex* (22), *Brassica oleracea* (6) and *Ficus elastica* (22) if stage III is eliminated.

Successful rooting and growing on of tissue-cultured shoots after their transplantation from culture has been achieved in a wide variety of species. In several species pretreatment of the bases of excised shoots with auxins has promoted rooting. However, such hormone dips can occasionally be toxic to the delicate tissues of cultured plantlets, e.g.: *Vaccinium* cultivars (15) Debergh and Maene (21) recommend that shoots with fragile leaves and stems be pretreated with an aqueous auxin prior to transplantation. They have developed two successful techniques involving the prolonged use of weak auxin solutions (2 mg l^{-1} IBA). Isolated shoots were either soaked for ten days in 2 mm of the auxin solution (especially successful for *Begonia* × *tuberhybrida*) or planted directly into an artificial substrate (rockwool) previously saturated with the auxin solution. Using the latter method, the auxin concentration is gradually lowered by appropriate misting or irrigation. This promotes root elongation after the auxin-induced root initiation. The rate of leaching can be easily controlled for the species in question.

A partial tissue culture technique for ferns has been developed by Knauss (41) which is essentially similar to transplantation from stage II cultures. This involves the culture of fern gametophytes which are macerated in a blender and then spread over a soil mix. From the fragmented gametophyte tissue, large numbers of sporophytes develop (41).

IMPORTANCE OF STAGE III CUTTINGS

Even though it may be possible to transplant a species from stage II cultures, a short stage III period may not only increase survival rates (e.g.: *Asparagus officinalis* (34)), but also

markedly improved the vigour of the transplants (e.g.: *Brassica oleracea* (4)), and uniformity in growth of the plantlets (e g.: *Chrysanthemum* × *morifolium* (23)). However, with other species it is not possible to transplant directly from stage II shoot proliferation cultures and a preparatory step (stage III) is obligatory. The objectives of stage III are to fulfill one or more of the following (53-56).

a) the division of shoots and their individual rooting,

b) rendering the plantlets capable of photoautotrophic growth,

c) fulfillment of dormancy requirements, and

d) attempt to confer some resistance to moisture stress and microbial infection.

The length of the stage III culture period may be relatively short After transplantation, survival rates of *Dracaena surculosa* (Syn. *D.godseffiana*), *Scindapsus aureus* and *Syngonium podophyllum* were maximized with only seven days of stage III culture, whereas *Cordyline terminalis* required 14 days (52).

1 **Formation of Roots.** When inducing roots on shoots cultured *in vitro* it is advisable not to let the roots grow too long as this increases the probability of root damage during transplantation. Also roots frequently die after transplantation and new roots must then develop *in vivo* if the plants are to survive (20,21) Unfortunately this is usually accompanied by a cessation in plant growth (21). When rooting *in vitro* is necessary, it is preferable to transplant the plantlets just after root initiation and before root elongation. If stage III culturing is necessary to provide objectives other than rooting, then the culture medium used may not necessarily be the one which initiates root formation the quickest, but rather the one which initiates root formation just as the other objectives of stage III are fulfilled. For rooting *Citrullus lanatus* plantlets, Barnes (9) used a liquid medium with a vermiculite substrate for support and aeration This resulted in a significantly superior root system with numerous lateral roots and extensive root hairs compared to rooting on an agar based medium (9). There was also less damage to the roots and higher survival rates on transplantation out of culture. The rooting of *Malus* spp. has also been very successful under similar conditions (69). To aid vascular connections between shoots and roots, it is important that the roots are initiated directly from the shoots and not from callus at the shoot bases. Therefore, any unorganized tissue should be removed from the shoot bases during their subculture onto a rooting medium. When roots arose from such callus in *Salpiglossis sinuata*, plantlets failed to survive on transplantation (38).

2. **Induction of photoautotrophic growth.** The stress experienced by tissue-cultured plantlets immediately after transplantation is undoubtedly reduced if their mode of nutrition is switched from heterotrophic to photoautotrophic growth prior to transplantation. Therefore, whenever the other stage III objectives are possible under photoautotrophic conditions, the stage III culture medium need not contain an exogenous carbohydrate. For example, *Solanum laciniatum* shoots readily rooted on MS mineral salts (17), whereas rooting on such inorganic media has not been successful for *Saintpaulia ionantha* (62).

3. **Fulfillment of dormancy requirements.** The possibility of having to fulfill dormancy requirements of plantlets before their transfer out of culture has been discussed by Murashige (53-56). He suggests that unique temperature regimes may be necessary in the stage III culture of plants with bulbs, corms, tubers or other similar storage organs and possibly other plants adapted to a temperate climate. Apparently the necessity of pre-exposure to low temperatures is especially important for propagules lacking foliage (56) To prevent dormancy in the apical buds of *Prunus insititia* after transplantation from tissue culture, it has been necessary to provide a two-month chilling pre-treatment at 0°C before potting and/or a post-potting spray of 200 mg l^{-1} GA_3 (37). There was also a strong tendency for plantlets of *Gladiolus* and other bulbous plants to become dormant and form resting corms or bulbs, both in culture and when planted into soil (39). However, this dormancy could be overcome by a cold treatment at 5°C for 3 to 4 weeks (39). The necessity of stratification prior to transplantation has also been recognized by Hilderbrandt (36) for cormlets of some *Gladiolus* × *hortulanus* cultivars Maintaining cultures at low temperatures is also useful as a means of storing plantlets until sufficient numbers accumulate for transplantation on a mass scale and/or when a suitable market exists for plants. Rooted plantlets of *Fragaria* × *ananassa* have been stored for several months under refrigeration prior to transplantation (11). Transplanted plantlets of *Rubus* spp. have even been stored at 4°C under low light intensity for 14 months with losses less than 5% (69).

4. **Tolerance of moisture stress and pathogens.** The hardening of plantlets to improve their tolerance of moisture stress and pathogens can be achieved to some extent in stage III tissue cultures by increasing the agar concentrations and/or the light intensity. A switch from liquid to agar-based medium during the final culture phase reduced wilting of *Brassica oleracea* Botrytis group plantlets after their removal from culture (31). Such a change has also allowed the successful transplantation of *Syngonium podophyllum* (52). Increasing the agar

concentrations from 1 to 1.4 percent for the rooting phase created considerably drier culture conditions and resulted in higher survival rates for many herbaceous perennials after transplantation (68). Such changes no doubt improve the water relations of the plantlets by promoting stomatal functioning and/or cuticular development. Promoting cuticle formation can also help in creating a barrier to pathogen infection (48).

Increasing light levels by 3 to 10x during the final culture phase is known to improve survival and/or growth after transplanting in bromeliads (53). Higher light intensities for many species including *Carica papaya* (67), *Citrullus lanatus* (9), various ferns (14) and *Ficus* spp (47) have helped. Higher light intensities not only increase cuticular development (48), but may also assist in promoting photosynthetic activity. In *Asparagus officinalis*, higher light intensities also induced the differentiation of cladophylls (34). Plants with cladophylls had a considerably higher survival rate after transplantation. It was suggested that cladophylls may have helped to establish photoautotrophic growth (34).

5. **Potential problems with stage III culturing.** It is important to realize that stage III culturing can have some subtle detrimental effects on transplantability. For example, although rooting of *Hosta decorata* has been possible on a range of NAA concentrations, high survival rates on transplantation were only possible for those plantlets rooted on a medium containing no or low NAA levels (58). A similar response has been reported in *Rosa* hybrids where the concentrations of plant growth regulators and the inorganic salts on which the plantlets were last cultured, greatly influenced subsequent transplantability (33).

A related problem involves the early transplantation of plantlets. For example, if various bromeliads are transferred into soil too soon, a residual effect of the culture medium results in continued axillary shoot proliferation (51). Unfortunately, this is undesirable in many plants, including bromeliads (51) and woody species to be used as rootstocks, where single-stemmed plants suitable for grafting are required (37). The tendency for weak multi-stemmed plants to develop after transplantation in *Prunus insititia* rootstocks has been overcome with a two month chilling treatment at 0°C prior to transplantation and/or spraying with 200 mg l^{-1} GA_3 subsequent to transplantation (37). When light intensities are increased during stage III culturing to assist hardening-off, it is noteworthy that such treatments are also known to reduce rooting to *Asparagus officinalis* (7,34), *Gerbera jamesonii* (59) and *Saintpaulia ionantha* (10). Therefore, when rooting and exposure to higher light intensities are important during stage

III culturing, it may be necessary to start the cultures under low light for a short period (1 to 2 weeks) to initiate root development, then subsequently increase the intensity.

PROPAGULE SIZE FOR TRANSPLANTATION

From studies reporting survival rates for different sized propagules after transplantation from tissue culture, it appears that propagule size must be over a certain minimum to maximize survival rates. In addition, Leech (45) found that the initial mean shoot height of *Pinus taeda* plantlets surviving transplantation was 2.6 cm, compared with 1.4 cm for those which died He also noted that, among the surviving plants, those with larger initial heights tended to have greater initial shoot growth for the first 17 weeks after transplantation. Greater uniformity in plant growth after transplantation was achieved if *Chrysanthemum* × *morifolium* plantlets less than 1 cm high or with poor roots were not potted up (23). Well rooted plants have also been reported to improve acclimatization of *Malus* spp. (69), and survival rates of *Acacia koa* (60) during transplantation.

STRESS REDUCTION DURING TRANSPLANTATION

The placement of culture vessels in a greenhouse for several to 10 days before plantlet removal has occasionally been recommended to allow for some acclimatization to greenhouse light and temperature regimes prior to transplantation. This has been successful for *Prunus avium* and *Prunus insititia* (40). However, a potential problem with such procedures as heat accumulation within the enclosed culture vessel due to a "double greenhouse effect". This can be overcome by removing the closures of culture vessels provided the plantlets are adequately watered to prevent wilting. The possible introduction of microbial contaminants at this stage is considered unimportant. Takatori *et al.* (64) flushed the culture vessels daily for one week with half strength Hoagland solution to slowly dilute and remove the unused sugar and other organic constituents of the culture medium, thereby promoting the switch to photoautotrophic growth.

Although leaving a gelled, sucrose-containing culture medium intact around the roots has been reported to help reduce stress when transplanting *Lactuca sativa* plants from tissue culture (43), this practice is not advisable. When removing plants from tissue culture it is important that all the culture medium be thoroughly washed from around the roots. Any traces of culture medium will be rapidly colonized by microorganisms after removal from axenic conditions. Severe problems associated with damping off, etc., could result from any

active microbial growth around the very tender root tissues of cultured plants. The gelled culture medium should only be left intact if it contains no organic constituents. Rooting can occasionally be achieved on such media, e.g.: *Solanum laciniatum* (17), and transplanting with gelled media intact may help to prevent damage to the delicate roots and assist in acclimatization to the soil mix.

SUBSTRATE PREFERENCES FOR TRANSPLANTATION

The nature of soil mixes used for transplantation can influence both survival rates and subsequent growth. Different species appear to do best with different substrates, so no general guidelines can be given for all plants However, it is reasonable to expect that soil mixes in which a species is usually grown for conventional vegetative propagation will be suitable to use for transplantation from tissue culture. A thin layer of sphagnum moss over the surface of the planting mix improved both the survival and rooting of *Rhododendron* spp. (3).

For most plants it is important that the soil mix be porous enough to prevent water-logging conditions Good aeration after transplantation from tissue culture is known to be important for the survival and growth of *Grevillea* hybrids (27), *Rhododendron* spp. (3) and *Rubus idaeus* (61). The pH of the soil mix may also be important. For example, plantlets of *Fragaria* × *ananassa* transplanted into peat do best at a pH between 5 5 and 7.0 (19). During re-establishment *in vivo* the addition of fertilizer to the soil mix greatly improved the health and survival of *Rhododendron* spp. (3) In other studies commercial fertiliser preparations have been routinely added to soil mixes, or plantlets have been irrigated with the inorganic salts of the tissue culture medium or full or half-strength Hoagland solution (38,45,66). Williams and de Lautour (66) found a slow-release fertilizer to be just as effective as half-strength Hoagland solution. The application of nutrients as foliar sprays may have the added benefit of helping to prevent desiccation. Plantlets of *Carica papaya* have been sprayed with 0.1% Hyponex (N:P·K = 7:6:19) after transplantation from culture (67) whilst those of *Pyrus communis* were fertilized once a week by spraying with an atomized solution of 0.2% fertilizer (N.P.K = 20·20:20) (44)

The hardening-off of tissue-cultured *Acacia koa* plants was more successful in non-sterile Hoagland solution compared with various soil mixes (60). This assisted with the initiation of photoautotrophic growth and the development of functional roots (especially when light was excluded from the root system) (60). Such procedures should prove useful for

those plants which can tolerate their roots being continually submerged in liquid, as this may assist them to overcome the water stress problems associated with transplantation.

To assist tissue-cultured plants in acclimatizing to soil mixes, they may be aseptically planted into culture vessels containing sterilized soil mix for a short period. This has been very successful for the carnivorous plants *Cephalotus follicularis* (1) and *Pinguicula moranensis* (2). Such a step can be easily incorporated into the stage III tissue culture period. *In vitro* rooting in a liquid medium using a soil mix for support and aeration has been readily achieved for *Citrullus lanatus* (9) and *Malus* spp. (67). To promote the switch to photoautotrophic growth in *Coffea arabica*, Herman and Hass (35) aseptically transferred rooted plants into culture vessels containing a sterile soil mix saturated with the inorganic salts of the tissue culture medium.

DISEASE PREVENTION DURING TRANSPLANTATION

Unsterilized soil mixes have occasionally allowed successful transplantation of tissue-cultured *Brassica oleracea* (28). However, this practice resulted in serious microbial infection problems for *Lactuca sativa* (43). Although plants may have some genetic capacity to resist disease, when removed from tissue culture their small size, poorly developed cuticles and soft, immature tissues makes them very vulnerable to pathogenic attack. The principles and methods of disease prevention during plant propagation outlined by Baker (8) and McCully and Thomas (50) should be adhered to when transplanting from tissue culture. Disinfected soil mixes and containers plus good hygiene and sanitation are important.

Fungicides have also been frequently used to guard against pathogenic attack when transplanting tissue cultured plants. This may involve treating the soil mix itself and/or the plantlets either before or after transplantation Jiffy 7 expandable peat pellets have been soaked in 0.3 mg l^{-1} Terrazole before transplanting *Daphne* × *burkwoodii* (16). *Artemisia dracunculus* var. *sativa* and *Acalphya wilkesiana* were dipped into an aqueous captan mixture (26,63) and *Trifolium* hybrids were washed with 0.045 percent benomyl prior to transplantation (65).

IMPORTANCE OF ENVIRONMENTAL CONDITIONS DURING TRANSPLANTATION

As with conventional cutting propagation, success in growing on tissue-cultured plants essentially relies on the maintenance of turgid plantlets until growth begins. A small

loss of turgidity can slow plantlet growth or reduce survival rates. The most important environmental factors are humidity, temperature, and light.

1. **Humidity.** In tissue culture, plantlets are grown in very high humidities (ca. 100 percent). Due to their poor control of transpiration, a gradual change from very high to low humidity is especially important, otherwise plantlets rapidly wilt and become excessively desiccated, from which they are unable to recover, and eventually die. For example, the relative humidity must be maintained above 90 percent for at least 15 days after transplanting *Fragaria* × *ananassa* (19) and above 80 percent for 14 days for *Saintpaulia ionantha* (10).

High humidity can be maintained with the use of intermittent mist and/or humidity tents. With intermittent mist the moisture content of the growing medium can become excessively high and result in abnormal O_2 and CO_2 levels (22). Waterlogged soil mixes are known to inhibit the growing on of tissue-cultured *Grevillea* hybrids (27), *Rhododendron* spp. (3) and *Rubus idaeus* (61). Poorer growth and/or survival of tissue-cultured plants under intermittent mist compared with humidity tents have been reported for *Begonia rex* (22), *Citrullus lanatus* (9), *Nephrolepsis exaltata* (22) and *Saintpaulia ionantha* (22). In addition, the leaves of tissue-cultured *Sinningia speciosa* became dotted with small black necrotic spots when grown-on under intermittent mist compared with healthy leaves under humidity tents (32). Therefore, it is recommended that freshly transplanted plants from tissue culture be placed under closed tent-like structures designed to maintain high relative humidities. The use of capillary mats under tents enables very high humidity levels to be maintained. Plants can be gradually hardened by allowing progressively more air flow through the tent as new shoot and/or root growth appears.

The spraying of plantlets with antitranspirants and/or waxes immediately after transplantation may also help, to reduce wilting and promote survival and may, to some extent, overcome the necessity for high humidity chambers. Survival rates of 95 percent have been attained for *Anigozanthos* spp. and *Macropidia fuliginosa* when plantlets were sprayed with 1 percent (v/v) 'Acropol' (a poly-vinylacetate antitranspirant) and placed directly on greenhouse benches, compared with only 80 percent survival for plantlets in high humidity chambers (49).

2. **Temperature.** As most plants show optimum growth at even, moderate temperatures between approximately 20°C and 27°C (22), such conditions are recommended when transplanting tissue-cultured plants. Lower or higher temperatures and/

or drastic fluctuations may result in uneven growth. Root development may be hastened by the use of bottom heat, especially when ambient temperatures are low.

If humidity tents are used, then temperatures within them should be monitored. This is because excessively high temperatures may occur during high light intensities and when the ambient temperatures are high. Extra shade or ventilation could be used to overcome this problem.

3. **Light.** It is generally recognised that freshly transplanted plants from tissue culture show greater growth and higher survival rates if they are initially placed under low light and gradually moved to higher light intensities. Light intensities of approximately 60-130 μ Em^{-2} sec^{-1} have been recommended for plantlets when they are initially removed from tissue culture (22). For the rapid growth of *Acacia koa* Skilmen and Mapes (60) found that plants removed from tissue culture required light intensities of at least 100 μ E m^{-2} sec^{-1}.

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A NURSERY FACILITY IN THE BULLER AREA OF NEW ZEALAND

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Knights Nurseries was established on 16 March, 1968, on the West Coast of New Zealand's South Island in the county of Buller, close to the town of Westport. That a tree and shrub nursery was not established sooner was due, firstly to the heavy rainfall of the area, 2¼ million gallons to the acre, or 8½ ft. at sea level and, secondly, the soils in this area are classed Podzols with a very acid pH of 4.5. However, the development of container-growing overcame this second consideration.

The first requirement was to find a 20 acre block of free-hold land. Land that could be drained, close to native sub-tropical rainforest for shelter as a setting, while still remaining close to the railhead at Westport.

Having found a suitable block of land, we designed a landscape plan of the proposed nursery, aiming for a low maintenance attractive layout. The time to use a bulldozer is before planting trees, so time taken in advance design is well spent.

The next job was to plant shelter and dig drains to a creek as the land was very swampy but with plenty of fall. We needed to drop the water table 4 ft. The shelter material we chose was *Populus nigra* and we planted 6 ft. poles at 2 ft. centres.

To make a gravel pad for containers and the access roads, we used a bulldozer to contour the land. There being no drainage downwards all rainwater must runoff, any hollows just fill with water. (The topsoil was pushed into a heap to be made into potting mix.) Gravel fill was pushed over the top to form a hard firm pad that could be used the year round and over this we spread a layer of rock chips to help prevent weeds and stop the roots of container stock penetrating the gravel pad.

An irrigation system was used, with overhead sprinklers on 4 ft. high, ¾ in. pipes to allow tall plants to be watered.

The first propagation facility we used was an A-frame type cold frame with 35% shade cloth, 24 ft. long, 6 ft. wide, using a mix of 60% crusher dust and 40% hardwood sawdust. this was very successful; we were able to root a wide range of plants.

We then progressed to a 30′ x 40′ propagation shade house with 10° sloping concrete pad, covered with 40% shade cloth,

with 4 rows of misting nozzles. We ran the misting system 24 hrs a day and, in mid-summer, we rooted ericas and callunas (in 2 to 3 weeks), rhododendrons and camellias. In fact, with high sunshine hours and warm temperatures, most cuttings rooted well and quickly We use bottomless boxes placed in galvanised trays; the boxes are filled with the rooting mix, the cuttings are stuck, and then are placed in the outside propagator. The trays are slid out from under the cuttings ready for use under the next box. When the cuttings had taken, the tray was pushed under the box of cuttings for removal to the potting shed, with their roots holding the medium firm. When potting the cuttings from the tray, the box was removed allowing easy access to the cuttings with no roots through the base of the tray to contend with.

Various potting mixes have been tried. At present we are using spaghnum peat 10%, soil 50%, and sawdust 40%. The mix is a John Innes type, using steam sterilized soil, to eliminate weeds and fungus. We have used methyl bromide but found that this does not kill clover-type weeds.

Next we built a polythene propagation tunnel 60 x 20 ft. with a full concrete floor. This house can be used at a later date for retail sales by removing the irrigation system and sand beds The propagator has timber-framed ends clad in polite sheets, two paths 2 ft wide with a central bed 10 ft. wide with 2 rows of misting nozzles and two 3 ft. beds down either side with one row of misting nozzles. At one end there are two 30-in doors and, the other end, a 7 ft. wide door to bring in machinery. Both ends of the propagator are vented.

Tanalized timber extends around the edges of the bed to retain 3 inches of sand base with heating cables for bottom heat. Propagation trays, tubes, or bottomless boxes can be placed on the sand base, this allows excess water to pass down into the sandbase and capillary action helps to keep them moist This saves the need for constant watering. Sand beds hold heat in the water and give this off during the night, reducing heating costs Heating is from a 2 Kw fan on a thermostat with a two-heat switch.

During the summer we maintain 30°C and a high humidity at 80 percent. In the propagator our rooting medium is sand — sawdust — spaghnum moss, in the ratio, 2-6-1. We mix Captan with the hormone powder at a ratio of 1-10. Cuttings treated in this way have very good clean roots

In the mid-1970's poplar rust from Australia arrived on the wind. It started as a small orange blotch about ¼ in. diameter and soon was on all the trees. In the following years the rust defoliated the trees very early, new growth was stunted, and

the trees lost vigor. We cut out our shelter belts and looked for a suitable replacement. We have replaced these with *Populus flevo* and *Salix matsudana*.

Our potting shed was built in 1970 with 4 ft. concrete walls with a timber frame of 10 ft. x 26 ft. x 32 ft. All daily work is carried out in the potting shed and for soil storage and tractor storage we built a 45 x 38 ft. cyclone truss shed. This enables us to work 12 months of the year. Even with 6 months continuous rain, we always had dry soil.

For weed control the gravel pad is sprayed with Paraquat and Simazine for long-term weed control, using Roundup for any hard to kill weeds. For containers we use Simazine or Ronstar but not as an overall spray. We use a hand dosing gun with a spray tank containing Paraquat and Simazine or Ronstar. Tractor spraying is used around the base of trees or shrubs having mature stems only. A paint brush dipped in Roundup and Ronstar, wiped over the foliage of the weeds, is very effective, and is quicker than hand weedings.

POLYTHENE VS. ALUMINIUM FOIL FOR KEEPING PLANT MATERIAL FRESH AND HEALTHY

GRAEME C. PLATT

Platt's Nursery, Albany

Transparent and opaque polythene bags are extensively used by nurserymen and plant propagators We put cutting material in them to keep them fresh, we store seeds and we even sell trees and shrubs nicely packaged in lovely polythene display packages. We also use them for a dozen and one other purposes and take it for granted they are doing the job well. Polythene bags are clean, cheap, don't go soggy, are reasonably tough, and competitively priced. About the only shortcoming transparent and opaque polythene bags have is that they don't do what they are supposed to do, i.e. keep plant material fresh and healthy. In fact, it is hard to find any container more useless for the storage of live plant material. Cutting material collapses, seeds lose viability, flowers wilt, fruit rots, and it all happens better and quicker in polythene bags. Waxed paper, waxed cardboard, wooden boxes, damp sacking, damp cotton, and even tin cans are all superior to polythene for the purpose of keeping plant material alive and healthy.

On the other hand, aluminium foil is the material which far outshines all others with regard to keeping plant material fresh during storage. In any comparison between these two

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On the other hand, aluminium foil is the material which far outshines all others with regard to keeping plant material fresh during storage. In any comparison between these two

materials, it is important to understand their diverse physical properties Polythene is excellent for admitting light which will pass through a thin, clear polythene bag with little impedence. Aluminium foil, on the other hand, is extremely inefficient at admitting light — in fact, all light is reflected off its shining surface. Polythene is very inefficient at conducting heat and, therefore, is a reasonably good insulator. A 1 cm. thick sheet of polythene can be melting on one side and be cold on the other. Aluminium foil is very efficient at conducting heat. A 1 cm. thick sheet of aluminium foil will be the same temperature on both sides very quickly.

These diverse physical properties are the basis for the huge difference in the performance of these two substances as a packaging material. Polythene bags admit short wave energy in the form of radiation and light. This energy is converted into long wave heat upon striking the substances contained within the bag. This heat is retained within the bag by the insulating properties of polythene, which is actually operating as an efficient little solar heater. Aluminium foil, on the other hand, so efficiently reflects nearly all the short waves striking its surface, that there is no heat build-up either inside the bag or on its outer surface.

Furthermore, as aluminium foil is an excellent conductor of heat, should any long wave heat build up, it is readily conducted evenly through the foil and rapidly lost. Therefore, it is much cooler inside the bag under the same energy conditions as the polythene bag. This can be readily demonstrated by placing a thermometer inside both the polythene and aluminium foil bags. These thermometers should have a piece of black polythene wrapped tightly around the bulb and held in place by a rubber band. These bags should then be sealed around the top of the thermometer with a second rubber band, to trap the air inside. The thermometers should be so arranged as to not touch the sides of the bag, and be so placed that the temperature can be read without removing them from the bags. A third thermometer is required to take the temperature outside the bags. Temperatures under different situations are shown in Table 1.

The temperature readings were mostly made on a cool, cloudy day, with a light to moderate wind blowing. The recording taken in the sunny automobile seat shows the folly of collecting propagating material in a polythene bag, and then tossing it on to the seat of the car, as many have done from time to time. The temperature of 60.25°C. exceeds that recorded in most of the world's hottest deserts. Temperatures of that magnitude are no place to store plant material. In only one instance did the polythene bag temperature show a cooler

Table 1. Temperature comparisons between polythene and aluminium foil bags

Location of bags	Air Temp °C	Foil Bag Temp °C	Poly Bag Temp °C
Storage shed with little lighting	17 25	17 00	18 00
Automobile back seat — dull and cloudy day	23 50	23 25	25 00
Automobile front seat — dull and cloudy day	22 50	22 50	24 00
Dwelling house room with electric lights on at night	17 00	17 00	17 25
Dwelling house room, dark at night	19 50	19 50	19 50
Domestic refrigerator	3 00	4 25	4 00
Windowsill — bright and cloudy	20 50	20 50	25 75
Windowsill — dull and cloudy	18 75	18 75	20 75
Shaded horticultural glasshouse — bright and cloudy	19 50	20 00	28 00
Shaded horticultural glasshouse — dull and cloudy	16 25	16 50	19 25
Bright sunlight on grassy lawn — cool and windy day	21 00	22 00	42 00
Wire netting frame — dull, cloudy, windy day	17 00	17 00	22 00
Automobile seat — bright, hot sun	32 00	30 00	60 25

reading than the aluminium foil. This recording was taken in a domestic refrigerator, and the explanation for this difference is probably because our refrigerator temperature fluctuates from between 2°C. and 5°C. with its thermostatic control — a truly accurate reading would be impossible under such fluctuating conditions

These figures also explain why polythene bags sweat. Any substances contained within them are maintained at a higher temperature than the air outside the bag. Therefore, water vapour that is given off is condensed on the bag's surface, which is being cooled by the outside air.

Aluminium foil has the disadvantage that it is not a very good material with which to make bags, as it rips and tears easily. We are now using foil paper laminate bags in the nursery, designed primarily for the purpose of roasting chickens. While they are the best available at the moment, they are still not strong enough. When damp they tear very easily, because the paper reinforcing goes soggy. Any bag of the future, I feel, should be a laminate of two layers of very thin aluminium foil, with a strong flexible substance sandwiched in between. This could be a synthetic meshing, or even a very thin layer of polythene might be satisfactory. However, it must be strong and flexible. We made some bags from reinforced foil building insulation paper. These proved very good at keeping plant material fresh, but were too stiff and unmanageable to be universally useful

In conclusion, I would like to say that, after a number of years of experiencing all sorts of problems with keeping plant material fresh and healthy in polythene bags, I have found aluminium foil to be demonstratively better under most circumstances. Its only fault is a lack of physical strength. I see no reason why foil laminate bags and boxes cannot be manufactured, with a consequent improvement in the keeping quality of any substances contained within. I would recommend their use in preference to polythene.

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WORK FLOW AND COSTING IN PROPAGATION

IAN BALDWIN AND JOHN STANLEY
Nursery Business Consultants
Rode, Somerset

"Costings" is a term frequently used by propagators, growers and company directors to express the calculations and procedures necessary to find out one of the most basic questions in nursery production, i.e. "How much does this plant cost me to produce — Could I buy it in cheaper?" The idea of buying in may not be attractive unless the source of material

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is safe and the producer is reliable. If these two factors are assured then it may, indeed, make good sense to buy in from a specialist propagator and follow the trend that has been seen in glasshouse, field, vegetable, and fruit production during the past ten years.

Such an enormous decision cannot be made without facts — and realistic, factual costs of propagation are extremely difficult to come by from other people and even more challenging to work out one's own. It was to this end that we have tried to produce a logical, systematic schedule for the calculation of the cost of producing a cutting by conventional means. The actual document is shown in Appendix 1. and the purpose of this paper is to try to explain some the reasoning behind it.

A survey carried out along similar lines with ten growers in Oregon, U.S.A. by their local State University Extension Service showed some interesting results as shown in Tables 1 and 2.

Table 1. Cost breakdown of propagation of *Photinia* × *fraseri* by cuttings in Oregon in 1979

	Percentage of total cutting cost
Cost of cuttings before insertion	23 6
Cost of rooting and growing	59 7
Overhead cost	10 8
Working capital interest	5 9
	100 0
Of this total, the employer and employee input is	63 0

Table 2. Cost breakdown of propagation of *Juniperus sabina* 'Tamariscifolia' by cuttings in Oregon in 1979

	Percentage of total cutting cost
Cost of cuttings before insertion	19 9
Cost of rooting and growing	65 9
Overhead cost	9 0
Working capital interest	5 2
	100.0
Of this total, the employer and employee labour input is	55 0

From these figures it was interesting to note that labour costs amount to 63% and 55% of total costs, and means of reducing these figures are considered later.

From the Oregon survey one grower found that he was, in fact, selling *Photinia* × *fraseri* plants at one U.S. cent less per cutting than the calculated cost of producing it!

What goes in a costing? Firstly it must be said that views on this subject are very different and, in the past, many organizations and advisory people have recorded only the so-called variable costs of materials and direct labor, saying that to calculate and allocate fixed and overhead costs was too laborious and imprecise. Other industries have gone to great lengths to obtain complex formulae to be able to allocate for example, a portion of the cost of running the managing director's car to each washing machine or rivet produced, and this "cost accounting" can mean computors, large amounts of paper, and dubious results.

We have aimed for something in between, so Sections 2, 3, and 4 of the formula in Appendix 1. are reasonably straight forward in that they record the more obvious costs of direct labour and actual materials used

Labour Hours. We often fail to appreciate that, although a propagator may be paid, say, £90 for a 44 hr week (including overtime) the cost per week to employ him or her will be nearer to £110 (or more) when such costs as Employers National Insurance contributions, holiday pay, sick pay, and training days are included, not to mention other possibles such as accommodation and use of a vehicle. Furthermore out of 365 days in a year, the average person is unlikely to work more than 240, if you allow for weekends, holidays, sickness, and training; this then puts up the price of labour per hour even higher.

e.g. 365 days × 9 hours =3285 hours/year
if the wage is £5000, then hourly cost is £1.52
but at 240 days × 9 hours =2160 hour/year
then if employment cost is £6500, then hourly costs rises to £3.00

It is this second type of hourly cost which should be used in costings.

Stockground. Section 1 deals with the cost of a stockground or, if absent, the cost of travelling out to collect cutting material. This is usually overlooked especially when it comes to consideration of stockground maintenance and the "*opportunity cost*" in terms of rental value of the site occupied by the stock plants. If they were not there what could be done with the land? At worst it could be rented out to a farmer or grower and, at best, used for extra production or even a crop of houses! The rent is suggested at 5% because in this country horticultural rents are notoriously low in relation to land values.

Indirect Costs. These are costs which, although incurred and often substantial, are not easy to allocate specifically to

one crop or batch, even though they are a cost of being in the propagation business (compared to overheads in Section 7 which are a cost of being in business in general). Points to note here are:—

1 Structures such as glass or polytunnels and equipment, such as environmental control gear, are usually depreciated (for tax purposes) from the original cost and in days of inflation this can be extremely misleading. A polytunnel in 1985 will cost two or three times the cost of its predecessor erected in 1975 and the purpose of depreciation is to build a fund for replacement Thus a polytunnel of £1000 depreciated over seven years should create £1000 to buy a new one — the only problem being that a new one by that time costs £2000. the idea of using current replacement cost is not new, other industries use it in pricing calculations all the time. In fact, to be more realistic the cost of future replacement should be included as it is now for car hire, machinery hire, etc. although the problem with this in our business is knowing what technological advances are going to do to future glass or polytunnel replacement costs.

2. "Amortized" is a word used to describe the method of calculating the annual repayments of capital plus interest (equivalent to depreciation plus interest) by a pre-worked table available from most banks, A D.A.S., or the Farm Management Pocketbook (Wye College). The percentage referred to is the likely borrowing rate for the period of years over which the item is being written off.

Services. Unless oil, gas, electricity, and water are metered the calculation is very difficult and not necessarily accurate. The methods of allocating are either by labour or output.

Labour refers to the nurseries where labour hours are well recorded and services costs are allocated in proportion to the amount of labour hours each nursery department uses.

For example, if conifer propagation uses 13% of all labour hours on the nursery it is allocated 13% of service costs in Section 6. Output refers to the fact that the output of propagation is measured in relation to total nursery output and this proportion forms the basis of service cost allocation.

For example, if ericaceous propagation produces 10% by value of all the nursery output then it is allocated 10% of the service costs.

Neither of these methods are particularly accurate but some representation of service costs must be shown if the costing is to be complete. With careful use of fuel and insulation this section is not likely to be more than a low percentage of the cost of propagation.

Overheads. These are general business costs. Section 7.1 comes from work in the U.S.A. which has shown that the cost in terms of management time for the planning and overseeing of the propagation unit can be equal to another 15% of the propagation unit labour cost.

7.2 is included because when a batch of cuttings is sitting there it is tying up money in terms of materials, labour, and services, which is usually borrowed on an overdraft. In this case we have allowed a crop to be *in situ* for 4 months, hence the annual costs are divided by 3.

7.4 can be allocated in a similar way to services (above).

Standing Charge. A very telling, if depressing, calculation is to total sections 1.1, 1.2, 5 and 7 to get the overall costs of propagation *before* plants are involved. If this is expressed on a square metre of bed area it can give the "standing charge" that each square metre has to be able to return from cuttings produced after the cost of labour and materials have been deducted in order to make a profit out of propagation.

For example, if the labour, service, and material costs come to £925 for a tunnel, and the standing is £15/m^2 per year; a tunnel with bed space of 32m^2 will have a standing charge of £480 per annum even if empty! This means it will have to produce cuttings worth 925 + 480 = £1405 in a year to pay its way.

Reality. In reality no grower would attempt to carry out this exercise of total costing on every major crop every year. Many of the sections may prove difficult to fill in accurately and the time involved would be enormous. However the industries supplying us with polythene, petrol, pots, peat, tractors, etc. could tell us exactly what their costs are and can consequently "adjust" their prices to keep up with inflation, whereas we think we know what our costs might be. An exercise such as this costing may be worthwhile doing for a major crop or a dubiously profitable one as a once-off trial to see how near the truth your estimates were.

Value versus Cost. As the previous breakdown has shown, before analysing any work to try and reduce the amount of labour input we need to know what parts of the job add value to the business and what parts of the job add costs. If we study the operation of preparing and sticking cuttings we can break down the job as follows:

Value Operations	*Cost Operations*
1 Cuts made on the cutting in the correct position	1 Handling the cuttings between mother plant and preparation
2 Treating with hormone	2 Excessive handling at preparation
3 Sticking the cutting in the growing medium	3 Double handling at sticking
	4 Carry trays to rooting area

What we need to do is to concentrate on the value operations and reduce the cost operations to a minimum. In this situation all the cost operations are the handling of cuttings and trays and we therefore need to concentrate on four areas.

1. *Handling.*

We need to analyse whether we are handling the cuttings in the right way. Can the cuttings be prepared at the stock plant and then stuck straight away or can the cuttings be laid out all facing the same way in the handling container so that there is no need to sort them out at preparation? These are two questions that must be asked and answered objectively — which are often difficult when looking at our piece of work, although easy when looking at other people's work.

2. *Ergonomics.*

Ergonomics is the study of the body at work and how we can best position for easy work by improving the work layout. If the layout and body position are correct then work productivity should increase.

3. *Are we using the correct tools?*

Historically the knife has been the recommended tool for taking cuttings, but various other implements are now on the market which should be considered. If the cutting will snap clean using the fingers then no tools need be used but, assuming this is not possible, then one needs something with a clean sharp edge.

A number of propagators now use secateurs (clippers) or florists scissors, which are cheaper than the more expensive propagators knives, and stay sharp for long periods.

Even cheaper are Plasiplug knives which are now being recommended by the Agricultural Training Board in Britain as a cheap, reliable tool which can speed up the taking of cuttings and reduces the double handling of plant material at this stage.

One enterprising American nurseryman is using finger knives which were originally developed for the post office and, as they are cheap and easy to use, he finds that he can train school trainees very quickly.

4. *Sticking.*

A study of most people when they stick cuttings will show that they normally store the cuttings in one hand and stick with the other. This system has evolved through habit and may not be the most efficient.

If anyone new needs to be trained in sticking cuttings then they should be trained to stick using two hands with the store

of cuttings in front of them. Double-handed sticking is strange at first but like learning to drive a car, it improves with practice and a double-handed sticker can soon outstick someone doing it in the traditional way.

The system works very well for Sonoda Nurseries in California where the propagator has trained all the stickers in this method and it has helped greatly in reducing the labour bill in propagation.

APPENDIX — COSTING IN PROPAGATION

DIRECT COSTS	£	£
1 **Pre-sticking Costs**		
1.1 Maintenance of stock plants		
labour to maintain, sprays, etc	_____	
materials used, fertilisers, sprays, labels, etc	_____	
1 2 Rental value of area occupied by stockplants (take 5%		
p a of land sale value)	_____	
Divide 1 1 + 1 2 by number of stockplants for this crop =	_____	
1 3 Time to travel to, take cuttings and return from stockplants @ _____ per hour	_____	
Sub-total for 1	_____	_____
2 **Preparating and Sticking**		
2 1 Labour for preparing and sticking @ _____ per hour	_____	
2 2 Materials — hormone, fungicide, labels media, "one-trip" containers	_____	
2 3 Labour for preparing or mixing media @ _____ per hour	_____	
Sub-total for 2	_____	_____
3 **Rooting and Growing Cuttings**		
3 1 Labour for pest and disease control, removing dead or diseased material, watering, mist and environmental monitoring, shade control, etc @ _____ per hour	_____	
3 2 Materials used, fungicide, insecticide, growth regulators, polythene tent	_____	
Sub-total of 3	_____	_____
4 **Lifting and Grading and Clearing up.**		
4 1 Labour for lifting, labelling and grading cuttings @ _____ per hour.	_____	
4 2 Materials used to clean or wash cuttings, labels, packaging material for movement to customer or next area of use	_____	
4 3 Labour for disposal of waste, tidying up and washing down for next crop, including sterilizing used trays and containers @ _____ per hour	_____	
4 4 Material used in cleaning up and removal of waste, e g sterilizer	_____	
Sub-total of 4	_____	_____

INDIRECT COSTS

5 **The Propagation House**

5 1 Replacement cost (current value)
(a) Glass amortized over 15 years @ _____% _____
or
(b) Polythene/plastic — amortized over 7 years
@ _____% _____

5 2 Heating system (replacement cost) amortized over
10 years @ _____% _____

5 3 Environmental control equipment, vent gear, mist/fog
machinery, electronics, irrigation, amortize over
7 years @ _____% _____

5 4 Other items (e g concrete, benches, partitions, shade
material) amortize over 10 years @ _____% _____

5 5 Returnable containers (if used) or trays (if returnable)
20% of current replacement cost (5 year life) _____
Sub-total for 5 _____ _____

6 **Services**
Electricity, oil/gas, water cost if metered _____
or allocate in proportion to % labour used in crop or batch (see notes) _____
or allocate in proportion to % output of crop or batch in
relation to total nursery output (see notes) _____
Sub-total for 6 _____ _____

7 **Overheads**

7 1 Labour and systems management — take 15% of hired
labour costs for propagation _____

7.2 Interest on working capital, because of seasonal production Add up previous sections 1.1, 1 3, 2, 3, 4 and 6 and take ⅓ of this total (equivalent to three crops, each four months long) and charge at _____%
of annual interest (prevailing borrowing rate) _____

7 3 Annual rental value of area occupied by propagation dept , take 5% of land sale-value _____

7 4 Proportion of administration, office costs, advertising,
general maintenance of nursery, insurance,
miscellaneous small tools + sundries Allocate as in section 6 either by Labour-hours method, or _____
Output method _____
Sub-total of 7 _____ _____

Summary

X = Total of Direct Costs 1+2+3+4 _____
Y = Total of Indirect costs 5+6+7 _____
Number of rooted/sold cuttings from this crop
= _____(z)
Cost of propagation per cutting
(divide line X+line Y by line Z)

Accompanying Notes

(i) Rental is charged in lines 1.2, 5.5 and 7.3 because the

opportunity to rent out the site, if owned, to another business must be considered as an alternative way of generating money from the unit (opportunity cost principles).

(ii) Labour, whenever charged, should be at the cost of employment, including National Insurance, holiday and training days pay, *not* at gross wage cost. This is then divided by the actual hours worked in a year.

(iii) Whenever amortization is included it represents the cost of depreciation *and* interest on capital over the chosen life span of the item at the prevailing interest rate.

(iv) Sections 5+6+7 can be used to express the "standing charge" of the propagation unit *whether a crop is produced from it or not.*

In fact, it is the charge that represents the existence of the unit and all the cash that it requires to remain functional. If the service charge is subtracted, then the resulting figure shows what it costs to have an empty propagation unit!

(vi) Line Z uses the number of cuttings successfully rooted or the number sold (which may not be the same thing).

(vii) Allocation of indirect costs in sections 6 and 7.4 can be either in relation to the proportion of hours worked on that crop when compared to the financial output of the whole nursery (see paper for examples).

(viii) In 7.2 interest is charged at borrowing rate per annum whilst the costs incurred that totalled up for 7.2 are divided by 3 to represent a four month crop. A six month crop would necessitate dividing the costs incurred by 2.

Acknowledgements. Ann Fisher, Sacramento, California, and Oregon State University, Agricultural Extension Service.

N. CLAYTON: What basic rate of wages did you use in your calculations?

I. BALDWIN: The figures were based on a skilled craftsman rate (£6.00/hr) plus his overtime, and we looked at all the costs involved including management time.

K. LAWRENCE: Are the finger knives available in this country?

J. STANLEY: It can be arranged! At present the American post office one is not, but I believe the German one is. The American one is more robust[1].

W. MATHEWS: The metal one is available in Holland, but I imagine continuous use would make the finger very swollen.

---

[1]Ed Note Available in the U S from A M Leonard & Sons, Piqua, Ohio; sold as "ring knives"

I. BALDWIN: The people we saw had no trouble after three weeks continuous use.

M. SCOTT. Are the blades replaceable?

I. BALDWIN: No, when blunt they are thrown away and a new one used.

M. HELLIAR How much do they cost?

I BALDWIN: Just under a dollar.

D. CLARK: Do you have any further breakdown of cutting costs prior to sticking, such as average percentage of cost of collection?

J STANLEY: I have not got the figures to hand but remember that if you did not have your own stock beds the cost was doubled.

B MORGAN· Do you have any information on number of people collecting cuttings in relation to those preparing?

J. STANLEY: Around one to two in the American situation where a lot of labour is used. Labour costs in the States may appear relatively low, but preliminary studies in the UK suggest that the percentage labour cost is similar, i.e. 63% of total costs. While the Americans employ a lot of cheap labour, the reduced labour in British nurseries is used more effectively.

W. MATHEWS. How can you arrive at your costs with the different speed of workers?

J. STANLEY We had to base the costs on an average nursery situation rather than comparing output to different workers.

D. CLARK. We have looked at aptitude tests for people going into propagation and find marked differences among people, particularly in agility of finger work. If this can be sorted out early enough, it will make a tremendous difference to the efficiency of the section.

A. BRIANT. Some of your percentage figures surprise me The cost of actual striking of cuttings seems low compared with collection costs.

I. BALDWIN: Included in these costs were those involved with the maintenance of the stock ground, its rent, travel to and from the area in time and petrol, and costs of collection and trimming labour.

L. RUDIN: Have you any comparison between hardwood and softwood cuttings and have you considered the direct striking into pots for some of the more easily-rooted container species?

J. STANLEY. The work study in America was done with *Photinia*, a very easily handled cutting. There would be big

differences in costs for harder or more difficult to handle material. The direct striking method is the next stage to consider once the basic figures have been obtained. It will increase indirect costs as more land and protection is needed, but reduce overall production costs

L. RUDIN: Direct striking is increasing in Sweden for species like *Pyracantha* and *Cotoneaster* where three cuttings are inserted in a 1.5 litre pot.

PROPAGATION USING THE FOGGING TECHNIQUE

MARTIN J. HALL

H. Evans & Sons (Europa) Ltd.
Hadlow, Kent

We have mist so why use fog? A question often levelled at our Company over the past two seasons since we installed the MEE Fog System at our Sidcup Nursery in an existing wooden glasshouse block of 9,000 square feet.

At a time of uncertainty and financial constraint any capital investment has to be certain of obtaining a quick return on investment In our case the results obtained by using the fog have surpassed our original expectation.

The use of fog in propagation isn't new and work with Fog Pots in Holland and Switzerland is well documented. Recent engineering technology, much of it derived from N.A.S.A. Space Research, has enabled this system to become a commercial reality

It should be stressed that this equipment is of a far higher precision than anything so far seen and, as such, needs careful attention in its location, installation, and running.

In the United Kingdom the system is being used for green plants and nursery stock propagation, A.Y.R. chrysanthemum cutting propagation and the production of cress. The system is, at the moment, being considered for mushroom production on a large scale.

What is fog? The MEE Fog System is a device for humidifying and cooling the plant environment. It is also a method for controlled application of foliar feeds, insecticides, fungicides, or any liquid or water soluble substance. Fog can be used to control transpiration and evaporation losses during plant propagation and multiplication. It is far superior to the use of misting because overwetting of the growing medium is no longer a problem. Fog can be used during cold weather for freeze protection of outdoor plants and as a means to supple-

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ment and increase the efficiency of heating systems (thereby saving significantly on fuel costs).

Humidifying and cooling the plant environment is one of the most important things that can be done to help increase plant production. When a plant is stressed to the extreme by too high a temperature or too low a humidity, it wilts But long before it wilts the plant's natural mechanisms for survival take over and the stomata close. Closed stomata mean the plant leaf can no longer exchange the gases that are so necessary for the manufacture of food. Photosynthesis stops. When photosynthesis stops the plant won't grow. This typically happens for several hours on every sunny afternoon, even in winter! The obvious solution is to relieve the plant stress and this can be done quite effectively with the fog system.

How does the system work? A very special small nozzle — an atomizer — creates the fog In a typical installation about one nozzle for every 50 square feet of growing space will be required. The atomizer, which is about as big as the tip of the little finger, is installed in half-inch plastic pipe and located over the growing zone. The atomizer must operate at high pressure, so a booster pump is used to increase the pressure to about 500 psi. The water must be very clean so several filters are included in the system. The water is filtered before it enters the booster pump, filtered again after it leaves the pump, and then one final time just before entering the orifice of the fog nozzle atomizer All piping and fittings in the system are of a non-corrosive material — either plastic or brass or stainless steel.

The water must also be free from micro-organisms that can create slime deposits and clog filters and nozzles. Mains water is usually treated to remove such micro-organisms But if untreated raw water is used, a chlorine injector must be included in the system. Only a small amount of chlorine, about one part per million, is required to control organism growth This amount of chlorine is much too small to be harmful to plants or to be detected an an odour in the water.

As water jets from the atomizers it is broken into small fog droplets.These fog droplets are so small, about one-tenth the diameter of a human hair, that in a dry atmosphere they immediately evaporate to raise the humidity and cool the air The cooling efficiency of the fog is so great that the air can always be cooled to the maximum theoretically possible by evaporative cooling. The fog system output can be controlled to adjust the temperature and humidity to the desired level. If the output is controlled to saturate the air, then the droplets will no longer evaporate and will remain suspended as in a natural fog.

How does the system work in relation to propagation? For most propagation and plant multiplication work it is desirable to maintain zero transpiration loss without overwetting or leaching of the growing medium. This can be achieved with proper control of the fog system. When the fog is properly controlled transpiration loss can be completely eliminated without irrigating or extensive wetting of the growing medium. This means that soil moisture can be maintained at optimum levels while assuring an adequate oxygen supply to the root zone and no moisture loss through the leaves.

To assure zero transpiration loss it is necessary both to maintain a 100% relative humidity around the plants and to maintain a very light mist of liquid water on the plant leaves. It is necessary that the leaf surfaces be slightly wet because in sunlight the leaf surfaces are always warmer than the surrounding air. By maintaining a very light fog around the plants (not enough to significantly decrease incoming solar radiation), the above conditions can be achieved. Fog droplets are too small to precipitate and cause any significant irrigation but the droplets do migrate through the air and eventually collide with the plant surfaces. After 10 minutes or so in a light fog a light misting of water will occur on the plant leaves.

Fog density is controlled by the number of fog nozzles in a given area, by the ventilation rate, and by the cycle time of the system. Thus a propagation area can be created in several different ways. A house set up for normal growing practices can be converted to a propagation house simply by decreasing the ventilation rate or by increasing the fog output rate. The ventilation rate can be decreased by closing vents or by turning off some fans. The fog output rate can be increased by increasing the on-time of the fog cycle, or by adding more nozzles. By planning ahead an extra line of fog nozzles could be installed with a manual control valve to be turned on only when the area is to be used for propagation.

A portion of a house can be converted to a propagation area by isolating it with poly curtains. By proper arrangement of the curtains the ventilation rate can be decreased and a proper balance of air flow and fog density achieved. This can be done in greenhouses and in shadehouses and usually with dramatic results.

When properly used, fog propagation will usually cause a dramatic increase in plant production. But a word of caution is necessary. The fog system is not like the misters you are acquainted with. In misting, water is always sprayed directly onto the plants. In fogging water is never sprayed directly on plants, and in fact precautions must be taken to ensure that plants are not directly in or under the spray pattern of the fog

nozzles. The best location for placement of fog nozzles is overhead, facing upwards, and over aisles or walkways. This ensures that any drip associated with the nozzles will fall in aisleways and not on plants. Also it should be recognised that true fog droplets are produced only when the nozzles are operating at full 500 psi pressure. In the few seconds when pressure is building up or dropping off during the on-off cycle larger mist-type droplets are produced. Fog droplets will typically drift 15 to 20 feet from the nozzle location before evaporating, but mist drops will fall within about 3 feet from the nozzle. Mist drops irrigate, fog droplets do not. Thus, to ensure that plants are not overwetted fog nozzles should be located at least 3 feet from the edge of the growing zone whenever possible.

At present the system hasn't been fully exploited on the nursery. By the use of timers and solonoid valves the area is capable of being increased three-fold using the existing pump. We are only now looking at the application of chemicals for the control of pests and diseases.

How does the system cater to pest control? It can be used for the controlled application of foliar feeds, insecticides, fungicides, or any other liquid or water soluble substance. If a very dense fog is formed in the growing area, fog droplets will migrate deep into the foliage and eventually wet both the upper and lower surfaces of leaves, stems and flowers To achieve this dense fog, the ventilation rate should be kept as low as possible and the fog system run full on for 5 to 10 minutes. In a greenhouse all vents should be closed and ventilating fans turned off. (Internal fans such as turbulators and heater tubes may actually aid in diffusion of the fog.) In a shadehouse or outdoor area the area to be treated should be curtained off to reduce mixing of outside air.

Once a dense fog has been formed it will usually persist for 5 to 10 minutes after the system has been turned off This should be an adequate length of time to ensure thorough wetting of all plant surfaces. Solutions to be applied can be injected into the fog system water with a special metering injection pump, or can be pumped directly from barrels of premixed solution. A good technique to use is to first saturate the area with a pure water fog. This will prevent evaporation of the nutrients or insecticide solution and minize the amount of active material needed.

In an age of fuel conservation dictated by ever rising costs, the possibilities of using the fog system for freeze protection are numerous. Low energy consumption and ultra low water usage make freeze protection very viable.

Farmers and horticulturists have long recognised that on cold nights crop damage from freezing will be considerably lessened if fog or clouds move in and blanket an area. The reason for this is that the individual droplets in a fog act as very good reflectors of the long wavelength heat radiation which is given off by solid objects during clear-sky night-time conditions. Solid objects such as the ground and plants absorb solar radiation during the day and re-radiate this energy as heat radiation during the night. Fog produced by the fog system works just like a natural cloud to trap this radiated heat and prevent the temperature of the plants from dropping too low. It has been shown that only drop sizes which are close to the wavelength of the emitted radiation are capable of reflecting the radiated energy. The fog system produces droplets in the 10-micron diameter size range, wich is exactly the same as the wavelength of the heat radiation. For freeze protection a dense fog is necessary to reflect the maximum amount of radiated heat.

The fog system also works in other ways to prevent damage from freezing Tiny droplets produced by the fog nozzle saturate the air with water vapour. As this water vapour condenses onto cold leaf surfaces, latent heat is released which warms the leaf. If this water then freezes, more heat is released when prevents the leaf from freezing. (This is the principle behind the use of sprinkler systems for freeze protection).

The fog system can also be used as a supplement to heaters to lower the amount of energy needed to keep a growing area warm. The fog works to reflect back and trap in the heat given off by the heaters, which would normally be radiated away into space. This cuts down on the amount of heating usually required to maintain a desired temperature.

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HYBRID POPULATIONS IN SOME NATIVE TREES RAISED FROM SEED

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Where related species grow in geographically adjacent areas, they can often be separated on ecological requirements as well as on morphological characters, and hence remain distinct given stable natural conditions. However, the intervention of mankind creates disturbance on many levels which modifies traditional habitats and may enable otherwise stable plant communities to expand and invade new areas. With taxonomically allied species involved in a dynamic situation, the resulting hybrid populations are not infrequent and generally occupy habitats intermediate between those of the putative parents.

Some native trees and shrubs raised from seed in the nursery may be represented by substantial hybrid populations, with varying significance for the grower and planter. However, the bulk of species raised from seed remain true-to-type, and the incidence of hybridization is far greater in cultivation, whether by chance or design.

BETULA

The two tree-like species currently recognised are *Betula pendula (B. verrucosa)*, the silver birch, and *B. pubescens*, the downy birch. They are readily separable by chromosome number, habit, trunk, shoot, leaf and fruiting characteristics, but, nevertheless, were formerly grouped under the blanket name *Betula alba*, which is still found in some seed lists.

Whilst direct hybrids between the species are apparently rare and are sterile, a very numerous population exists which combines some features of both species in varying degrees in the individual, and can be found in the wild and in cultivation. This fertile race is postulated to be of hybrid origin and is associated with the re-establishment of vegetation after a primary forest is cleared; hence in Britain's disturbed landscape the hybrid birch is common.

The bulk of mature planted birch trees possess the rugged white bark with black ridges typical of *Betula pendula*, which suggests that nurserymen a generation ago used seed collected from a pure stand of silver birch for seedling production.

Much recent planting incorporates material obviously influenced by *Betula pubescens*. As the trees mature, trunk colouration is often at best a creamy-brown, and the bark is smooth, and peels off in flakes.

This apparent anomaly may be explained by the collection of home-produced seed in an indiscriminate fashion in recent years, this would doubtless please the conservationist element among amenity planting groups but not the private gardener seeking a true silver birch. The propagating nurseryman must learn to recognise authentic sources of seed supply, if home-collecting, or to purchase seed of known provenance.

In conclusion, the grower should seek to produce only pure *Betula pendula* if his aim is to sell "silver birch" trees; but even this affirmation is confounded by the fact that hybrid birches with pure white trunks are by no mans uncommon in cultivation Doubtless, as mature plants they are valued, but with open-pollination their progeny must necessarily be of mixed quality.

CRATAEGUS

The two native species of hawthorn, *Crataegus monogyna* and *C. laevigata (C. oxyacantha)* are distinct in vegetative and floral morphology, and inhabit quite different soil regimes, the former of light, well-drained soils, i.e. sands and chalk, the latter associated with heavy, poorly-drained situations in woodlands. Both species are self-incompatible, and the necessity to out-breed, coupled with the loss of ecological barriers in past centuries has established a massive hybrid population. *(Crataegus × media)*. The hybrid is self-compatible, and with back-crossing to both parental species, has produced every possible variation in leaf-shape from the dissected form of *C. monogyna* to the lightly lobed *C. laevigata*.

The qualities of free fruiting and abundant seed production and tolerance of a broad spectrum of soil types has enabled the hybrid thorn to be used as a cheap form of hedging for hundreds of years. By contrast, the pure species are limited even in their most favourable habitats; *Crataegus laevigata*, in particular, is close to extinction

For the nurseryman, the genetic diversity found within the hybrid population is currently largely reflected in the flower form and colouration, both single and double, from pure white, and pink to red shades, these selections being propagated by vegetative means. However, the seedling rootstocks required for budding vary considerably in their suitability, and require careful selection. By inference, perhaps trees selected for seed production should be within populations close to *Crataegus laevigata*, which has a more robust habit of growth than *C. monogyna*.

In essence, the availability of hawthorn in quantity for hedging and amenity planting, and the diversity of clonal se-

lections for ornament are directly the result of the genetic combination of the two species. If this combination and recombination had not been possible, it is unlikely that hawthorn would have achieved anything other than local importance for hedging, and Britain's landscape and gardens would today be rather different

QUERCUS

Numerous botanical works attest to the abilities of the two British oaks, *Quercus robur* and *Q. petraea (Q. sessiliflora)* to hybridise. Both species are variable in vegetative characters, so that identification is not always easy and not all writers are agreed that hybridization is extensive. Indeed, research has indicated that cross-pollination between the species is of a low order.

The common oak, *Quercus robur* is distinguished by the following: leaves oblong or obovate, broadly lobed at the base, hairless when mature, and with a short petiole, acorns several together on common stalks.

The durmast or sessile oak, *Q. petraea* has elliptical leaves, tapering to the base, which is unlobed, distinctly petiolate, with downy hairs beneath, when mature associated with the veins. Acorns unstalked

In practice, many trees in south-east England, while generally agreeing with the description of *Quercus robur* above, may have leaves only narrowly lobed at the base, this feature may or may not be used in argument to assert slight introgresson by *Quercus petraea.*

While the subject of hybrid oaks remains academic, the nurseryman need only concern himself with collecting acorns for propagation purposes from those trees which produce high quality seedlings for tree production.

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PLANT CONSERVATION — A ROLE FOR IPPS?

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I should like to explore some of the ways in which members of the IPPS might be able to help with our attempts to save rare plants that might otherwise be lost from cultivation in the British Isles.

Few people would challenge the view that we are, at present, in some danger of losing from our gardens a lot of the species and old cultivars that have been grown in them in the past. This is for a variety of reasons, but most of them hinge on the word 'economics'. Indeed, sufficient concern was being voiced about this for the Royal Horticultural Society to sponsor a conference on the subject in 1978, the Proceedings of which were reported in an article by C.D. Brickell in the April 1979 issue of "The Garden". The National Council for the Conservation of Plants and Gardens (NCCPG) was formed directly as a result of that Conference and since then has raised sufficient funds to be able to employ me, starting in March this year, to try to co-ordinate its work.

We have two main strategies by which to attack the problem. The first is to try to set up a network of local groups, initially on a county basis, consisting of keen plantsmen — both professional and amateur, and covering as wide as possible a range of horticultural interests — who can undertake the following tasks:

1. To collate information on the plants that are still commercially available in their area — to some extent it is true that, if we are to identify those plants that are rare, we must first know those that are not!

2. To search and list their local gardens, both to try to locate rare and unusual plants and to identify important gardens that are in some danger, in the hope that steps can be taken either to help them or to rescue their important plants before it is too late.

3. To help raise funds for the work of the NCCPG.

4. To look for particular plants that we already suspect to be rare in cultivation. Copies of a list giving some suggestions of these can be obtained from Wisley.

5 To collect information about — and perhaps grow — a particular plant or group of plants. This leads on to our other

main strategy, which is — as we identify good collections and sources for the more unusual plants — to attempt to establish a system of National Reference Collections whereby various other parties — be they botanic gardens, parks departments, The National Trust, private individuals, or the trade — agree to co-operate with the NCCPG in bringing together and maintaining as many species or cultivars as can still be found in cultivation, so that these can be properly named and evaluated and then maintained into the future. (Again a paper giving details of the Conditions of Acceptance the NCCPG is seeking to agree with interested parties is available from Wisley).

Until we have collected a lot more information from across the country, it is very difficult to be able to say with any objectivity exactly which plants are rare; but what we can do is to identify the factors that cause plants to be rare. Fashions change, and of course some plants are rare because they are not sufficiently attractive or gardenworthy. However, we would argue that many good plants are also rare for one or other of the following reasons: a few are difficult to grow without specialist care; some are recent introductions that have been, as yet, insufficiently distributed; some are tender and therefore easily lost; some are easily propagated but for some curious reason have been neglected, though they deserve to be more widely grown; and some we should be concerned about because they are rare plants in their wild state. However, undoubtedly one of the main things that helps make plants rare is a lack of commercial availability, because they are either difficult to propagate or uneconomic to maintain — maybe because they are slow to increase. This is one area in which we need your help.

There are plants for which demand at present certainly exceeds supply, e.g. double hepaticas, *Paeonia suffruticosa* 'Rock's Variety'; and many of the terrestial orchids, which are slow to increase vegetatively and which we are as yet unable to raise from seed, e.g. *Cypripedium calceolus*. So it may be that for some plants we need to experiment with new methods of propagating them — or perhaps it would be safer to say, of making present knowledge more widely available! Surely, given better promotion, some of the following plants would sell widely — if only we could find ways of making the material available: *Schizophragma integrifolium*, capable of growing on a north-facing wall; *Dendromecon rigida*; *Carpenteria californica*; *Trillium grandiflorum* 'Plenum'; *Cardiocrinum giganteum* — and so I could go on, the list is endless! Also, how many of our unusual plants fail to set good seed simply because we only maintain one self-incompatible clone of them and they need a partner for cross-pollination?

I suspect that one of the reasons why certain plants have declined has been that their stocks have gradually accumulated viruses and other disease problems during their time in cultivation. It may well be that we need to turn to specialists with modern techniques to develop "clean" stocks which we can re-introduce to general circulation. Here I am thinking particularly of certain hardy plant groups such as primrose cultivars, Russell lupins, etc. The re-establishment of healthy stocks may be essential for the survival of such plants.

I mentioned our local groups earlier. We are trying to encourage them to help with the propagation and distribution of plants which might otherwise run the risk of being lost. For this purpose we are to hold a conference on propagation for them next month at Pershore College, to which I intend later today to invite official representatives from the IPPS. The NCCPG is very keen not to compete directly with the trade — indeed I am sure it would mostly warmly encourage any nurserymen prepared to add new items to their commercial list; the greatest safeguard for unusual plants is that they do remain commercially available. However, initially, we shall certainly encourage our local groups to propagate items that the Trade is unwilling or unable to produce. They will need your expertise and advice, whether as amateurs or professionals, and I sincerely hope that some of you may be prepared to join your local groups and share your knowledge with them.

ETIOLATION OF STOCK PLANTS FOR IMPROVED ROOTING OF CUTTINGS: I. OPPORTUNITIES SUGGESTED BY WORK WITH APPLE

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Abstract. The percentage rooting of leafy cuttings of the apple rootstock, M 9, was increased on average from 11% to 78% by prior etiolation A period of exposure to light before taking pre-etiolated shoots as cuttings was essential and it was not necessary to continue to exclude light from the future rooting zone The only limitation to the practical application of the technique appears to be that the conditions under the black polythene covers used to exclude light from the stock plants are favourable for *Botrytis* infection Because complete darkness is not essential, this problem can probably be overcome by effective ventilation of the covers

Terminology. There are many reports of stimulating adventitious rooting by various treatments involving the exclusion of light. Treatments range from excluding light from the base of the cutting during rooting, as is normal for cuttings

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planted in conventional rooting media, to growth of stock plants in complete darkness. All have been referred to as "etiolation". Definitions of the term are correspondingly variable. Most, e.g. (8) refer specifically to the typical appearance of plants *grown* in complete darkness (i.e. elongated internodes, no chlorophyll and small leaves). Etiolation has also been defined as the exclusion of light, without any clear limitation as to stage of development or to the effects it may have (17). However, both Hartmann and Kester (7), and Garner (6) clearly favour the first of these definitions, reserving the term etiolation for *growth* of shoots in darkness as distinct from exclusion of light from initially light-grown tissue which, in time, may lead to loss of colour, and may be described as blanching. This more restricted definition is used here to distinguish between the various types of treatment that have been used in the study of the effects of light on rooting at East Malling and elsewhere.

Exclusion of light from the base of cuttings during rooting. Illumination of the base of the cutting during rooting completely prevented rooting of *Chrysanthemum* (1), reduced rooting of *Picea abies* from about 50% to about 5% (15), and greatly reduced root numbers in *Salix alba*, and in mung bean (12). Although an inhibitory effect is not always observed, e.g. (16), I am not aware of any reports of the stimulation of rooting by light.

Blanching treatments applied to shoots on stock plants. Herman and Hess (9), and more recently Kawase and Matsui (13) reported that root primordia develop rapidly under black polythene or paper wrapped around the stem of plants of *Phaseolus vulgaris*. With *Hibiscus rosa-sinensis* no root primordia were visible after 5 weeks but rooting of cuttings was improved (9). Recent unpublished work at East Malling has demonstrated increased rooting of cuttings following blanching in a wide range of plants including *Acer platanoides* 'Crimson King', *Tilia cordata*, *T.* × *vulgaris*, *T. platyphyllos*, *Corylus avellana*, and several apple scion cultivars and rootstocks. For example, the effect of black tape applied to non-etiolated shoots on the rooting of leafy cuttings of apple rootstock M9 is shown in Table 1.

Etiolation. There are few reports of the effect of true etiolation other than with hypocotyl cuttings made from young seedlings, e.g. (4). Gardner (5), and more recently Delargy and Wright (3), reported large increases in rooting percentage of cuttings of difficult-to-root apple scion cultivars as a result of etiolation followed by continued exclusion of light from a short basal section of each shoot.

At East Malling Research Station, etiolation studies have centred on M9, a commercially important apple roostock which roots poorly from cuttings (11). Results obtained over 4 years show that etiolation transforms the rootability of M9 cuttings (Table 1) with rooting percentage increased from, on average, 11% to 78%. The response was consistent despite a change of site, different ventilation of the polythene covers, occasional *Botrytis* infection, different rooting media, and, in 1981, covering being delayed by three weeks. Maintaining localised darkness with black tape was always advantageous but the average further increase in rooting percentage was only 7%.

Table 1. Effects of etiolation and of blanching on rooting of leafy summer cuttings of apple rootstock M9 observed over 4 years All cuttings were treated with 2500 ppm IBA (Roots per rooted cuttings in brackets)

Date Covered	Rooting Percentage			
	Etiolated		Non-Etiolated	
	+ Tape	− Tape	+ Tape	− Tape
May 12, 1978	92 (25 3)	70 (12 9)	** 36 (3 6)	8 (2 3)
May 18, 1979	88 (41 0)	83 (22 0)	—	15 (1 7)
May 9, 1980	95 (45 0)	90 (37 7)	30 (4 2)	10 (4 0)
May 7, 1981	76 (38 8)	73 (18 3)	25 (6 0)	15 (4 8)
May 27, 1981	*76 (16 1)	*75 (8 7)	30 (5 1)	6 (1 0)

* cuttings prepared from dark-grown part of shoots

** tapes applied 2 weeks prior to collection, in later years applied as shoots reached about 40 mm in length

Effects of low light intensity. Using stock plants grown at a range of light intensities in growth cabinets, stimulation of rooting at low irradiance has been reported for apple rootstock M26 (2), *Chrysanthemum* (1), and *Pinus sylvestris* (16). In general, effects were small but this may only reflect the narrow range of irradiance used (generally 8 to 40 Wm^{-2}).

Results of experiments with field-grown stock plants of M9 covered with polythene of different light transmission characteristics, show that very large responses can be obtained without complete exclusion of light (Table 2).

Table 2. Percentage rooting of apple rootstock M9 cuttings from stock plants covered with polythene of different light transmission characteristics (Roots per rooted cutting in brackets)

	Light transmission through cover			Uncovered control
	0 00%	0 25%	2 5%	
+ Tape	70 (40 8)	86 (37 0)	88 (41 2)	25 (6 0)
− Tape	65 (15 4)	82 (18 6)	79 (21.8)	15 (4.8)

Mechanism of responses. Despite the numerous reports of improvements in rooting through the exclusion of light, there

is little clear evidence as to the mechanism involved nor is it clear whether this is the same for the various treatments referred to above.

Since the effect of auxins in promoting rooting is well established, as is also the destructive effect of light on IAA *in vitro*, effects of light on endogenous auxin concentrations have frequently been suggested. Kawase (12) reported that the rate of decline in endogenous auxin in mung bean cuttings during rooting was reduced by about half when light was excluded. However other reports, e.g. (13) have failed to demonstrate a convincing effect on auxin concentration. Furthermore, there are many reports of dark treatments which, far from making auxin treatment unnecessary, greatly increased the responsiveness to auxin treatment (2,3,9,13). Pre-etiolated M9 cuttings behaved in this way (Table 3) but if etiolation was followed by the application of black tape to maintain darkness over a short basal section of the shoot, preformed roots eventually developed and, long before roots were visible, the need for auxin treatment was much reduced. One possible explanation of the enhanced effectiveness of auxin in dark treated tissues might be higher levels of rooting cofactors but Herman and Hess (9) were unable to demonstrate convincing differences in cofactor levels using a mung bean bioassay and concluded that a complex of many factors was probably involved.

Table 3. Interaction between the effects of IBA (2500 ppm), etiolation, and black tape treatments on percentage rooting of apple rootstock M9 cuttings (Roots per rooted cutting in brackets)

	Etiolated		Non-Etiolated	
	+ Tape	− Tape	+ Tape*	− Tape
− IBA	85 (8 4)	45 (7 9)	0 (−)	0 (−)
+ IBA	95 (45 0)	90 (37 7)	30 (4 7)	10 (4 0)

* Tapes applied as soon as shoots were sufficiently long (ca 40 mm)

Pre-etiolation as practised at East Malling. Etiolated shoots are produced by covering sections of hard-pruned hedges with black polythene (500 gauge) stretched over a wooden frame and buried at the edges. Very limited ventilation is provided by small slits in each end wall, covered by a further piece of polythene arranged to exclude light but not air. Covers are generally erected as bud-break commences. As a further protection against loss of etiolated shoots through *Botrytis* infection, hedges are sprayed with a systemic fungicide before covering and again if infection is seen. After four weeks, when shoots are about 100 mm long, a panel is removed from the north side to admit some light and thus allow the development of a few green leaves before cuttings are taken two weeks later. This is essential to the subsequent survival of the cuttings. The dark treatment may be maintained around the basal

2.5 cm of a sample of the etiolated shoots by wrapping with self-adhesive black plastic tape. Cuttings are propagated under mist, generally following treatment with 2500 ppm IBA applied as a 50% acetone quick-dip. Rooting is assessed after four weeks.

Opportunities for practical application. It seems reasonable to assume that the effect of blanching on rooting already operates in practical propagation systems, such as stoolbeds, in which soil excludes light from the base of shoots. It is hard to envisage widespread adoption of alternative more labour-intensive methods of blanching, such as the application of polythene tapes to individual shoots. For large scale operation, etiolation, achieved by covering stock plants with black polythene for a few weeks, is more feasible.

The only practical difficulty emerging from our experiments with M9 is that of possible *Botrytis* infection during the period of growth under the black polythene covers. Although this had no effect on rooting of cuttings, infection of shoots on the stock plants reduced the number of cuttings available in 1979 and 1981. Fungicides helped to counter this problem but effective ventilation of the covers would probably be better. Without ventilation the plants are continuously wet from condensation except on very hot days. Effective ventilation is difficult to provide without allowing some light to penetrate. However the results shown in Table 2 clearly indicate that complete darkness is unnecessary and may actually be undesirable because cuttings from the low light treatments were larger and stronger than those grown in complete darkness. Further work will be required to determine the highest light intensity that can be used without reduction of rooting. Also, it remains to be seen whether the presence of water on the plants contributes to the rooting response observed with poorly ventilated covers. However, observations of the effect of placing wet cotton wool underneath the black tape used for blanching light grown shoots suggest that any such effect is likely to be small.

Amongst those features of the response of M9 to etiolation that favour its practical development, the most important are the size of the response and the fact that application of black tapes to maintain localised darkness after the covers are opened is not essential. Furthermore, the pre-etiolated cuttings are not so delicate as to require special handling and stock plants recover rapidly. It is impossible to predict how many other difficult-to-root plants may also meet these criteria. This will be determined from trials with a range of species such as those reported by Rowell (14).

The technique has proved effective also for the difficult-

to-root apple scion cultivars, Cox and Golden Delicious, but only when followed by a black tape for the remainder of the growing season. Similar treatments have been successful with other apple scion cultivars (3,5). If a light absorbing or reflecting material could be found which was suitable for spraying onto plants after etiolation and also had the necessary elasticity and resilience to substitute effectively for black tape, the technique could become attractive.

Alternatively, practical application of etiolation to such difficult subjects may come indirectly through elucidation of the basic physiological mechanisms involved, leading eventually to the development of novel chemical aids to rooting. This is the primary objective of current work at East Malling.

Acknowledgements. Among the many colleagues who have contributed to the work reported here I am particularly indebted to Dr B H Howard who was responsible for all the work undertaken before 1980 and has also played an active part in more recent studies

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ETIOLATION OF STOCK PLANTS FOR THE IMPROVED ROOTING OF CUTTINGS II. INITIAL EXPERIENCES WITH HARDY ORNAMENTAL NURSERY STOCK

DAVID J. ROWELL
ADAS, Cambridge

Work at East Malling Research Station has shown that the etiolation of stock plants of apple rootstock M9 can result in an increased rooting percentage of softwood cuttings. An observation was carried out to see if there was a similar response on ornamental species, and in 1980 and 1981 a range of species was tested in cooperation with Mr. J. Watts, propagator for Darby Nursery Stock Ltd. Results to date have been variable. In 1980 a number of species, especially lilacs, showed a marked response to etiolation but in 1981 results have been disappointing.

1980 TRIALS

At bud burst in spring stock plants of the following species were covered with a black polythene tent supported over and around the plants on a simple wooden frame. Immediately prior to covering, the plants were sprayed with benomyl as a precaution against *Botrytis* infection.

		Covering date
Species covered	*Polygonum baldschuanicum*	April 4
	Cotinus coggygria 'Royal Purple'	April 4
	Corylus maxima 'Purpurea'	April 1
	Corylus avellana 'Contorta'	April 1
	Syringa vulgaris 'Charles Joly'	April 8
	S vulgaris 'Madame Lemoine'	April 8
	S vulgaris 'Ludwig Spaeth'	April 8

In the 2 to 3 weeks after covering, the growth rate of the buds was monitored and when the shoots had grown approximately 8 cm the black polythene was raised on the north side of the tent about 30 to 45 cm to allow the shoots to green up. After a further week cuttings were taken and placed in a mist house for rooting.

RESULTS

Effects on Growth. The effect of the blackout treatment

15 Stromquist, L -H and L Eliasson 1979 Light inhibition of rooting in Norway spruce (*Picea abies*) cuttings *Can J Bot* 57 1314-1316

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RESULTS

Effects on Growth. The effect of the blackout treatment

and the higher temperatures under the black-out was increased growth compared with uncovered stock plants. This was particularly noticeable with *Polygonum baldschuanicum* which had grown up to 15 cm within two weeks of covering. Of the lilacs, S. 'Ludwig Spaeth' gave the fastest growth, approximately 8 cm in 3 weeks compared with 2 cm on the control plants.

Corylus avellana 'Contorta' did not respond as much to the treatment and after 4 weeks it had only made 4 cm of growth compared to 2 cm on the control plants. As a result it was necessary to extend the blackout period and, during this time, caterpillars and aphids developed rapidly, causing extensive damage which meant that thee was no suitable cutting material of this cultivar.

Effects on Leaf Characters. Leaves on cuttings of the red-leaved, *Cotinus coggygria* 'Royal Purple' and *Corylus maxima* 'Purpurea' were green after the "hardening off" treatment and only gradually regained their red colouration. Also the leaves on *C. maxima* 'Purpurea' were very thin and soft. Leaves on the *Syringa* species were softer and more shiny than those on the control plants.

Cutting Production. There was generally a significant in-

Table 1. Increase in cutting material in etiolated treatment over non-etiolated.

	percent increase in cuttings
Polygonum baldschuanicum	122
Cotinus coggygria 'Royal Purple'	42
Corylus 'Purpurea'	8
Syringa 'Charles Joly'	78
Syringa 'Madame Lemoine'	31
Syringa 'Ludwig Spaeth'	37

Table 2. Rooting obtained from cuttings in the etiolated and non-etiolated treatments.

	Etiolated			Non-etiolated		
Species	Cuttings taken	Type of cutting	Percent rooting	Cuttings taken	Type of cutting	Percent rooting
Polygonum baldschuanicum	April 30	nodal	39	May 13	nodal	0
Polygonum baldschuanicum	April 30	heeled	51			
Polygonum baldschuanicum	May 9	heeled	68			
Cotinus coggygria	May 9	nodal	48	May 14	heeled	82
Corylus 'Purpurea'	May 6	nodal	33			
Corylus 'Purpurea'	May 9	nodal	8			
Corylus 'Purpurea'	May 12	nodal	0	May 12	nodal	45
Syringa 'Charles Joly'	May 6	nodal	83			
Syringa 'Charles Joly'	May 9	nodal	92			
Syringa 'Charles Joly'	May 12	nodal	67	May 13	nodal	48
Syringa 'Ludwig Spaeth'	May 6	nodal	78			
Syringa 'Ludwig Spaeth'	May 9	nodal	70			
Syringa 'Ludwig Spaeth'	May 12	nodal	56	May 12	nodal	46
Syringa 'Madame Lemoine'	May 12	nodal	27	May 28	nodal	0

crease in the number of cuttings produced by the etiolation treatment compared with control plants, as shown in Table 1. Rooting obtained is shown in Table 2.

Additional treatments: Nodal cuttings of *Polygonum baldschuanicum* taken from young non-etiolated plants gave 55% rooting. Cuttings of *C. coggygria* 'Royal Purple' forced under clear polythene gave 66% rooting.

DISCUSSION

Rooting of cuttings taken from the untreated stock plants, especially *Cotinus coggygria* 'Royal Purple' was much better than was expected based on the previous experience of the propagator.

Polygonum baldschuanicum. The stock plants used in the trial were 5 years old, and it is known that the rooting percentage declines with age of the plant. Thus, when cuttings were taken from 1 year old container plants as an additional treatment, rooting was increased from 0% (unreated stock plants) to 55%. The effect of the etiolation treatment was to overcome the problem of age of the stock plant and to greatly increase the numbers of cuttings available.

Cotinus coggygria 'Royal Purple'. The etiolated plants rooted less well (48%) than either the control plants (82%) or the plants forced under clear polythene (66%).

Corylus maxima 'Purpurea'. The etiolated plants had very soft thin leaves and were susceptible to scorching. Obviously additional shading is required if the technique is to be successful. Etiolation did not give much increase in cuttings.

Syringa cultivars. With *S.* 'Charles Joly' and *S.* 'Ludwig Spaeth', rooting was almost doubled in the etiolated plants compared with the control plants and there was also a considerable increase in cutting production. The much more difficult to root cultivar, *S.* 'Madame Lemoine' also gave some response to etiolation. The roots produced on the etiolated cuttings appeared to be more fibrous than those on the control. There was also considerably more extension growth on the etiolated plants after cutting.

1981 TRIALS

Following the encouraging results in 1980 the work on lilacs was continued and new species were included in the trial. With the lilacs it was hoped to see if there was any carryover effect of the etiolation treatment in 1980

		Covering date
Species covered	*Syringa* 'Charles Joly'	April 15
	Syringa vulgaris 'Madame Lemoine'	April 15
	Syringa vulgaris 'Ludwig Spaeth'	April 15
	Syringa vulgaris 'Katherine Havemeyer'	April 15
	Viburnum × *juddii*	March 24
	Viburnum carlesii	March 24
	Elaeagnus × *ebbingei*	March 29

Immediately before covering, the stock plants were sprayed with benomyl and chlorpyrifos as a precaution against disease and pests. Rooting obtained is shown in Table 3.

RESULTS

Table 3. Percent shooting obtained under etiolated and non-etiolated treatments

Cultivars	Cuttings taken	Etiolated 1981 Etiolated 1980	Etiolated 1981 only	Etiolated 1980 only	Non-Etiolated
Syringa 'Charles Joly'	May 28	36	55	34	58
Syringa 'Madame Lemoine'	May 18	*	*	28	6
Syringa 'Ludwig Spaeth'	May 18	32	20	1	3
Syringa 'Katherine Havemeyer'			37		28

Other species	Cuttings taken	Etiolated	Non-etiolated
Viburnum × *juddii*	May 19	8	7
Viburnum carlesii	May 19	11	16
Elaeagnus × *ebbingei*	July 2	57	46

* These treatments were lost during propagation because of severe botrytis infection The Katherine Havemeyer was not included in the trial in 1980

DISCUSSION

There does not seem to have been any marked response to the etiolation treatments in 1981. It proved to be a much more difficult season with *Botrytis* infection, both under the black polythene and in propagation and, despite additional spraying, considerable losses occurred, especially with lilacs. If the technique is to be of use commercially then a system of blacking out which is easier to manage must be developed. A walk-in black polythene covered tunnel would seem to be a possibility. This would allow easy access to inspect the stock plants and to carry out operations such as spraying and taking cuttings.

CONCLUSIONS

Etiolation has not yet given the same consistent result on ornamentals as on M9 apple rootstock. However there would seem to be potential for its use on lilacs, especially if the improved extension growth is a regular feature of the treatment and if *Botrytis* can be controlled.

J. GAGGINI: Could I ask David Rowell if the etiolation effect can be related to the extra heat under the polythene and if he has compared transparent or translucent polythene with black?

D. ROWELL: We did not measure temperatures, but since East Malling has been able to produce the effect by black taping of cuttings, temperature does not seem to be the main factor involved. Temperature would affect rate of extension growth. Our trials did not compare clear polythene, but Darby's have found use of clear polythene a better material for *Cotinus*.

R. GARNER: We need to be clear of the meaning of etiolation. True etiolation is the total exclusion of light, and the plant responds by no lamina development. Under black polythene sufficient light enters to allow lamina development, so this is not true etiolation and would be better termed, "partial blanching".

B. RIGBY: Is the speed of growth conducive to producing a faster rate of auxin production from the tip or is it related to the stretching of the pericyclic sheath allowing easier root growth?

R. HARRISON-MURRAY: We have no evidence of enhanced auxin concentration in the "etiolated" shoots, and equally the anatomical effects are numerous. There is still some lignification in the phloem which may act as a barrier to roots, but it is not stretched in any way since the diameter of the etiolated shoots is less than control shoots. A characteristic of the etiolated shoots is their inability to increase in girth for some time after treatment. They lag behind the controls for a considerable period of time. So far we have no strong leads as to the basic mechanism involved, but results vary considerably among species. In M9 the extension growth is not really stimulated and the internodes are not conspicuously longer.

H. SHEPHERD: Was the failure to root of certain species in the Darby trial due to decay in the softer cuttings or was it a genuine failure to root?

D. ROWELL: In general, the 1981 cuttings took longer to root than in 1980, but the etiolated material was more susceptible to *Botrytis* under mist.

P. GAUT: The covers have to be opened at intervals for inspection. Is there any information on how long covers can be opened before adverse effects occur? If you were able to open them for a period each day perhaps disease risks would be reduced?

R. HARRISON-MURRAY: With M9 we know we can open

them up every day for 5 minutes without adverse effects. We have started this ventilation as it does reduce the *Botrytis* problem. In fact, with M9 continuous exposure to low light does not reduce the "etiolation" effect, so complete exclusion of light is not a prime requisite for improvement of rooting.

MY EXPERIENCE WITH DOUBLE CLAD TUNNELS

JONATHAN VAN DER BORGH
Toxward Nursery
Horsham, West Sussex

We have always been concerned with waste in our business. We have tried to prevent waste of resources where possible, and have used waste products if available.

On our dairy farm, for example, we installed a Retriever unit in 1974. This is a water tank with a copper coil inside which uses the waste heat from the compressors for the refrigerated bulk milk tanks, and uses it to heat 60 gallons of water to 128°F from the ambient temperature of the day. We need water at 150°F to circulate and clean the milking pipelines, so we only have to buy the energy for the additional 22°F required. For an outlay of £740 in 1974, we are saving currently £1,250 a year in fuel costs.

Also on our dairy farm, we use old railway sleepers for silo walls, old motor car tyres to cover the silo sheets, wood shavings for cow bedding and we feed wet brewers grains to the cows as a part of their bulk winter ration.

In 1974 we started our container nursery on an acre of waste land, that is to say, land which was unsuited for dairying, but with frontage on the farm drive.

We built and installed everything ourselves, aiming at a low-cost enterprise, and we were guided from the outset by Don Gilbert of ADAS. A great deal of the credit for the present state of our nursery must go to my colleague, John Miller, who as well as propagating and growing our plants, has been builder, joiner, plumber, electrician, designer and innovator.

We started with two Robinsons tunnels 54 × 16 ft., in one of which we installed a mist bench with a capacity of 35,000 cuttings at a time. This tunnel was clad with 600 gauge UV clear polythene and the floor was concreted. The bench is raised 2½ ft. above ground level, constructed of Dexion slotted angle and old corrugated asbestos and timber from the dairy farm. To prevent heat loss underneath the bench, we made an envelope of black polythene sheeting, filled with surplus polystyrene granules, in all 1½ in. thick.

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We also installed a Nobel Instruments unit to control the heat under the bed, to keep electricity costs to a minimum. The mist operates on leaf control in summer and time control in winter.

For frost protection we installed an Aladdin Hot Box paraffin heater. In each of the first two winters we used an estimated 2,500 litres of oil for the burner in the propagation house. We experienced high levels of condensation on the inside of the tunnel walls, and this froze when the outside temperature fell below 25°F.

In 1976/77 we decided to double-clad our propagation tunnel and to try and keep the two 600 gauge sheets apart with blown air. We purchased from Airflow Developments Ltd. a 40 BTF single inlet blower with a ventilated 12 watt output, shaded pole motor, approximate speed 2,500 r.p.m. This cost £19. The blower was slung 3½ ft. above the mist bench. The outlet was attached to a tube made of polythene sheeting and "plumbed" into the side of the tunnel. The two sheets were fixed with battens attached to timber (4 × 1½ in.) which was fastened to the tunnel frame with U bolts. The windows were also double-glazed with the same clear polythene.

Above the door we constructed an air inlet vent 2½ ft. × 6 in., covered with Rokolene netting, to enable air to be drawn into the tunnel, to ensure a constant supply of fresh air.

The tunnel took 5 minutes to inflate. The warm air from the mist bench provided insulation from the outside air temperature, considerably reduced condensation on the inside of the tunnel walls, and there has been no further need for the paraffin heater for frost protection. The net annual saving at 1980/81 prices is estimated at £300, after allowing for electicity for the fan and the additional polythene sheet.

The slight reduction in light intensity has not been detrimental, in fact our experience on the whole is that we require shading in the mist tunnel for more days than otherwise.

We now spray Clovis Lande 'Sun Clear' on the inside of the tunnel walls which has practically eliminated condensation.

In 1980 we further improved the system, by constructing wooden trunking, slung above the mist bench, with two blowers attached to it. The blown air is now introduced into the tunnel walls, via the trunking, on both sides of the tunnel through old 3 in. plastic down-pipes. These two small blowers (total cost £41) inflate at the same time two additional double-clad tunnels on either side of the propagation tunnel, through underground pipes.

It is difficult precisely to calculate the cost saving of having all three tunnels inflated, but we use the two additional insulated tunnels in winter to store weaned cuttings, pot up early liners and ericas and carry out other operations under protection and in relative warmth.

VOICE: What is the light reduction with a double skin?

J. Van der BORGH: Estimation with a light meter from a camera suggests that the extra sheet cuts out a further 9% of light, but this has not affected plant growth.

PLANT HUNTING IN SPAIN

KELVIN LAWRENCE
Kelvin Lawrence Nurseries
Tilford, Surrey

Our purpose in going to Spain in December, 1980, was to renew acquaintance with two species of plants which we had previously found growing wild and flowering in mid-winter on the Sierra de Ronda in southwest Spain, inland from Gibraltar. These plants were *Clematis cirrhosa* and *Iris planifolia*, both flowering naturally in mid-winter, whose presence would be unsuspected unless you were travelling in that part of Spain in December and January. Both Chris Brickell and Roy Lancaster, who had seen my photographs, thought the *Clematis cirrhosa* of that region was a particularly good form and well worth introducing into cultivation here if we could bring plants back.

From Le Havre, our first stop in France was at the famous Minier Nurseries near Angers, where we spent two rewarding days. We then pointed the car south towards Spain and crossed the snow-covered Pyrenees by the Somport Pass, 5,000 ft. high. Although this is a "Chaines Obligatoire" pass in winter, we had crossed several times before without chains, and had no trouble this time. The sun on the Pyrenean snows was dazzling — what a marvelous combination sun and snow can be. It is worth mentioning here that in early summer the Pyrenees are a rich source of alpine plants, in our experience more varied than in the Alps. One can spend many happy days among the gentians, primulas, *Daphne cneorum* scenting the air, *Saxifraga longifolia* spewing from the perpendicular cliffs, and if you look in the right places *Ramonda myconi (Syn. R. pyrenaica)* in rocky crevices, but now sadly becoming scarce On the top of the Bonaigua Pass at 6,000 feet, we once counted 180 flowers on a huge clump of *Gentiana verna* within an area of a square foot.

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There are many alternative routes from northeast to southwest Spain, and we try to plan a new route each time, as far as possible using secondary rather than main roads. The Gredos Mountains west of Madrid, rising to 6,000 feet are often snow covered in mid-winter, but if the roads are open they are well worth driving through. Travellers taking a more easterly route should not miss a marvelous bit of country between Teruel and Cuenca in New Castille. In one area, in lovely open hilly moorland, the slopes are covered with a patchwork of *Juniperus sabina* in circular mats, a single plant sometimes covering a diameter of 15 feet. Towards Cuenca on high ground at the top of an extensive natural pine forest, is an extraordinary area of rock called the Ciudad Encantada, the Enchanted City, where rocks have been eroded into fantastic shapes by wind and rain over the centuries. This should not be missed, being one of the least known, but most rewarding sights in Spain. The surrounding country is spectacular and full of interest. If a southerly route is preferred, the road from Puerto Lumbreras to Granada passes through a village where most of the houses are built into the rock and are literally cave dwellings with a mere facade of bricks and mortar. Chimneys poking up here and there through the rock give the only clue to the rock dwellings beneath. One understands that it is not poverty that prompts people to live in these caves, so much as the need for cool conditions in the hottest area of Spain, and the freedom from the necessity of paying rates. Beyond is a remarkable bit of country, reminding one more of a moonscape, comprising a huge area of eroded rock, resembling miles of grey slag heaps — perhaps more intriguing than beautiful. Approaching Granada, the snow-covered Sierra Nevada massif rears up on the left to over 11,000 feet. It is interesting that the highest motor road in Europe winds up the mountain from Granada to 10,000 feet up, little short of the summit.

From the coast between Gibraltar and Marbella, the Sierra de Ronda rises in a series of hills up to 5,000 feet for about 40 miles inland. This was the area in which we were interested, and where we had previously found our two species of plants. We discovered the Iris again on Christmas Eve alongside a tiny road some 20 miles N.E of Ronda, just outside a village, on rocky stony ground, well grazed over, but undamaged by sheep and goats. *Iris planifolia* is a lovely plant with wide leathery leaves and flowers some 4 inches or more across on 3 to 5 inch stems, of a lovely translucent pale to dark blue. Two pure white forms were discovered. This is a fleshy rooted Iris and probably difficult to establish in gardens. But what a reward awaits anybody succeeding.

On Christmas Day, in sight of the Rock of Gibraltar far below we renewed our acquaintance with the clematis, in full flower, clinging to brambles for support. Later we found it growing among the branches of young olive trees. In colour the flowers are deepish primrose yellow with the faintest green flush, up to 2 inches diameter, in stalkless open bells in profusion on the hanging stems. On the higher ground we found only isolated plants; but lower down behind Algeciras, along the "Strada de Toros" — the Road of the Bulls — we found it in greater profusion. We extricated a few roots from among the brambles on the higher ground, and these survived the journey and are flourishing.

Other plants we found growing wild and in flower in late December were a most attractive white *Narcissus tazetta* variety, and *Vinca difformis*. An unlikely plant association was to see a cactus (*Opuntia*) growing out of the middle of the vinca. We were too early for miniature narcissi; but it was sufficient reward to find and bring back two such beautiful plants flowering naturally in mid-winter.

DISCUSSION GROUP REPORTS

I. CUTTING HANDLING

Chairman: David Clark
Speaker. Brian Morgan
Reporter: Paul Labous

The chairman of the group, David Clark, opened the discussion by making reference to the paper given by John Stanley and Ian Baldwin, on "Work Flow and Costings in Propagation" which set the scene for our topic.

Brian Morgan then outlined the main points at which cuttings are handled, as follows:

1. At the stock plant
2. Collection and storage of cuttings
3. Compost mixing and preparation of trays
4. Preparation and insertion (this is the "bottleneck" in the whole system)
5. Transportation to the propagation unit
6. Hygiene, e.g. application of fungicides.

Having identified the "bottleneck" as preparation and insertion of cuttings, Brian Morgan, through A.D.A.S. has developed a system which should be applicable to a wide range of nurseries, to speed up these operations This has led to an

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increase of between 20% and 50% in increased throughput, to date.

The essential principle involved in the method is that once the cutting is picked up, it is never put down until it is inserted in the rooting medium, thereby saving time. The cutting material must be roughly prepared prior to this operation, by another, or other, person(s). Stripping and trimming of material is carried out by using either a Stanley model knife, or a Plas-Plug knife. Large spined subjects are trimmed with small secateurs and wounded where necessary with the blade of the tool.

David Clark opened the general discussion by focusing attention on the "bottleneck" in the system, i.e. "preparation and insertion" of cuttings. From this discussion it became obvious that there is considerable variation in the methods employed by nurserymen in this one operation. Twelve members of the discussion group used a "traditional" method, i.e. preparing cuttings separately to the "sticking" process, and nine members used the ADAS technique where preparation and sticking are combined. There is, surprisingly, less variation in the speeds obtained in this operation by different nurserymen. Trevor Price gave the rate of 25,000 cuttings in a 40 hour week with two people preparing and inserting cuttings and one junior collecting material and preparing compost and trays. This is a rate of 312 cuttings/hour. Bill Matthews gave a rate of 10,000 cuttings in a 30 hour week, per person, or 333 cuttings per hour, and Brian Humphrey reported 10,000-12,500 cuttings per person in a 40 hour week, or 250 to 312 cuttings per hour.

Brian Morgan gave the average rates under average conditions which could be achieved by his method, as 666 cuttings per hour for conifers, and up to 1000 cuttings per hour for tip cuttings, e.g. cotoneaster, for preparation and insertion only.

Dr. Phillip Gaut made the point that speed may not be the main criterion, and is it possible that a person working slower may produce a better percentage "take" ultimately than a faster worker? It was the general opinion of the group that slowness often is associated with bad workmanship and that the faster, more skillful worker probably produced a better percentage "take." This point, perhaps, needs further investigation

The discussion then turned to methods of collecting material. There are two main methods by which nurserymen are collecting as follows·

a. cutting large sections of plants and preparing them as cuttings at a later stage at another location

b. taking smaller sections which are more or less the correct size to make the final cutting.

Andre Briant for example, reports that on his nursery, large branches of the stock plant are collected for many shrubs. Material for conifer propagation, however, is collected by taking sections which are about the size of the eventual cutting. John Watts mentioned that sufficient material to produce cuttings is collected at rates of between 450 and 700/hr., the faster rate being from managed stock beds. Generally, it was agreed that the use of stockgrounds would increase the rate at which useful material was collected, although there are exceptions, depending on the species.

Some reference was made to the use of cold stores which prove most beneficial in the handling of cuttings, especially when collection has to be carried out later on in the day when temperatures may be fairly high. The reduction in physiological stresses within the plant may improve rooting, although Brian Morgan mentioned some very recent experimental work which may indicate that cuttings under stress actually root easier.

Time did not allow for an "in depth" discussion on the aspect of transportation of inserted cuttings to the propagation unit, although it was agreed that the British seed tray was too small a unit and a container about three times its size, holding about 160 tree or shrub cuttings, is probably more suitable.

Finally, the Chairman asked for ideas for future OND projects to be considered for I.P.P.S. student awards.

It was agreed that a project which investigates whether it is necessary to trim softwood or semi-ripe cuttings before insertion would not only be an excellent subject for OND work, but would also give some valuable results for use in the industry.

II HARDWOOD CUTTINGS

Chairman. Bruce Rigby
Speaker· Nat Clayton
Reporter: Mary Helliar

The chairman for this discussion group was Dr. Bruce Rigby, who opened the session with a suggestion that cost cutting in the future might well be achieved by propagating from hardwood cuttings.

Nat Clayton agreed, and said that for him the value of hardwood cuttings was as a simple system for one-year production where the main ingredients for success are:

1. quality of the wood
2. soil that can be worked in winter
3. irrigation

He went on to describe his system, which was to begin collecting and making cuttings as soon as there was some spare time in his winter work programme. He used a bandsaw to cut the wood into 6″ lengths, and bundles of 25 were plunged in sand. Cuttings were prepared from early winter and lined out from February as soil conditions permitted. No hormones were used, but any doubtful cuttings were discarded at planting. This reduced field failures and increased the percentage of saleable plants.

Nat lines out up to 90,000 cuttings per acre in slits made by discs following dunging and deep ploughing of the land. Once all lining out is finished Simazine is applied at 1 to 1½ lb (a.i.) per acre. He had also tried trifluralin with reasonable success. In late June a 12.18:18 compound fertilizer was used as a top dressing. Initially the usual range of *Sambucus*, *Salix*, *Populus*, etc. was grown, but now new lines are tried each year and, among recent successes, were deciduous viburnums and rods of *Salix aegyptiaca* chip-budded with Kilmarnock willow. However, some subjects were not so ready to root, and these were given two weeks in peat on a heated bed before being put outside. Nat's experience raised discussion on several aspects, all related to deciduous species.

First was the physiological aspect, the time to take hardwood cuttings. Work on fruit rootstocks at East Malling Research Station had shown a distinct regenerative curve, on which there were two points when the roots appear fastest and the resultant growth is best. These two periods are (1), at leaf fall, and (2) at early bud break. Garner's early work correlated rootability with a soil temperature above 45°F at 9 to 12″ depth. Philip Macmillan-Browse pointed out that leaf fall on modern vigorous stock hedges would be later, and suggested taking cuttings slightly earlier than natural leaf fall.

At present there is no explanation why rooting is better at these two specific periods, and seasonal variation, even day to day variation, frequently occurs. It is particularly obvious in fruit, where early leafing types such as quince and plum root best from autumn cuttings. Results with apple are better from cuttings taken in spring.

Generally a similar pattern is seen in ornamental lines, but most subjects root much more easily than fruit stocks. Even in the "depression period" on a regenerative curve, cuttings still root but take longer to do so.

Heinz Clasen reported that in Germany several hundred hectares of hardwood cuttings are grown in Schleswig-Holstein, and all material is collected before Christmas and cold stored until there is time to cut and prepare it in January and

February. If the cuttings cannot be stuck immediately they are kept in polythene bags in a cold store until spring.

Mention of cold storage drew other accounts of low temperature effects on rooting. Nick Dunn reported better results this year when apple cuttings, prepared and dipped in December, had been given two months cold storage before being put in heated bins Dr. Lamb at Kinsealy, similarly, had good rooting of blueberries after low temperature treatment. Heinz Clasen cited another case where *Hibiscus* cut and prepared before Christmas had been a total failure, but when cold-stored at 0.5°C until July there was 100% success.

Both Dr. Richard Harrison-Murray and David Whalley were sceptical of these results as they had tried this in their research with variable results, both among genera and from year to year. It was suggested that rootability might depend on the length of the previous growing season.

The relationship between temperature and root and shoot development drew more comment from Dr. Garner, who pointed out that roots have no dormant period, and given adequate temperature and physical conditions they will grow. Buds on shoots, however, have an inbuilt chilling requirement and, however much bottom heat is given they will not develop until they received the minimum amount of chilling. Dr. Keith Loach thought that the failure to develop shoot growth was sometimes due to insufficient carbohydrates and there was a need to produce leaves quickly that could photosynthesise.

Establishment in the field was not discussed in any depth, but Robin Currie felt that results were often affected by soil temperature and weather after insertion in the field. The main reason for deep insertion in the soil was to prevent desiccation of the cutting; however depth can be varied to determine single or multi-shoot development of the plant.

Another topic covered briefly was the possibility of using polythene mulches through which cuttings could be pushed, as Long Ashton Research Station had recommended. The problem was one of lifting, a degradable plastic is needed, but a suitable one may soon be coming on the U K. market

The following items were added in discussion: the uptake of rooting hormones by woody cuttings is better from liquid than powder formulations, "partial blanching" of *Corylus* and *Acer* stock plants at East Malling Research Station had met with some success; the difficulty sometimes encountered in rooting *Platanus* may be due to clonal variation of the hybrid (Forestry Commission work) and finally, on the subject of herbicides, Ronstar had been successfully used on *Salix* and *Populus*, and Devrinol (napropamide) incorporated into the soil

in a trial had given good results, but not when it had only been sprayed on the surface.

III. TRAINING ON THE NURSERY

Chairman: Tom Wood
Speaker: Mike Dunnett
Reporter: Leslie Morgan

Tom Wood started our discussion on the subject of training on the nursery in his role as Chairman, outlining some of his ideas about training. He then introduced Mike Dunnett, our Speaker. He put forward the following opinions and questions.

1. What are we training for?
2. We should be aiming for value for money.
3. Rates of work for trainees.
4. The role of the I.P.P.S. in training.

As for the first point raised by Mike, there were several ideas such as, an easier life for the management, motivation of the individual, and increased production.

It was felt that the second point made by Mike about value for money had been seen over the past twenty years with the increased efficiency in the nursery industry. Part of the reason for this must be training, but there is still room for improvement.

As for point three — rates of work for trainees. This was the most contentious problem as there are so many different methods and individual speeds of work involved when setting rates for the different jobs but it was felt that some rates should still be set. There were also some interesting comments on the proficiency test itself, such as is it really only for general workmen, as it only involves set tasks such as planting cuttings There was a suggestion that there should be a more advanced proficiency test involving timing of cuttings and the more technical work involved in propagation. Another point brought out at the meeting was the problem of validating improvements in our apprentices.

IAN BALDWIN: There seems to be no easy answer to this problem as it involves more work for the management as there is a need for more records on each apprentice.

TOM WOOD: Debriefing after block release may also help in validating improvement in apprentices, since it shows management interest in the individual.

As for the last point raised by Mike, a majority of members of the discussion group thought that the I.P.P.S., as a body of professional men, should put pressure on the P.T. Council, and should take a lead to formulate a policy for members to

determine standard rates for the different jobs performed by apprentices.

MARGARET SCOTT promised to send out a circular to members to get figures for propagation. It is hoped we will be able to get a good percentage of members replying to the circular It was also thought that an I.P.P.S. workshop should be held to iron out some of the further problems involved with training. One of the major problems for the Society will be to gain recognition by the official body involved with craftsmen's education so we have to apply as much pressure as possible.

QUESTIONS AND ANSWERS

1. *Cutting Handling*

N CLAYTON. The Training Board proposed a course on the ADAS handling of cuttings technique and response was so great we had to do two courses on the nursery. To see how effective the technique was we time people for the first 15 minutes doing their own method, and the last 15 minutes of the day using the new technique. Figures bear out those discussed since, in the first 15 minutes, rates varied from 17 to 61 cuttings inserted and, by the end of the course, had improved to 37 to 72. The best improvements were achieved by people who had not worked with cuttings before.

M DUNNETT Was the conclusion of the group that the traditional methods of cutting preparation should be abandoned immediately in favour of doubling output from the new method, or were other factors involved?

P. LABOUS: The new method saved time in that cuttings were not being double handled and has set a target to aim for

B. HUMPHREY: In some cases it is not practical to insert cuttings at preparation. Some growers prefer to fill and stack trays for transport to the propagation unit, and cuttings are taken there after preparation. The overall picture will vary with nursery layout and management, and box filling, cutting preparation and insertion need careful consideration. While the ADAS technique has produced a standard to aim for, it must not be taken out of context of the nursery management

2. *Hardwood Cuttings*

B HUMPHREY. A comment on London plane tree (*Platanus* × *acerifolia*) which, in fact, is a complex of clones resulting from a cross of P. *orientalis* and P. *occidentalis*. The Forestry Commission has been doing a study of the London plane for the Department of Environment and have identified a complete range of clones from those of almost pure *P. orientalis* in origin to those of almost pure *P. occidentalis*. It is quite clear that the higher the level of P. *occidentalis* genes in the

clone, the more easily it roots. The clone most common in the trade is one called 'Pyramidalis' which has a very strong P. *occidentalis* component and is the easiest clone to root. Unfortunately it is perhaps the worst clone for suckering, poor bark, and susceptibility to *Anthracnose*. So we have, unwittingly, selected out in the trade the easiest to root but the worst for performance.

L. DICK: You seem to use Simazine successfully with hardwood cuttings. Some literature suggests its use will result in cutting death

N. CLAYTON: We have been using Simazine now for 6 years with no problems, but it is not applied until the cuttings have settled and are beginning to move. We use it at 1 lb a.i./ ac.

B. HUMPHREY: We also use Simazine, applying it immediately after inserting the cuttings but at a lower rate or 0.5 lb a.i./ac.

J. EASTMAN: There is evidence to show one needs care in which formulation to use. There has been damage reported from using liquid Simazine rather than the wettable powder.

3. *Training on the Nursery*

B. HUMPHREY: This discussion group has put forward a proposal that the IPPS become more involved in aspects of training. Could they amplify how this might be achieved?

M. DUNNETT: Growers in the West Midlands have been trying to revamp National Proficiency tests for nursery stock. In coordination with four other nursery stock training groups, this has been accomplished and will be presented to the Proficiency Test Board in the future for their consideration on a national basis. The test content therefore has been adequately covered. We have gone out on a limb, however, by trying to put down rates of work speed as well as the quality element as important for the craftsman status. This is a difficult area and a contentious one. In the discussion group it was felt that this was a possible area which IPPS, as a very professional organisation, with practical members could become involved in. It would also be an excellent way for IPPS to become involved, but not too deeply, in the training scene, since there are many other training organisations. However, we felt IPPS should be seeking an identity in training and the work rate field provides the opportunity, particularly as the "cutting handling" Group was discussing just this. What needs further discussion is the "Modus operandi". In the West Midlands it was just practical to get together for discussion, but this is obviously not feasible on a national scale. A survey form was suggested which could be circulated to members. This could be returned to the Com-

mittee for correlation and averages worked out. This could then lead to "Workshop" days based on the findings of the survey. If this was successful, those recommendations could then be sent on to the National Proficiency Test Board for consideration. This type of survey would give a broad spectrum of data to work on.

D ROWELL: The effectiveness of a survey depends very much on how it is set out, and there is a service in ADAS which can be consulted on the best way to achieve the aims of a survey

B. HUMPHREY. Would members agree that IPPS should become more involved in this type of political activity?

T WOOD: IPPS in the G.B. & I Region has increased from its small beginnings to a position of having a wealth of experience and information on tap. We are an active Society and need jobs to do, and we are in an industry which needs this type of job done. We established in the Discussion Group that there was a need for this type of information. Training groups are regional, IPPS is national and more than competent to gather this type of information. A survey, if supported by the Membership, would be a powerful means of achieving the objectives and would be of great help to the industry which, after all, we are all involved in.

R FLINT: With the workshop proposal it would be possible to develop and perhaps uprate the propagation proficiency test. Possibly achieving a technician grade test which would involve more decision making activities, such as time of taking cuttings, wounding, hormones, spraying, etc., rather than the purely fundamental test of making cuttings This is a natural extension of the existing test and hopefully could be put forward to the NPTB for consideration in due course.

B. HUMPHREY: The National Proficiency Test Board is a powerful organisation with union backing and it will not be easy to penetrate their rules and regulations. It will be essential for us to set our own house in order, so to speak, and have a firm concensus of opinion based on the survey technique if we are to carry the idea on into the political arena. On behalf of the Conference I would like to pass these views and ideas on to the Committee for further action.

THE POTENTIAL ROLE OF THE COMPUTER ON THE NURSERY

JON VARLEY

Department of Horticulture, Wye College, Wye, Kent.

Computers have been in existence for over 50 years, but only within the past five years have they become cheap enough to play a part in the running of small businesses. Computing power that would have required a room full of electronics some ten years ago is now available within a unit no bigger than an electric typewriter. Cost, as well as size, has dropped dramatically, and complete small-business computer systems can be bought for as little as £1500. In the past, only a few large corporations could justify the cost of a computer — usually well over £20,000.

New technology is the key to the changing face of the computer industry — and especially the development eleven years ago of the first microprocessor. By using the descendants of this rather slow and ungainly (in comparison with modern equivalents) device, computer designers have been able to produce small, versatile, and powerful machines which have been dubbed "microcomputers". Such is their popularity in business areas that the new generation are being designed as pieces of office furniture, and acquired the new name of "Business Computers".

Whatever the technology, a computer is only as good as the programme it is running. In the past, computer programmes were like the computers they were written for — large and expensive. Programmes for large present-day computers still are, often costing tens of thousands of pounds. However, with the micro-computer came a similar revolution in programming — mass production and large markets allowed sophisticated packages to be sold at relatively low costs, just a few hundred pounds down to as little as ten pounds. Payroll, sales and purchase ledgers, letter and document production, stock control and invoicing are applicable to the majority of businesses and therefore have a vast market. Many such packages written for microcomputers have become available cheaply and the numbers are still increasing.

More specific business areas began to appear profitable to programme writers. Estate agents, solicitors, garages, and doctors all have their own custom-built packages and more will doubtless follow But what of horticulture in general, and plant propagators in particular?

The computer as a management aid. Any small business, and the nursery is no exception, must consider the possibility of using a small computer to aid with management tasks and general running of the office. In some areas, because of the irregular nature of work on the nursery, a computer would be of even more value than to a factory or an estate agent.

For example, payroll packages can include complicated overtime allowances and casual labour — working out tax, National Insurance, etc. without danger of wrong calculation and with a great saving in time. Accounts can be automatically produced in the correct format for auditing or use in planning. Computer-based invoicing can save much confusion, and keep an eye on credit limits and payment times. Word processors can produce catalogues, catalogue updates, newsletters and advertising leaflets of excellent quality and in large quantities without resort to commercial printers, and can also make business communications look very professional — something that must not be overlooked in a competitive market. All these programmes can be bought off the shelf — or can be supplied as a complete system, together with computer and printer Their cost is low — anything from £50 to £400 for a sophisticated programme, or about £4000 for the complete computer system plus a selection of business programmes.

Of the "general use" programmes, the one I have not mentioned is stock control. This poses a problem for the nurseryman, but also offers perhaps one of the most exciting possibilities for using computers on the nursery

Stock control in general business is usually more simple than on the nursery. A small manufacturer may produce a hundred or so items — these can be handled easily with a small computer. A nurseryman may produce four or five hundred cultivars — not only that, but he may sell them at four or five different ages, and each age will have a different price. This means the computer will have to be bigger, and therefore costlier, and the programme is less standard and must be modified or even rewritten — again a costly procedure. The computer is pricing itself out of usefulness.

Another variation of use to the nurseryman would be the ability of the stock control system to categorise plant types and, if necessary, suggest alternatives that may fill the customer's requirements. In other industries this rarely happens — if a buyer wants a pump of a certain capacity or physical size, it's no use suggesting he buy one nearly the same size and the same colour, whereas if a buyer requires a *Cotoneaster simonsii* for hedging, it may be that *Cotoneaster lacteus* would suit his purpose just as well.

Invoicing and credit control is best linked to stock control, and advertising discounted lines could be done at the same time.

Planning with computers. Farms have enjoyed access to planning programmes for some years now, and even market gardens have benefitted from a computer-planned planting and labour-use schedule. Nursery stock production is less fortunate, and again the reason is the variable nature of the industry. A farmer can punch in his acreage, whether arable and livestock, and out come several options over a five, ten or fifteen year period that detail crop types and times of planting and harvesting, expansion and labour needs. If this were applied to nursery production, all growers would soon be producing the same five or ten species and, of course, this is neither practical or desirable. However, in the more generalised field of economic planning, the nurseryman with a microcomputer can use such very sophisticated planning aids as the Visicalc package which can be adapted to handle many forecasting parameters, and can instantly perform, "If x changes then what happens to y?" type calculations. To apply it to a specific example, it could help a nursery manager to decide whether to sell off a line as small plants, or allow them to grow on for a year or two to become specimens. Allowances could be made for labour input, space costs, etc. The cost of this type of programme is as little as £100.

Nursery mechanisation and the computer. The new technology of microprocessors has also been swiftly adapted to other situations and, for the nurseryman, one of the most important applications is in the area of mechanisation of the nursery and environmental control The computers involved in these applications are not only the sophisticated "business" computers, but also smaller units, also based on microprocessors, that can carry out a specific task repetitively and accurately.

Electronic controls for propagation equipment have been with us for years, but a small microprocessor unit could control multiple functions, such as misting devices, underbench heating, and drip irrigation. It could also take into account many things a simple electronic device could not, such as the amount of sunlight and the need for irrigation sequencing to avoid low water pressures in main supplies The more sites of control, the cheaper microprocessor control becomes in comparison with older electronic devices Irrigation of outside areas can be similarly governed, using information about soil moisture and sunlight to decide upon sprinkling or irrigation of soil-planted species.

Nurseries with large areas of polythene tunnels or glass-

houses can benefit by use of a computer control system for protected environments. These systems can provide much better control of growing conditions for the plants, and can integrate all control functions within one machine. They can also make use of fuel for heating more efficiently. Dutch glasshouse control systems have been available for five years now, and this year has seen British computer control systems for greenhouses arrive on the market.

At Wye College, we have developed a protected environment control system based on a microcomputer used widely for office work, the Commodore PET. Our machine controls the commercial glasshouses at Wye College, which include pot chrysanthemums and tomato growing areas. Adaptability of the system allows us to put not only environmental conditions under the control of the computer, but also CO_2 levels, thermal screens, automatic irrigation and hydroponic systems Future additions could include mist propagation units, supplementary lighting and screens for daylength control, and nutrient mixing and distribution through drip irrigation systems. As the system incorporates a weather station, it may in the future be possible to predict high-risk periods for fungal diseases on outside-grown crops.

Control systems are more costly than office systems, not because they use larger computers, but because of the installation costs and associated hardware (such as sensors) that go with them. At present, a small control system for greenhouses costs around £5000, but larger systems get more economical compared with older electronic systems.

Small computers are best at doing one thing at a time, and separate systems are probably the wisest choice if both office and control functions are considered.

Plant propagators and computers. There are many nurseries that would benefit from computer systems that are available now, in terms of efficiency, office work, and possibly control applications. Many other nurseries may benefit from waiting until more specific packages become available. However, these specific packages will only become available if computer programmers and package designers are approached by nurserymen and told that a market exists Standardisation of nursery practices will also play an important part in making computers more applicable to the industry, as standard operations are much easier to include in computer programmes than non-standard ones Standardisation is appearing in certain areas — size bands for pricing lines, propagation and growing-on methods are all becoming less magical and more organised. Only a very large company can afford to have a computer consultant write a purpose-built programme package

— but other sources of programmes exist. Universities are an obvious place to look — if an interest can be created there, then both University and nurserymen can benefit. The Government itself has launched the MAPCON scheme, which in some cases gives grants for both development of microprocessor-based systems and consultations by possible users of such systems — this area should be exploited to the full by the nursery industry.

Fears are often expressed about cuts in employment where computers "take over" jobs previously carried out by the labour force. So far in horticulture, we have not seen this happen. In the office, the computer allows some areas to become more efficient and less arduous, or else accomplishes things that were not previously possible, and in the control field the computer replaces either eletronic or mechanical devices, work that was not done manually anyway.

To sum up, the commercial plant propagator must now consider the use of computers for both office and control applications, and must exert pressure on the relevant institutions or industries to produce more specific computer-based products for his own needs. Whatever happens, the computer will continue to infiltrate the industry, and the plant propagator must take advantage of this versatile and useful tool.

T. WOOD: You were speaking of rooms full of equipment being reduced to a desk console. Does one still need clean air? We, in the nursery industry, work in a very dirty environment and could not get away from dust and sand.

J. VARLEY: It can be a problem. In the Wye glasshouse unit we have built a small room, which is isolated but not air-conditioned. The dust does not affect the computer, but does the data storage facilities such as disc storage. While not actually needing air conditioning, it does need a relatively dust-free environment. This does not apply to the control equipment.

A COMPARISON OF CONTROLLED AND SLOW RELEASE FERTILISERS FOR THE ESTABLISHMENT OF LINERS UNDER GLASS.

PAUL M. UNDERHILL

Wardington Nurseries,
Banbury, Oxon.

This trial, winner of the Student Project Award 1981, was carried out at Hadlow College, Kent.

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Subject: *Skimmia japonica*
Propagated: 21st October, 1980
Potted: 2nd February, 1981
Compost mix 75% Irish moss peat (Medium grade)
25% sand ($CaCO_3$ content above 1%, therefore no ground limestone was added)

Rates of commercial products used:

Mix 1. Osmocote 18:11:10 (9 month 'standard').

1.8 kg/M³	Osmocote	90 g/50 litres
2.4 kg/M³	magnesium lime	120 g/ " "
0.3 kg/M³	W.M. 255	15 g/ " "

Mix 2. Osmocote 17:11:11 (9 month 'fast start').
as above.

Mix. 3 Sierrablen 19.6.10 (plus iron)

1.8 kg/M³	Sierrablen	90 g/50 litres
2.4 kg/M³	magnesium lime	120 g/ " "
0.3 kg/M³	W.M. 255	15 g/ " "

Mix 4. Nutricote 16·10·10 (180 day formulation)

2.73 kg/M³	Nutricote	137 g/50 litres
2.04 kg/M³	superphosphate	102 g/ " "
0 33 kg/M³	255 W.M.	17 g/ " "
2.4 kg/M³	magnesium lime	120 g/ " "

Mix 5 Ficote 16:8:7

4 kg/M³	Ficote	200 g/50 litres
0.75 kg/M³	superphosphate	38 g/ " "
2.4 kg/M³	magnesium lime	120 g/ " "
0.33 kg/M³	W.M. 255	15 g/ " "

Mix 6. Vitax Q.S.2,12:6:6:6 plus trace elements

4.5 kg/M³	Vitax	225 g/50 litres,
2.4 kg/M³	magnesium lime	120 g/50 litres

Mix 7. Plantasan 4D,20:10.15.6 plus micronutrients

3 kg/M³	Plantasan	150 g/50 litres
1.2 kg/M³	ground lime	60 g/ " "

In the case of controlled release fertilisers the release rate is based on temperature. Most of the companies which market these products publish release curves based on 25°C. Measurement showed that the compost temperatures were not above this level until April. This implied that nutrients were being used as they became available, as was further indicated by compost analysis.

Skimmia usually makes only one flush of growth in a season. This was completed by the 4th April, when the total number of shoots was recorded (Table 1).

Table 1: Effect of fertiliser treatment on shoot number in *Skimmia*

Fertiliser mix	Shoot numbers					
	1	2	3	4	5	6
	Number of plants					
Mix 1	7	30	44	15	4	—
Mix 2	10	24	46	15	5	—
Mix 3	12	22	38	24	4	—
Mix 4	11	33	40	13	4	—
Mix 5	11	16	59	13	—	1
Mix 6	12	30	47	11	—	—
Mix 7	13	28	38	19	2	—

Conclusion. Type of fertiliser had little or no effect on the amount of branches produced.

The total extension growth was also recorded (Table 2).

Table 2: Effect of fertiliser treatment on extension growth in *Skimmia* (Average of 100 plants per treatment)

Fertiliser mix	Extension growth (cm)
Mix 1	13 4
Mix 2	13 9
Mix 3	12 9
Mix 4	13 0
Mix 5	12 9
Mix 6	6 8
Mix 7	11 3

Conclusion: Most of the resin-coated types showed similar extension growth, and the slow-release types showed less growth.

At the end of the season the plants were graded. Grade 1 plants had two or more even shoots, Grade 2 being plants with one shoot or two uneven shoots (Table 3).

Table 3: Effect of fertilizer treatment on grading of *Skimmia* plants

	Number of plants per grade		
Fertiliser mix	Grade 1	Grade 2	Waste
Mix 1	73	27	0
Mix 2	80	20	0
Mix 3	64	36	0
Mix 4	54	46	0
Mix 5	72	28	0
Mix 6	33	67	0
Mix 7	69	31	0

Conclusion: The mix which gave the highest percentage of Grade 1 plants was Osmocote 17:11:11 (fast start).

The Nutricote plants (94% chlorotic) were generally poor, attributable to the high level of superphosphate recommended. The Vitax QS plants showed poor growth with 24% chlorosis. Plantasan gave 18% chlorotic plants. The healthiest looking, greenest, and most attractive looking plants were those in the Ficote mix.

Nurseries should try out these products under their own conditions to ascertain which gives the best quality liners for potting on.

PROPAGATION OF MARGINAL AND AQUATIC PLANTS.

GRAHAM BURGESS

Artscapes Aqua,
Church Street, Whitchurch, Hampshire

Aquatics are a very specialised group of plants so first I will describe the natural conditions under which such plants grow. One word, WET. The degree of wetness will vary from moist soil or mud to several metres of fairly clear water.

It is obvious to anyone that there is a marked change in the vegetation at the edges of ponds and lakes. As the soil above the water table becomes shallower the moisture content increases and oxygen levels drop. The first indication is that the only trees that thrive are those that need lower levels of oxygen, e.g. willow, alder, etc. Such vegetation is called "carr" vegetation. The highly variable flora of drier land gives way to sedges, rushes kingcups, and water docks.

Some plants are adapted to grow with their roots rooted below the water. Above the water their aerial stems photo-synthesise as normal terrestial plants. These plants, sometimes half in and half out of the water, are called EMERGENT PLANTS.

As we move further away from the bank and, if the water becomes deeper, these plants cannot grow and we come to a zone of plants which are THE FLOATING-LEAVED PLANTS. They are rooted in the bottom but they send up stems and/or leaves (sometimes different types of leaves above and below the water) and these photosynthesise above and below the water.

Some of these plants hang in the water, preferring to drift about drawing nutrients directly from their watery surround-ings. The floating leaved plants grow best in still waters.

In amongst these plants, and in the deeper parts of the water, we find another zone of SUBMERGED PLANTS. The submerged plants rely on the light penetrating the upper hori-zons of the water, and on the nutrients in the water for photosynthesis. Like the sea weeds they have little need of strong stems — the water buoys them up. One can find a degree of internal strengthening in species adapted to growth

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in streams but generally they are very fragile and bits break off easily.

Natural propagation. The aquatic trade is not as well developed as the terrestial trade, perhaps because it is a cold, wet and malodorous business at certain times. The range of plants is relatively small and some of them grow naturally at a rapid rate so production always satisfies demand in the more common plants. The season can be very short, especially in England. Aquatic plants soon outgrow their surroundings, and sometimes they do not keep well, so some reliance is put on supplies from established stock beds which may be the margins of lakes and ponds.

Natural propagation occurs through:

Seed dispersal: by wind and water (wind-blown seeds and floating fruits and seeds), also by burrs attached to fowl or mammals. The seeders always have a strong back up of vegetative propagation.

Spores. A few aquatics are spore bearing, e.g. *Equisteum*, but for trade purposes vegetative propagation is quite fast enough.

Vegetative propagation. The emergent plants generally spread by rhizomes often making mats. Pieces of these break off, float away, and new colonies are started.

Floating Leaved Plants. Certain water lilies spontaneously produce buds or "eyes", as they are known in the trade. These branch off or break off, float away and make new plants. the production of eyes is spasmodic; it is not quite as simple as getting axillary buds to grow. They are more like latent buds. By trimming back hard and planting in shallow water some lilies may be induced to produce more eyes. One *Nymphaea*, "Colonel Welch" will produce a yellow flower and this, on dying, may produce young plantlets viviparously. It is an exception.

Submerged Plants. These all rely heavily on vegetative propagation. Pieces break off during growth and these equivalents of stem cuttings float away and form roots. No need for a mist bench. Some plants produce "hiburnacula." These bud-like structures hold stored food material. At the end of the growing season they break off and fall to the bottom ready to grow out in the following spring, e.g. Hornwort; Water soldier; Water milfoil.

All of the underwater growth responses are more tied to temperature than anything else. One can control the temperature of a body of water by controlling its volume also the flow of new water through it. Water depth can give winter protection,

but too much and you have a cold sink which takes a long time to warm up. Aquatic nurseries are best situated where there is natural, clean water in copious supply. In summer the evaporation from water surfaces and associated crop cover is enormous.

I will now deal with some of the plants in more detail but I have only time to skim over and under the surface. The ornamental garden trade and the ecological and fish management trades overlap to a degree but they do have specialist requirements depending on many environmental factors.

Acorus calamus (Sweet flag). Superficially this looks like a flag iris but instead of the showy yellow flower on top. *Acorus* pushes a small tail-like inflorescence out of the side of its leaf stems. The variegated form is ornamental and propagates readily from offshoots which arise from the fast growing rhizome.

Alisma plantago-aquatica. (Water plantain). This rapidly spreading plant has fresh green foliage. The tuberous rhizome throws up shoots from the axillary buds which all the stems bear. After flowering, between June and October, the plant produces copious amounts of seed.

Aponogeton distachyon (Water hawthorn). This South African plant will grow and flower almost all summer. It is a true aquatic and highly fragrant. It may be propagated from seed or pieces of rooted plant. Water fowl enjoy eating this plant.

Calla palustris (Bog Arum). Like all of the aroids, this plant produces fleshy seeds. The spadix should be gathered before the seeds float away, then the seeds are separated and sown in wet pans. It can be propagated from rooted pieces of the fleshy rhizome.

Caltha palustris (Marsh marigold). When ditches and wet meadows were common this plant abounded. It spreads by seed but may be induced to root from its soft stems in the growing season. The double-yellow and double-white forms must be propagated vegetatively, as they are sterile.

Carex (Sedge). These grass-like plants may have triangular stems which are interesting. Some are tall (e.g. *Carex longus*) in appearance like a 5 ft umbrella plant, whilst one is very ornamental and no more than 2 ft tall — *Carex* 'Bowles Golden'. If left alone too long the tussocks or clumps become very tight and it is not possible to easily extract plants from the centre. When they are extracted they have few roots. Seed from the yellow forms shows some variation.

Glyceria maxima (*Glyceria aquatica* 'Variegata'). This highly ornamental plant is the perfect nurseryman's plant, though fishermen may grow to curse it. It grows quickly and pieces

detach with pleasant ease from the loose mat which densely covers the shallow water areas. Most of the other emergent mat-formers strongly resist lifting.

Iris kaempferi is close to *I. laevigata* but it has a prominent mid-rib. It will not stand in water all winter but the colour forms are varied due to centuries of work by the Japanese.

Iris laevigata. The type with blue flowers comes readily from seed; this is better than waiting for extensions from the rhizome. This useful, fully hardy emergent plant has numerous forms, some of which are very choice and scarce. *Iris l.* 'Lilacina'; *I.l. alba* 'Snowdrift'; *I.l.* 'Colchesteri' (Syn. *monstrosa*) *Iris laevigata* 'Variegata'. There are colour forms with purplish and reddish flowers. All these special forms have to be propagated vegetatively.

Iris pseudacorous (Common flag iris). This is common enough not to need specialist intensive propagation techniques. A good stock bed will easily meet demand. It needs moist ground. It has various forms, the best of which is the slower growing Iris p. 'Variegata'. The paler yellow, Iris p. 'Bastardi' will perhaps interest the collector.

Lysichiton americanum is the yellow skunk cabbage, and *Lysichiton camscatense* is the white-flowered Old World species. In a garden I once cared for there is a specimen (perhaps the first) of the hybrid and I have always called this, *Lysichiton* 'Brave New World'. This hybrid has hybrid vigour and a large whitish-yellow spath. *L.americanon* seeds freely *in situ*, and *L. camscatense* will produce plants if seed is collected late in the year and sown in wet pans away from rodents.

Menyanthes trifoliata (Bog bean). The leaves look like young broad bean (*Vicia faba*) leaves, hence the name. The white-frilled flowers add interest to the margins and shallower water. Propagate by divisions.

Orontium aquaticum (Golden club) is another aroid having similar seed characteristics. The pencil-thin spadix rises above healthy, bland green foliage. It is useful in that it will grow in 18″ of water.

Peltandra virginica is a good plant for the bank. It has healthy leaves and a fresh green, lush appearance. There is a relatively uncommon form with an orange streak down the back of the midrib on the obverse of the leaf. Propagation is by division.

Phragmites communis (Common reed). This is a true grass so it will propagate sexually from wind-blown or collected seed. Once established it hardly needs this, for it not only has underground underwater rootstocks producing side shoots, but

fascinating decumbent shoots which reach out across the surface for up to fifteen feet.

Pontederia aquatica is a useful emergent plant producing ornamental foliage and varying shades of blue flowers depending on cultivar. The type can be propagated from seed, sown green in wet trays, or by division. The white form is more scarce, less vigorous, and so far as I know does not come true from seed.

Sagittaria sagittifolia (Arrow head). A wild plant and a desirable ornamental emergent plant. Put it in an aquarium or deep water and it will produce strap-like leaves. In shallow water it presents bright white flowers above the arrow shaped leaves. Runners are formed under the mud. Once detached they will form new plants. This vegetative method is the only way to propagate the double form.

Scirpus albescens and *Scirpus zebrinus*. Both are garden forms of common wild plants. The former is five feet tall, the latter 2 to 3 ft. Each has its own distinctive green and white variegation and architectural value in the water garden. *Scirpus albescens* is more of an emergent species. Propagation solely by division.

Sparganium erectum (Bur reed) produces seeds and offshoots. The former float and attach themselves to animals.

Stratiotes aloides (Water soldier). This strange plant spends its life rising up and down in the water. It looks like an aquatic aloe with a prickly rosette of leaves. From the apical buds in the rosette, long pendulous shoots are formed and these themselves develop plantlets not unlike the stoloniferous appendages on strawberry plants. The plantlets have leaves and aquatic roots. They part from the mother plant and drift on in their own way. They may also form winter buds which develop the following spring. They do flower, male and female being on different plants. Males are reputed to be rare in Britain. A group of these in a pond or tank, with a foot of water over them for winter protection, will double their numbers in a year.

Typha latifolia. This is a valuable ecological plant for consolidating lake edges. The wind-blown seeds will only germinate after exposure to critical day and night temperatures and, like willow seed, it must be fresh and sown immediately onto a wet surface. It is generally propagated from the shoots arising from the rhizomes. These can be very brittle and, if some people are to be believed, quite tasty.

Nymphaea (Water lily). One could write a book on nymphaeas alone, but briefly the nymphaeas sold in the trade

today are species such as *N. tetragona*, a small plant readily raised from seed, *Nymphaea alba* usually from divisions, *Nymphaea odorata* from divisions, with a wealth of hybrids and colour forms.

The hybrids are derived from complex intercrossings between *N. alba*; *N. tetragona*, *N. odorata*, *N. mexicana*, *N. tuberosa*, and possibly others. All the best work has been done by M. Latour Marliac, a Frenchman. Between 1877 and 1913 he raised most of the best plants found in the trade today. There have been others who have contributed to the store of beautiful plants we have today. The prime interest has been in France, United States, Germany, Great Britain, Sweden, Switzerland and Australia.

The hybrids can only be propagated vegetatively by growing on the little offsets which I mentioned earlier, or dividing the rhizomes. There have been attempts at meristem culture but, so far, the difficulties are insurmountable.

R. DOOL: How do you get rid of duckweed in ponds, besides manually?

G. BURGESS: It can be killed with Paraquat, though its use will be determined by whether fish are present. If you can remove the fish, then you can spray with Paraquat.

R. DOOL: If you had a lily problem could you use Casoron G?

G. BURGESS: You can use Roundup on lilies sprayed from a boat. Casoron G is better for submerged water weeds.

VOICE: How long before the fish can be put back?

G. BURGESS: It depends on the volume of water, but if draining and refilling, it will be the standard wait for the water to recover again.

D. GILCHRIST: Is there a special formulation of Casoron G for water weeds?

G. BURGESS: Yes, a powder formulation but it is expensive. In addition, you have to check with the water authority that your water is not connected in any way to the domestic supplies. There are very few herbicides which are classed as safe for use in water.

PROPAGATION OF ALPINES

WILL INGWERSEN

Birch Farm Nursery, Gravetye,
East Grinstead, West Sussex

We use modern techniques for alpines where practical but, in some cases, we are going back to some of the older methods of propagation which we find are much more satisfactory from our point of view.

Our nursery is situated near East Grinstead on acid soil and on a very steep north and east slope which suits our alpine plants, and we are sure if they grow with us they will grow anywhere in the country, because we get extreme winter conditions. it is quite normal for us to have several nights in succession of sub-zero temperatures, and occasionally, though we have escaped these past few winters, we get very heavy snow falls. We have been known to welcome the snow, and visitors to the nursery have sometimes been rather astonished to find our staff shovelling snow into our Alpine house to cover the plants, because that's what they are accustomed to in nature. They have a long resting period snugly tucked away under the snow and that is something we cannot offer them very often in this country.

Before I get on to actual propagation of the plants, I would like to share with you something which came to my notice quite recently. You all have heard the old story of, "My Grandmother had green fingers, everything she touched rooted", an old wives tale to believe or not as you pleased. But I was telephoned not long ago by a scientist friend who had no interest in gardening whatsoever, but happened to be working on hormones. He had come across somethng he felt would interest me as a propagator of plants. He had discovered that the sweat of certain people was rich in plant rooting hormones! Did Grandma, in fact, have that combination of sweaty hands + the correct hormones?!

We grow around ¼ million alpine plants in pots every year, plus heathers, dwarf rhododendrons and dwarf shrubs, especially ericaceous species since our soil suits them. We also go to the extreme and grow some of the world's rarer and difficult-to-propagate high alpine plants. We, therefore, cater to two diverse public interests. Those who wish for quick results and good colour and, because gardens are becoming smaller, they find alpines very good, a large number being able to be grown in a restricted area. Our other clientele are those who seek the rare plants which are difficult to grow and offer a tremendous challenge to any propagator and, you will be

aware, are increasingly difficult to find in commercial horticulture. They are not plants which can be propagated to any great profit, taking a long time to increase and grow. In fact, if we sold any of our rare plants at realistic prices very few people would be able to afford them. It is not unusual for some of the high alpine plants like *Androsace* or *Dionysia* to take five to seven years to produce a saleable plant, incurring considerable production costs. I am, however, trying very hard to preserve a collection of these rare plants.

When garden centres first started I thought that that was the end of us, a highly specialised nursery growing a particular range of plants but, in fact, they have helped us. People go to the centres for plants and most have sales staff qualified to give advice. Their range of plants, though, is of necessity limited. People interested in plants read books and become interested in the specialist plants and then have to come to people like me because we are one of the few nurseries growing the range of rare and difficult alpine plants.

The methods of propagation we use are by seed — a great many plants are from seed — and vegetatively. Our propagation is a very mixed bag. You cannot adopt a "standard" procedure when you have between 8 and 9 thousand different cultivars and species of plants on the nursery. Therefore our propagation tends to be expensive and intensified.

We like to use seeds when we can and we grow a great many species by this method when they can be relied upon to grow true-to-type. Many other plants must be propagated vegetatively from cuttings, particularly the named cultivars.

We use a modern mist unit and, while this is very satisfactory, we are building up a "black list" of alpine plants which do not do well in mist and will not root. There are not many of these, fortunately. I felt that the problem plants would be those with woolly or hairy foliage, but on checking was astonished to find that these are doing well under mist and the problem plants are those with hard, shiny glabrous surfaces! For instance, we find *Lewisia* almost impossible to root from cuttings under mist, but using an old-fashioned cold frame in the open we can get 90% rooting with no trouble.

The modern mist bench took me back to my young days when I spent quite a time on the Continent learning my business. In France we had propagating frames in the full sun with no shading with cuttings inserted in them in sand beds. My job was to hand-spray these frames with a watering can every half-hour — a hand-operated mist unit, the forerunner to today's electronic controlled unit.

We keep careful records and, over the past six years, have

averaged an 85% strike of the cuttings put through the mist unit.

We like to take cuttings of alpine plants having soft tips. With *Aubrietia* for example, the stock plants are in open beds and are cut hard back after flowering. They quickly throw out a mass of non-flowering shoots which are ideal for cuttings. We don't use a knife on them just pull the shoots out, retaining a small piece of old wood on the base, and insert. They do not need mist but we put them through this as it is faster. In the cold frame they take five to seven weeks, but under mist they can be rooted in two to three weeks. The record for rooting was *Nepeta mussinii*, the common catmint, which was potted two weeks after inserting. We do not wean our plants from mist as we do not use it in quite the conventional manner. We have a long propagating house and keep full ventilation winter and summer, just closing up at night. Soil heating is kept at 70 to 80°F and, with keeping warm roots and cool tops, we find we can pot directly from the mist out into an open frame, as the cuttings have not grown soft.

With some of the shrubby alpine plants we have to make cuttings from the harder wood and include a heel. This applies to *Daphne*, with cuttings taken between June and August, when the wood has ripened. Most of this type of cutting is rooted under mist, but there are one or two *Daphne* cultivars which will only root in the cold frame.

It is very important to take the cuttings at the correct time and this is really a matter of experience. The experienced propagator can tell from the feel of the plant if it is the right time and this can mean the difference between success and failure.

Some alpines are taken from root cuttings, e.g. *Morisia monanthos*, a small yellow-flowered plant which grows on the seashore in Corsica and Sardinia.

If a plant will not root as a conventional cutting we then try every other method and eventually we find one which is successful. This can be illustrated with the herbaceous plant, *Oenothera glaba*, which is sufficiently dwarf to be used on a large rock garden. We could not propagate sufficient plants until our propagator discovered, by accident, that the old withered flower stems, cut into pieces, would root very successfully under mist. Following this, we tried this method with a number of other plants and had success with some. This is contrary to the generally accepted principle of using only vegetative growth for cuttings which, of course, is the correct method for the majority of species. All cuttings are treated with a rooting hormone powder which contains a fungicide.

We do very little grafting, in fact only one plant in the whole nursery, *Daphne petraea*. It is a crevice plant in the mountains and is not easy to root, and, in our own experience, plants on their own roots in cultivation are shy flowering. It used to be grafted on *Daphne mezereum*, but *D. petraea* is evergreen and *D. mezereum* deciduous, and I felt this was a mistake. We now use seedling rootstocks of *D. retusa* and *D. alpina*, which has proved very successful. We do a simple terminal graft, just splitting the stock and inserting the scion so the cambium is touching on each side, and washing over with grafting wax. We get an 80 to 90% take by this method, providing it is done at the right time of year when the flush of growth following flowering has ripened at the base to provide firm scion shoots.

Then there is division. A lot of alphines are mat-forming and lend themselves readily to division. The two principal seasons for this are spring and autumn and, if not early autumn, then it is best left until spring when plants can overcome being torn to pieces more easily. This is an easy method of propagation since many plants root as they run, e.g. *Phlox*, *Dianthus*, *Saxifraga*. In fact all plants can be used except those which grow from a single neck or crown. It is, however, possible to layer some of these plants particularly where stems grow parallel to the ground, especially if a little sandy soil is placed under the nodes and they are pegged down.

Daphne cneorum is not easy to root, but we have had success with a specimen plant by mounding the whole plant up with a mixture of equal parts of peat and sand, leaving just the tips exposed. After six months most stems have rooted and can be pulled off and treated as individual plants. This method produces saleable plants much quicker than conventional cuttings.

We propagate quite a number of bulbs, including lilies, though with imported material disease is a problem. Lilies are propagated by seed and scales. Scales are done in the old-fashioned way in a bag of vermiculite tied and hung in the greenhouse; this method has given us good results.

A major activity is seed sowing of alpines and other plants. With lilies we used to lay the seed flat on a seed pan and cover with soil, but we now fill the tray with compost and make a groove with a ruler and sow the seed edgeways, achieving 100% germination. This method has produced better results with most flat seeds, e.g. *Gentiana lutea*. We also use unconventional methods for the pasque flowers, *Anemone pulsatilla* (Syn.: *Pulsatilla vulgaris*), which makes a seed with a long awn at the top. This, too, used to be sown flat and was difficult to cover because of the awns. These are now speared

in individually, as are the *Geraniums* which also have the awns. In nature the seeds more often than not fall upright and the awns twist hygrometrically and drive the seed into the ground, so this was a lesson we learnt from nature, and results are much better than when the seeds are sown flat.

Most seed is sown in January or February in pans in conventional seed compost and covered with ¼ in fine grit and, if possible, left to freeze in an exposed site. The seed is actually sown onto the grit and watered in. This seems to give a more even germination and stops surface liverwort and moss growth, which can strangle young seedlings.

It is important with some alpines, however, to sow the seed as soon as possible after ripening, e.g. Ranunculaceae, Primulaceae. We have a saying on the nursery for these of "straight from the pod to the pot", since viability of older seed decreases rapidly. *Lewisia* is another example of a plant which needs sowing immediately upon ripening to get good germination.

Seeds of some alpine plants take a long, long time to germinate and we never throw a seed pan away under three years. It is quite common to see a three-year-old seed pan suddenly producing a marvellous crop of seedlings.

Leaf cuttings are also taken of species such as *Ramonda* and, in fact, most of the Gesneriaceae, which root well from leaf cuttings. Again, timing is important, best results being obtained in the spring when growth is just becoming active. The leaf is pulled off with a piece of the old stem and inserted straight or on a slant. With the rarer coloured *Ramonda* this is the only method of maintaining the true colour, since with seed all colours will be present.

J. LAMB: Is it possible to propagate forms of *Anemone pulsatilla* from root cuttings?

W. INGWERSEN: I have been trying to do it for years with mixed results. A lovely pink one, 'Mrs van der Elst', which seems to have almost disappeared now, we used to propagate from root cuttings and were lucky to get 25% success. Theoretically, it should be possible since it belongs to a family which does propagate from root cuttings, and it is still worth trying.

J. LAMB: When propagating *Ramonda* from leaf cuttings, how long does it take to produce a flowering plant?

W. INGWERSEN: Two years.

P. MacMILLAN-BROWSE: An observation on rooting of *A. pulsatilla* from root cuttings. The best results with root cuttings is to take them in their dormant season and, with *A.*

pulsatilla which seeds in July, this is August through October. By November it is starting into growth again for Easter flowering.

W. INGWERSEN: This confirms our own experience where best results were achieved when cuttings were taken in August.

B. HUMPHREY: Do the seeds of *Ranunculaceae* and *Primulaceae*, which are sown fresh, germinate before the winter or wait until the following spring?

W. INGWERSEN: They will usually germinate within 2 to 3 weeks if sown really fresh.

B. HUMPHREY: So then you have the problem of overwintering them.

W. INGWERSEN: Exactly. If we cannot sow when we would like, then we keep the seed in a refrigerator kept just above freezing until we can sow them.

THE I.P.P.S. ABROAD — HOLLAND AND BELGIUM

GEOFFREY W.J. FORSTER

Merrist Wood Agricultural College
Guilford, Surrey

September, 1980, witnessed the second group expedition of several Great Britain and Ireland Region IPPS members to the continent of Europe. Also in the party to Holland and Belgium was a strong contingent of IPPS members and their wives from the various American Regions, who had previously spent some time visiting nurseries and allied institutions in Britain.

As the theme of this year's conference is "The Gateway to The Future", I shall try to confine myself to some of the features that might be considered reasonably "new" to the nursery industry from the continent of Europe and provide some food for thought and ideas later. From the point of view of those members who participated, this will necessarily be something old; however memories may be jogged and it is quite possible that some of the features highlighted will not now be new to several well-established British nurseries.

I will be discussing items of equipment and one or two techniques that may be of value to the nursery industry in general.

Our tour commenced at the Boskoop Research Station where the Director explained the importance of the Boskoop

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Our tour commenced at the Boskoop Research Station where the Director explained the importance of the Boskoop

region in Dutch nursery production. Several experiments and trials were seen and it is interesting to note that, as well as being a means of transport, the canals also make ideal water storage areas where clean water is stored in flexible plastic tanks floating in the canal, to be pumped out for use later.

Close to the Research Station we were able to see traditional narrow Boskoop nurseries with very intensive production systems such as the production of *Betula* by summer cuttings in frames., later to be lined out and grown on. Many of the nurseries in this region are active exporters and much of the production is in containers.

At G.C. Stolweijk & Co., to aid handling and transport of plants, trolleys capable of being pushed across the bed and then down the central pathway without having to turn are in use. All the beds are of the same width and are surrounded with level concrete paths. To ease the difficulties of labelling a wide range of stock, coloured labels approximateing to flower colour are kept in mobile, easy-to-handle storage racks.

A feature of many of the exporting nurseries was the packing/loading shed or bay, many of the nurseries having purpose-built units, such as the loading bay at F.J. Grootendorst & Sons Ltd. Another common aid to production was the use of shade or netting structures to provide protection during the winter and shade during the summer. Several different structures were in use, often with frames or low poly tunnels below for propagation.

From the propagation stage plant handling again becomes important and the use of lightweight tiered trolleys with large castor wheels on firm level roads makes the moving of plants much easier and quicker. Large trays, taking up to 300 cuttings, with purpose-built trolleys to fit the tray size may not be a very flexible system but it can save a lot of time and effort.

Increasing the output from a given area is one way of reducing the cost per unit produced and the use of mobile benches with built in supports for polyethylene tents is one method of increasing the number of cuttings that can be rooted in an expensive propagation house. By using mobile benches about 80 to 90% of the floor area can be used for production.

To ease the workload in the field production of trees many items of equipment have been developed that are tractor-mounted. At Van Dam's a range of hydraulic tree lifters has been developed to fit narrow tractors and lift individual trees in the row from the path; these machines make light work of a heavy job in a short space of time.

Some of the nurseries visited were very extensive as well

as intensive and a feature of one of the Belgian pot plant nurseries was the high speed battery operated trucks used to move plant material and people around the glasshouses. Control of all the environmental factors was highly automated and several systems of plant conveyors suspended from overhead heating pipes were used to take plants from the benches to the packing table at the central path. The heating pipes also served to support a fully automatic, travelling supplementary light unit for use on young stock.

At another Belgian azalea nursery the high cost of a new glasshouse was being recovered by maximising the production of plants by using mobile benches supported on heating pipes at waist height. The crop was irrigated by a spray boom suspended from heating pipes at eaves level, and travelling half the length of the house. When ready for marketing each bench unit was rolled off the production line onto a compatible trolley ready for packing and thence despatch.

In conclusion, may I record the appreciation of the group for the work put in by the tour organisers, Raymond Evison and Tom Wood, and all the members of the Dutch and Belgian advisory and research units, and the nurserymen who made this tour possible. Without their unstinting efforts this very memorable and instructive tour would not have taken place.

QUESTION BOX

CHAIRMAN — JOHN GAGGINI

1. What action is the Ministry taking to communicate the results of their cutting handling system to the industry?

B. MORGAN: ADAS has been closely involved with ATB on this handling system. We have had a Masters course at which 10 propagators from different nurseries attended and since then they have spread the word. The ATB have already held over 20 courses around the country attended by 130 people, and another 30 courses are planned for the future. The technique has been promoted at major conferences like BGLA and Four Oaks. A video film has also been made for refresher courses showing the hand movements involved in the technique. In addition, a booklet which is a training guide has been produced in conjunction with the ATB. This training guide will have an outline of the times taken to insert a 1000 cuttings of different plant types, i.e. heathers, rhododendron, conifers, and *Berberis*. Not just one time but a range of times embracing estimates of good, typical, and poor. What ADAS has, in fact, done here is identified a problem, done something

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about it, and then passed it onto the people best able to do something with it, namely the ATB.

2. *Elaeagnus pungens* 'Maculata' is generally considered a difficult plant to root. Could members give their own experiences with this species.

J. BEESLEY: We have gone back to inserting the cuttings around the edge of a clay pot in a 5 parts grit:2 parts peat mixture. Cuttings are wounded and dipped in 8% hormone powder with Captan incorporated. The clay pots are then plunged in peat in a heated bench, and we get almost 100% rooting.

M. FARMER: I do all my propagation in clay pots including a range of golden and silver forms of *Pittosporum* which have brittle roots and would break very easily in trays.

C. CHOISEAU: When are these cuttings taken?

J. BEESLEY: Anytime during the winter.

M. SCOTT: I don't know if it is the particular clone we have at Efford but we have not found *E. pungens* 'Maculata' difficult. We take ripe cuttings in late October/November, use a 2500 ppm IBA solution as a quick dip and root in a 75% peat:25% grit mix in plastic seed trays. We get an average of 80 to 85% rooting.

D. GILCHRIST: Last year we reverted back to the old-fashioned cold frame and from an October strike, only achieved 10% rooting.

M. SCOTT: Yes, base heat is essential, we use a probe control maintaining 15°C in the compost, which means between 18° to 21°C in the sand, beneath the tray.

J. BEESLEY: We maintain 20°C, and also use a probe in the compost.

3. Is any work being done on the pH of the rooting medium? We are now buying peat from different sources and the pH ranges from 3.8 upwards.

M. SCOTT: Basically Irish peat is around 4.3 which seems OK for a wide range of species. The Dutch add lime to their rooting media but they are working with peat which has a pH in the 3.5 range. We have only done a small trial with *Thuja*, and found that the addition of ground limestone to Irish peat to bring the pH up to 5.0 improved rooting by around 10%. So increasing the pH could be a benefit to some species, but a lot more work needs doing before any recommendations could be made.

M. HELLIAR: With hardwood cuttings of apples, the addition of lime has been found to improve rooting. Along similar

lines a response was also achieved by changing the pH of the hormone mixture which in this case was a dip.

J. GAGGINI: Perhaps we should pay more attention to the pH of our rooting media. Is this a line of work the Experimental Centres could take on for a wider range of species?

M. SCOTT: Yes, especially if the Conference felt this was work which should have greater priority than at present. It is difficult to do a very wide range of species experimentally. We need guidance on those species which are difficult or have problems.

H. SHEPHERD: Trials at East Malling on a limited range of species showed that pH had relatively little effect on rooting compared with all the other variables.

T. PRICE: Coming back to *Elaeagnus*, we had two batches, one green and healthy, the other yellow and starved in appearance. Analysis showed that the green batch had a low pH, the yellow batch a high pH of 6.7.

J. GAGGINI: I have always considered *Elaeagnus* an an ericaceous species, as far as pH was concerned.

M. SCOTT: *Elaeagnus* is one of our indicator plants for phosphate, being very sensitive to too much, and this effect becomes progressively worse as pH increases. This would explain the yellowing effect as a lime-induced chlorosis.

B. MORGAN: A pH of 6.7 is far too high for *Elaeagnus*, it needs to be around 5.0 for good growth.

T. WOOD: We have very hard water, and under prolonged mist this chlorosis does occur. We have even gone as far as using sequestrene to counteract it on cuttings which take a long time to root.

D. GILCHRIST: Our *Elaeagnus* stock plants are in ground with a pH between 7 and 8, and, while having no chlorosis symptoms, cuttings do not root easily.

M. CLIFT: *Elaeagnus* has root nodules, as does *Genista hispanica*, which roots more readily in acid compost. Would this be the case for *Elaeagnus*?

B. MORGAN: There is no experimental evidence yet as to its specific requirements.

4. How can *Kalmia latifolia* cuttings be rooted?

J. ELLIS: We have germinated seed but the resulting seedlings were very tiny.

P. MACMILLAN-BROWSE: Some of the newer cultivars are easier to root from cuttings, and Richard Jaynes has written on the subject in previous IPPS Proceedings and in the *American Nurseryman*. He has also written "The Laurel Book".

P. HUTCHINSON: This book can be obtained from the RHS Bookshop at Wisley.

T. WOOD: We had excellent germination of *Kalmia* seed this year, the seed collected from bushes in my own garden. This was sown in early spring with a little bottom heat and the resulting germination was fine. We "patched off" some of this as you would *Begonia* seedlings, expecting them to stop growing, which they did. However, in a warm spell in September they developed quite large true leaves in the greenhouse. This relates to the natural conditions in Virginia, USA, where summers are hotter than here. Thus, if we artificially induce these hot summer conditions under glass or polythene we should improve their growth rate.

5. Has anyone any observations on polarity of sowing horse-chestnut seeds? For instance, if sown with the scar downward a straight vigorous seedling results but if the scar is uppermost, the stem has a bad kink and, if on its side, the stem is bent. (P. MacMillan-Browse)

J. GAGGINI: This is a similar situation to *Quercus ilex*, where good results were obtained by sowing with the point down. However, this was done because it was easier to sow in Jiffy 7's this way.

D. FORDHAM: On chestnuts we sow scar down, otherwise we could lose up to 30% with out-of-grade stems.

P. MACMILLAN-BROWSE: I would like to ask members who sow these large seeds if they could try different orientations in sowing and monitor the results, even on a very small scale. It is a subject we need more information on since it becomes very expensive to have waste seedlings in these low density crops.

T. WOOD: We have gone even further than this and graded our seed, particularly oak. Our prime seed is used for pot-grown oaks, and here we check where the radical will emerge before sowing, as we cannot afford a poor stem in a container. The larger seed also produces the more vigorous growth. This can also be done with certain maples. When the radical can be seen, the wing can just be poked into the compost in the correct orientation.

VOICE: With acorns has anyone tried pre-chitting and breaking off the tip of the root to stop a fang-root growth, getting instead a mass of roots more suited to containers?

P. MACMILLAN-BROWSE: That used to be the traditional method in Holland for producing horse-chestnuts in the field for budding.

T. WOOD: With oaks we sow them into a type of pot

which is moved shortly after germination to break the tap root.

L. DICK: This subject has the potential for an OND project, but we would need a supply of seed.

J. GAGGINI: Botanic Gardens should be able to help.

D. FORDHAM: With most of the seeds sown on the bed surface their own weight tends to orientate them naturally for the emergence of the root straight down. The horsechestnut, however, is the one which has the problems.

P. MACMILLAN-BROWSE: Dennis is correct about the germination, but I still believe that you can get a difference in the quality of growth according to the orientation of sowing the seed. It is something we need experimentation on with published results.

TECHNICAL SESSIONS
Tuesday Morning, December 8, 1981

The thirty-first annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:15 a.m. in the Grand Hall of the Holiday Inn, International Drive, Orlando, Florida.

PRESIDENT WOTT: Welcome to the thirty-first annual meeting of the Eastern Region of the International Plant Propagators' Society. This morning I would like to point out that it is a pleasure for us here at the Eastern Region to host the International Board. I would like to introduce from the Australian Region, Adrian Bowden; Great Britain and Ireland Region, Tom Wood; Western Region, J. Harold Clarke; International President, Donald Dillon; Vice-President, Raymond Evison; International Editor, Hudson Hartmann; and International Secretary-Treasurer, William Snyder.

We have an exciting program for you. I know that John Sparmann has put a lot of service into the program. I will now turn the program over to our first moderator, Don Shadow.

Editor's Note: Kathleen Freeland moderated a group of short presentations on solving difficult propagation problems. The following papers by Alfred Fordham, Leonard Savella, Richard Jaynes and James Wells were part of that session. Kathleen Freeland read James Wells' paper in his absence.

ELLIOTTIA — PROPAGATIONAL DATA FOR FOUR SPECIES

ALFRED J. FORDHAM

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Elliottia racemosa, the Georgia plume, is a small tree or large shrub native to the state of Georgia and southcentral South Carolina. A review of the literature concerning it reveals a history of frustration and disappointment. Despite the fact that it was discovered more than 180 years ago, and despite the fact that its impressive characteristics have often been described, it is still an exceedingly rare plant in cultivation. It has been reported to have lost its ability to produce seeds, to be difficult or impossible to transplant (even in areas

where it is native) and to have failed in most propagational efforts. It was also reported that a mycorrhizal association was necessary for the germination of its seeds and the well being of its propagules.

E. racemosa was discovered in the vicinity of Franklin and Hart Counties, Georgia, by William Bartram in 1773 and was later named for Steven Elliott who prepared the "Sketch of Botany of South Carolina and Georgia". For a time *E. racemosa* was considered lost. Through cutting of the woods and clearing of land for agriculture the original stands disappeared. Dr. Asa Gray visited the region and wrote "Not a vestige of *Elliottia* (in Columbia county) remains. A small patch is said to exist in Edgefield County, South Carolina, but all efforts to find it have failed."

Fortunately, the threat of extinction no longer exists and a number of stands have been found more recently both in the area of the original find and down into central Georgia. Also, information concerning pretreatment to germinate the seeds and a simple method of propagation by rooting juvenile shoots are now known. Therefore, there seems no reason why this beautiful subject should not become common in cultivation.

Propagation of Elliottia racemosa by Cuttings. In 1962, while visiting Mr. Henry Hohman of Kingsville Nursery, Kingsville, Maryland, we viewed his two plants of *E. racemosa* and discussed its propagation. A month or so later, the smaller of the two plants, a fine 8 foot specimen, arrived at the Arnold Arboretum from Mr. Hohman with his suggestion that I work out a method for its propagation. During my visit we had discussed the use of root cuttings in propagating *E. racemosa*, and when Mr. Hohman dug the plant he did not fill the resulting crater but let it remain empty. He thought the severed roots left in the crater well might produce shoots. This worked well, and a year later 18 plants were harvested from within the crater.

Mr. Hohman's plant prospered at the Arnold Arboretum and flowered well each year with inflorescences terminating the current seasons growth (Fig. 1). It should be noted that *E. racemosa* had not previously proven hardy at the Arnold Arboretum. The accession records show that all prior efforts to establish the species ended with the notation, "winter killed." Alfred Rehder in his "Manual of Trees and Shrubs" considered *Eliottia racemosa* to be a Zone 7 plant. Therefore, our specimen was lifted each autumn and placed in a cold storage unit. By 1972 my propagation trials had been successfully completed so our Hohman plant was planted out-of-doors to test its hardiness. It was positioned part way up a steep slope so that

on nights of radiational cooling cold air would drain away from the plant. Since that time it has survived with varying degrees of damage from winter to winter. Inflorescences terminate the current season's growth; therefore, flowers appear even after winters in which damage occurred.

Figure 1. Inflorescences terminate the current seasons growth — therefore, flowers can appear even after winters in which damage occurs. Photo A.J. Fordham

Repeated attempts were made to root stem cuttings of *E. racemosa* using an assortment of root inducing substances and a variety of timings. Success was mediocre. The next effort was to test whether or not root pieces would produce shoots. Shoots that arise from roots are physiologically juvenile and will root despite the fact that stem cuttings from the same

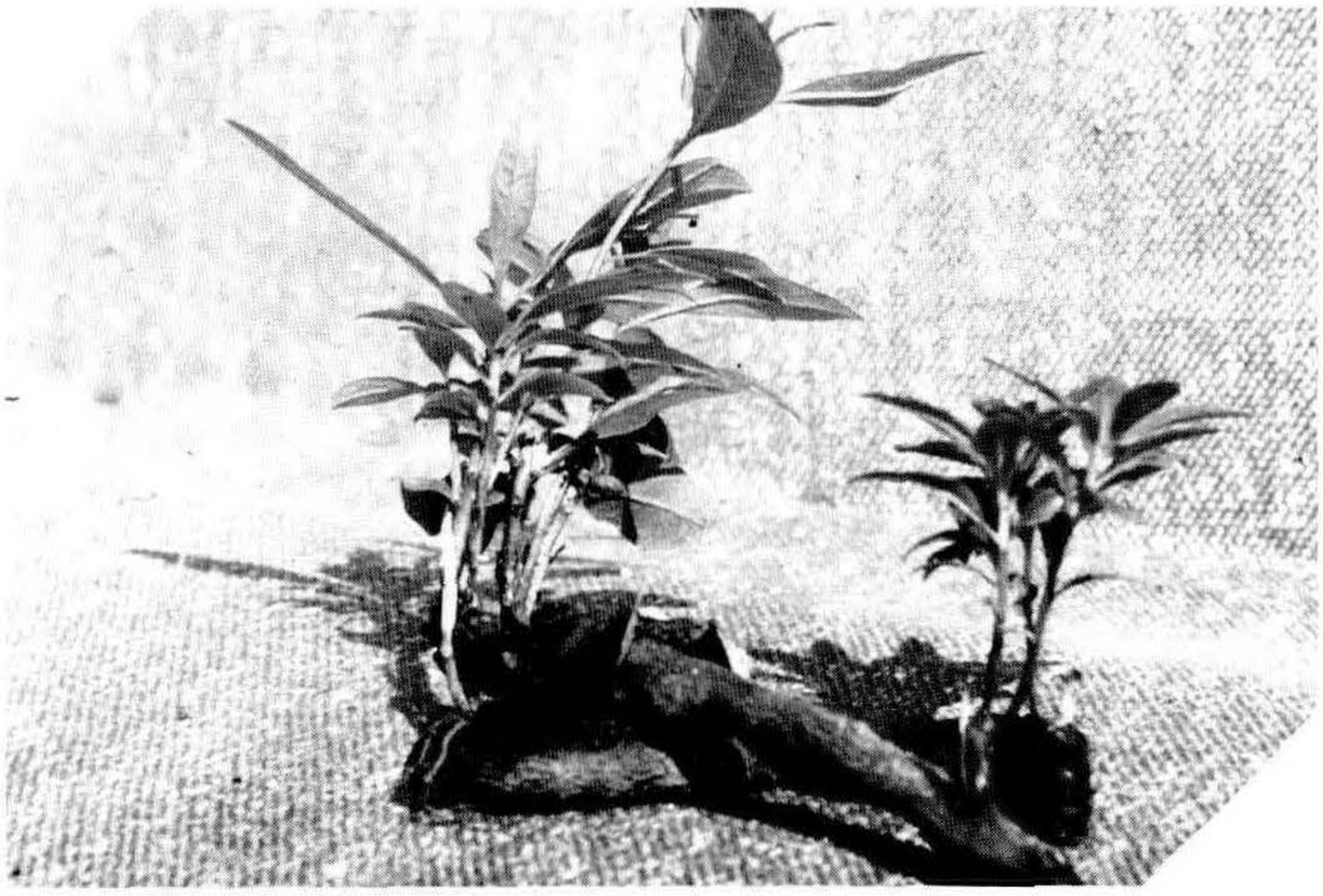

Figure 2. Shoots that arose from root pieces were physiologically juvenile and rooted very quickly. Photo A.J. Fordham

plant will not. With this fact in mind, root sections about ⅜ of an inch in diameter and about 4 inches long were taken from the plant when it was dormant. They were placed about ½ inch deep in flats of sandy soil. This was done on March 24th and by May 19th multiple shoots began to appear. The pressure of spring work was such that shoots were not taken from the roots until early July. By this time they were firm and woody (Fig. 2).

The first crop of shoot cuttings was divided into two lots. Lot #1 was treated with a root inducing product containing 3 mg of IBA in a gram of talc with Thiram added at the rate of 15%. Lot #2 was treated with a formulation consisting of 8 mg IBA plus 15% Thiram. In each case all cuttings rooted and did so quickly. The root pieces were left in place in the flats and they continued to produce shoots for 3 years. In autumn when they went dormant, they were transferred to a cold storage unit. In spring, when returned to the greenhouse, new crops of easily rooted shoots arose. These propagules have never presented survival problems.

Propagation of Elliottia racemosa by Seeds. Flowers of *E. racemosa* are attractive to pollinating insects. Observations at both Arnold Arboretum and the Watnong Nursery, Morris Plains, N.J. showed that one species of butterfly and 4 kinds of bees visit the flower in large numbers. The fruits, which develop after pollination, are 4 or 5 lobed capsules. The seeds are completely surrounded by a wing and are dish-shaped. Only a small percentage of the seeds are sound; many seeds abort. This, no doubt, can be explained by Dr. Frank Santamour's discovery that *E. racemosa* pollen is only 4% viable. In the literature one finds references stating that the plants are self-sterile and different clones are necessary to effect cross pollination. This, however, is not correct since isolated plants at the Henry Foundation, Watnong Nursery, and Arnold Arboretum have each produced sound seeds.

E. racemosa seeds have a cold requirement that must be satisfied before the seeds germinate. They can be prepared by mixing them with a dampened medium of sand or peat moss. The combination is then placed in a polyethylene bag and bound at the mouth with a rubber band to make it vapor proof. Three months of stratification in a refrigerator set at about 40°F prepares the seeds for rapid germination when they are sown. This recommendation applies to seeds treated within a few months of collection. Older seeds tend to acquire secondary dormancies and their behavior becomes unpredictable.

Propagational Information for Three Species of Elliottia.

In 1978 a team of plant taxonomists at the Harvard University Herbaria, using evidence from anatomy, chemistry, morphology and palynology, placed the following species in the genus *Elliottia*. Some propagational data are listed below with the thought they might provide guidance to those working with these plants.

1. *Elliottia bracteata* (previously *Tripetaleia bracteata*) Seeds had no dormancy and softwood cuttings rooted readily.

2. *Elliottia paniculata* (previously *Tripetaleia paniculata*) Seeds had no dormancy and softwood cuttings rooted readily.

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PETER VERMEULEN: I have a question regarding hardiness in *Elliottia*. Watnong Nursery is in north central New Jersey and the plant looked good in your slides. We have had −23°F in our area. Do you think that the range extends beyond the Philadelphia area?

AL FORDHAM: No. I think the plant looked good as it was in a favorable location and the past winter had not been too severe. If a bad winter occurs the plant would, no doubt, be badly damaged or killed as would be the case in the Boston area.

HOW I SOLVED THE PROBLEM

LEONARD SAVELLA

Bald Hill Nurseries, Inc.
Exeter, Rhode Island 02822

Propagation of *Picea pungens* 'Glauca' and other cultivars by grafting has been a successful method at Bald Hill Nurser-

In 1978 a team of plant taxonomists at the Harvard University Herbaria, using evidence from anatomy, chemistry, morphology and palynology, placed the following species in the genus *Elliottia*. Some propagational data are listed below with the thought they might provide guidance to those working with these plants.

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ies for many years. When grafting spruce we like to use 2 year old wood which gives us a large scion and a sizeable graft when completed.

When preparing the scions for grafting, around the first of February, we thought how nice it would be if we could root the healthy, well budded, lateral cuttings we were removing from the scion.

We decided that nothing would be lost if we tried, so we stuck approximately 200 cuttings in three different rooting media using several hormone powder combinations. By the end of May, three of the cuttings rooted. This was a success to me because I am a great believer that if you can get one to root the others should root, if taken at the proper time.

In June, when we were sticking our summer outdoor mist cuttings I found the key. I decided that when we finished sticking our dwarf Alberta spruce cuttings that I would stick the different cultivars of blue spruce using the same hormone powder (Hormodin 2).

We took 1000 cuttings of different sizes and from various locations on the stock plants. Half the cuttings were cut, the other half plucked. The cuttings were dipped and stuck in sand without removing the needles. When they were lifted in about 8 weeks the results were amazing. The cuttings had rooted 85%. The following year 5000 cuttings were stuck at the same time using the same treatments and again we got about the same percentages of rooted cuttings as we did the year before. The problems was solved.

WAYNE MEZITT: How large have you grown the rooted spruce in your nursery?

LEONARD SAVELLA: Six to 8 feet tall from the first successful batch of rooted cuttings. Be sure to take cuttings from the rooted cuttings because your percent success will increase.

TOM INTVEN: What time did you take the cuttings?

LEONARD SAVELLA: Between the sixth of June and the end of June when the terminal shoots are about 3 to 4 inches. If you want success the smaller the cutting the better. The closer the cutting to the main trunk the better. Terminal shoots are not the best. Lateral shoots that come off the one year old wood make the best cuttings: The cutting should pluck concave. This is the proper time.

DAVID DUGAN: How do you get a terminal established?

LEONARD SAVELLA: Once the cutting starts to grow it

will develop a leader. In 3 years a 5 to 6 inch well shaped plant will form.

HANS HESS: Len, would you give us some idea of the root structure you have on the cuttings? Our experience is that you have 1 to 2 roots and subsequently develop a poor root structure.

LEONARD SAVELLA: When they root the cuttings have 1 to 2 roots. After rooting the cuttings are transferred to flats containing a peat and sand medium. During transplanting, the root system is pruned. You will be surprised at the amount of new root growth you get from that pruning. The plants are again rootedpruned when set in the field. Root pruning is very important.

JOERG LEISS: Was your hormone treatment important? We found that hormone treatment made no difference.

LEONARD SAVELLA: We have not tried rooting without a hormone.

CARMINE RAGONESE: What is the purpose of dipping in water after making the cuttings?

LEONARD SAVELLA: To prevent desiccation.

WILLIAM SCHWARTZ: What was your temperature above and below the cuttings?

LEONARD SAVELLA: No bottom heat was used.

HOW I SOLVED A DIFFICULT PROPAGATION PROBLEM

RICHARD A. JAYNES

Connecticut Agricultural Experiment Station
New Haven, Connecticut 06504

There is an implication in the title of this panel that parallels a common misconception on the "ah ha!" theory of solving a problem or making a discovery. I suggest that the process is usually a gradual and evolving one rather than a sudden revelation. There is an analogy, for instance, with the "discovery" of a new cultivar. It generally takes 15-25 years to get a new cultivar to market, so, when do we say it is new? Was it when the cross was first made or when the plant was first selected? To the horticulturist or nurseryman neither event may be remarkable for it may be several years later before he is certain that the cross or selection is truly unique. Even then his excitement may be tempered until he is certain the plant can be propagated and he sees how it is received in the market place. Likewise, timing of when a problem is

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solved may be as difficult to pinpoint as to say when a discovery was made.

The problem I confronted was vegetative propagation of mountain laurel. I was breeding and selecting beautiful cultivars but had a poor record for propagating them from cuttings. The approach used to solve the problem was, at least in hindsight, simple and straight forward. It entailed determining what had been done by calling, writing, or visiting those with experience; attending meetings such as IPPS to ask questions; and searching the literature, such as back issues of the IPPS Proceedings. The propagation methods reported to work best were tried and then the most successful components of several systems were combined.

I did this and soon learned the conditions necessary for good rooting; that is, cuttings taken about October 1, placed in a medium of 2 peat: 1 coarse perlite, bottom heat 75°F, and placed in a humidity case (2,3). Wounding and auxin treatments have not proven critical under these conditions. However, Fordham (1) and Williams and Bilderback (5) have reported good response with auxins such as talc treatments containing 1,000 ppm of 2,4,5 TP or a 5 sec. dip in IBA plus NAA at 2500 ppm.

Success was still not outstanding, however, for I was dealing with a species that is difficult to root under the best of conditions. Perhaps, because I was working with several selections, it soon became apparent that ease of rooting in mountain laurel varies among selections just as it does among rhododendrons. Cuttings taken from different plants at the same time and treated the same way responded quite differently. Thus, we tested many plants and selected ones whose cuttings root reliably year after year. Named cultivars released that are relatively easy to root include 'Pink Surprise', 'Pink Charm', 'Nipmuck', and 'Quinnipiac' (3). Although the results vary from year to year, selections such as these yield at least twice as many rooted plants as do mountain laurel plants not selected for ease of rooting (60-90% rooting compared to 5-50% rooting, respectively).

The problem of vegetative propagation of mountain laurel has not been truly solved, but enough progress has been made so that more nurserymen now propagate named cultivars. Past experience with other plants suggests that there will be further incremental improvements in rooting mountain laurel cuttings. In addition, a dramatic change is presently occurring with the onset of tissue culture propagation. Several laboratories have successfully cultured mountain laurel and at least one commercial nursery lists such propagated plants for sale.

Other means to aid in the vegetative propagation of this species have been demonstrated. Cuttings from 1-2 year old seedlings root readily and, these seedling stock plants, when grown from seed of the right controlled cross, come true-to-type. For instance, plants of miniature habit (*K. latifolia* 'Myrtifolia'), when crossed with miniature, yield 100% miniature (4). However, this technique has not been adopted commercially.

My advice in trying to solve or at least improve a propagation method is to take advantage of the best features of systems that already have been demonstrated to be successful. Keep testing new and promising combinations, and repeat the successful ones. If you cannot be the one to improve the technique, at least, be ready to adopt improvements discovered by others. Be delighted if you solve the problem suddenly and completely, but be realistic in expecting solutions to usually come slowly and gradually.

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LEONARD SAVELLA: Have you had any success in rooting the banded types?

RICHARD JAYNES: Very limited success. We have one selection 'Carousel' which is showing promise.

RALPH SHUGERT: Have you tried rooting, lifting and refrigerating for 4 to 6 weeks?

RICHARD JAYNES: Yes, with some limited results. Mountain laurel is not like rhododendrons. It probably needs closer to 8 weeks of cold to break dormancy. Some propagators have taken cuttings after the first of January for rooting. The problem has been rooting reliability.

THE ROOTING OF RHODODENDRON STEM CUTTINGS

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When I came to this country in late 1946 I was aware that cuttings of hybrid rhododendrons were being rooted experimentally in Boskoop, Holland. What was still to be proved was the value of the method as a commercial procedure, and, most important, how would plants propagated in this way develop as they matured? The information from Boskoop was therefore obtained and held as a matter of interest, but was not considered to be of immediate practical importance.

In the winter of 1946 we grafted 35,000 rhododendrons onto *Rhododendron ponticum* understocks and these were planted out the following spring. The early summer of 1947 was hot, wet, and humid with the result that catastrophic losses were sustained in not only the new batch of grafts but also more mature plants. Clearly something had to be done. Discussions with other growers indicated that plants of *R.* 'Roseum Elegans' produced by layering were apparently more resistant to the wilt disease than were similar plants grafted onto *R. ponticum*. The need to experiment was clear, but opinions were widely held that rhododendrons just could not be rooted successfully.

We first reasoned that rhododendrons were not easy to root, and that if they were to be rooted successfully every possible aid or advantage which would encourage rooting had to be brought to bear. They also had to be assembled and applied in the right order to achieve optimum conditions. What might these conditions be?

Our first line of attack was to assemble all that could be found in the published literature. When assembled the list proved to be quite substantial. Reference to the Boskoop work showed that cultivars varied in their rootability, that timing was important as it is for almost all plants and that the type of cutting used was also an important factor. In addition close control of water loss during the rooting period was essential, the medium used affected the results, hormones were most helpful, but perhaps most important of all, wounding the cuttings greatly improved both the vigor and quality of the rooting. Although this was quite a substantial amount of information we continued to collect more. F.W. Burbidge in his book published in 1875 stated that *R.* 'Cunninghams White' could be rooted. Bowers in his book said the same as did Dr. L.C. Chadwick. We found another reference to the value of wound-

ing published in 1932 by Day which underlined the importance of this technique. Then there were the papers by Guy Nearing on his special frame, Henry Skinner on his leaf bud and mallet cuttings, and Hitchcock and Zimmerman at the Boyce Thomson Institute who tested both IBA and NAA. All had successfully rooted rhododendrons, and all had managed to grow plants to a state of relative maturity with success. It seemed a generally held opinion also that plants so propagated were clearly less susceptable to the rhododendron wilt disease.

With this mass of information before us we attempted to sort out and assemble a set of criteria which should work, and at the same time to initiate tests to prove these ideas, using cuttings of *R.* 'Roseum Elegans'.

We defined success as at least 50% of the cuttings inserted should be well rooted with a strong ball of well attached roots perhaps slightly smaller than a tennis ball. The problem of attachment had been well documented. Cuttings might root with a large ball, which coming from perhaps only one or two points of attachment, just broke away as the cuttings were lifted. We reasoned that the wounding technique should overcome this but our early tests were made with a light wound which was not adequate and we lost a year before we tested a heavy wound and found this the best. These tests began in 1947, but really did not get under way until the propagating season of 1948. Three years of intensive testing and careful recording of results produced a set of criteria which were presented to the first meeting of this Society in November 1951. It cannot be overemphasized that to sort things out into an orderly progression leading to success required very close attention to minute but vital details on each experiment and on each cultivar, as the range of cultivars was extended season by season. To illustrate this, it was soon observed that thin cuttings of a lighter caliper rooted more quickly and more vigorously. Thicker cuttings might root eventually but clearly thinner cuttings had the edge. Shorter cuttings not inserted too deeply appeared to root more quickly and better than longer cuttings inserted deeper. If longer cuttings were used, they tended to root higher up the stem and not at the base. These are two illustrations of fine points of observation which might not in themselves be of much importance in the rooting of easy to root cultivars, but which clearly would count a great deal when trying to assemble the absolute optimum set of conditions to root a more difficult cultivar. These differences needed to be observed and recorded at the time each test was lifted, so that as season followed season, the whole system could be slowly and finely adjusted to achieve good results on all cultivars. This then is what we did over the next few years,

and in fact, continue to do to this day. Our observation and recording of the most minute differences never ceases, for we are still attempting to refine, or "fine tune" our results no matter how good they may be.

After the publication of our paper in 1951 many other growers tested and retested our methods but in no instance have we found any substantial changes had been made. Methods have been adjusted to new materials and techniques which are available now, but close examination will show that the basic and important points remain unchanged. Briefly, here are the suggestions made in 1951 in order of importance.

1. Timing. Optimum period, August-September.
2. Type of cutting. Thin cuttings best, avoid terminal shoots.
3. Making the cuttings. Reduce to 3-4 inches, remove surplus leaves retaining about 4.
4. Wounding. One heavy wound is essential, a double heavy wound is better.
5. Hormone treatments. Essential to success, (0.8%) IBA on easy cultivars and up to 2% IBA on difficult ones.
6. Medium. At that time we suggested 90% peat and 10% grit.
7. Sticking. Do not insert too deeply,. Space cuttings so that leaves do not lie on each other.
8. Bottom heat. Maintain a temperature of 70°F.
9. Humidification or mist. Some form of controlling water loss is essential. Regular misting was the method suggested at this time.
10. Air temperature in the house. Try to keep this down by a water film or ventilation, but without drying out the cuttings.
11. Light intensity. Maintain the maximum light level without damage to the cuttings by drying out or burning.

It is interesting to compare these suggestions with what we are doing now nearly 30 years later, for the changes indicate what has been achieved by "fine tuning" over the years.

1. Timing. Now not considered so critical. With a better understanding of the importance of other factors cuttings are being rooted from early July through January.
2. Type of cutting. Thin ones still the best, but we root the thicker ones more easily. Very thick terminal shoots should still be avoided.

3. Making the cuttings. A double heavy wound is standard and leaves are often reduced in size up to 50% without apparent harm.
4. Hormone treatments. Still important, but we have a much wider battery of chemicals, mixtures and strengths to meet individual needs. Powders are generally used and contain the fungicide Benlate at 5%.
5. Medium. The standard is now 50% peat and 50% perlite.
6. Insertion. The same.
7. Bottom heat. The same but a much greater use is being made of natural summer heat in July, accepting much higher air temperatures and protecting the cuttings with heavy misting.
8. Mist (humidification). In general use. However the value of a closed case covered with polyethylene as a method of controlling water loss has been demonstrated.
9. Air temperature. Not so critical with the proper use of a good mist system.
10. Light intensity. Still critical, but it is clear that much higher light levels can be used with benefit if the cuttings are well misted.

In conclusion, what we did to solve a difficult propagation problem was the following:

1. Recognize and define the problem.
2. Assemble all available published information bearing on the problem.
3. From this material assemble what would seem to be the most logical and effective set of procedures which should lead to success.
4. Recognize areas of doubt, in which tests are needed to pinpoint optimum needs.
5. Commence a series of tests, using the easiest possible type to handle, in which unknowns are sorted out and optimums established.
6. Observe, record, and evaluate these tests in minute detail. As information becomes available, "fine tune" your methods by small adjustments, looking for an improvement in each case.
7. Continue until the production of all types of the desired plant is a practical and commercial success.

JUVENILITY AND PLANT PROPAGATION

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The phenomenon of juvenility is well-known to plant propagators, in that it plays a critical role in the propagation of a number of woody plant species. And while this phenomenon presents a major developmental process in plants, little is known about its precise nature, or about the level of control that plant propagators may exert over the maturation state of a given plant.

In order to examine juvenility and its relationship to propagation, some definitions must be made:

Juvenile — that stage in the life cycle of a woody plant during which flowers cannot be induced to form

Adult/mature — that stage in the development of a woody plant during which flowering may occur

Transition — that period between the adult and juvenile phases during which flowering may be initiated by the normal flower inductive treatments

Phase change/maturation — the process that controls the development of the juvenile form into the adult

In all of these definitions, the sole basis of differentiation is flowering. In the juvenile form, flowers cannot form; in the adult, they can; and in the transition, they may occur under specific conditions.

Importance. Juvenility is important to plant propagators in three major areas: the rooting of cuttings, the field performance of those cuttings, and the breeding of woody plants.

Cuttings of many species form adventitious roots more readily when taken from juvenile rather than adult tissue. In a number of woody plant genera, juvenile tissue is the only tissue which will force any roots. No single reason has been suggested for this difference in rooting ability. Research has uncovered four areas that may link maturation state and rooting. These areas are: stem anatomy, levels of rooting co-factors, levels of endogenous rooting inhibitors, and presence of preformed root initials.

In English ivy, as well as other species, mature stems contain a ring of sclerenchyma fibers that has been suggested as being a barrier to root development. However, some evidence suggests that the presence of this ring does not prevent rooting.

Also in English ivy, juvenile tissues appear to contain higher levels of rooting co-factors than adult tissues (3,4). In some plant material, the level of endogenous inhibitors increases with plant age (9). In *Eucalyptus*, a direct relationship exists between the presence of such an inhibitor and decreased rooting.

Finally, some plants, such as English ivy, possess preformed root initials in the juvenile phase which are absent in the adult phase.

Juvenility also can be important to plant propagators in the performance of cuttings after they are removed from the propagation bench. Libby and Hood (6) compared field performance (4 years after planting) of plants obtained from juvenile and adult tissues of *Pinus radiata*. Juvenile wood was collected from plants that had been 'hedged' to prevent maturation; adult wood was collected from normal 'tree-form' trees. Hedge-originated propagules were more vigorous in a number of measures of overall tree vigor, including dry weight (hedge-originated weighing 60% more than tree originated), current year's growth rate, trunk diameter and stem form. Tree-originated propagules were 10% taller than hedge-originated. Although this type of field performance data is rare, it does point to an often overlooked aspect of the effects of maturation upon growth.

Finally, juvenility is important to propagators because it places severe constraints upon the development of new selections and cultivars. With the length of the juvenile phase lasting for up to 30 years, progress in the area of the breeding and genetics of woody plants is very slow (Table 1). (For data on the length of the juvenile phase of specific plants, see USDA Handbook 450 — *Seeds of Woody Plant in the United States*. Under most genera is a giving the "minimum seed bearing age".)

Table 1. Length of Juvenile Period in Some Woody Plants

Rosa (Hybrid tea)	— 20-30 days	*Pinus* spp	— 5-40 years
Vitis spp	— 1 year	*Malus* spp	— 2-8 years
Prunus spp	— 2-8 years	*Hedera helix*	— 10 years
Pyrus spp	— 4-8 years	*Quercus robur*	— 25-30 years
Citrus spp	— 5-8 years	*Fagus sylvatica*	— 30-40 years

Morphological Changes Associated with Maturation. Although the common measure of juvenility is flowering, this is not the only morphological character that changes over time. The development of a number of characters is influenced by the phase of the plant. Perhaps the best example of the morphological changes is found in English ivy, (*Hedera helix*), where the juvenile and adult phases are very distinct. The juvenile form possesses lobed leaves, anthocyanin pigmenta-

tion in the leaf petiole, alternate leaf arrangement, prostrate growth habit, preformed root initials, and no flowers. The mature form lacks lobed leaves, the anthocyanin pigmentation and the preformed root initials; and possesses a spiral leaf arrangement, upright growth habit, and flowers.

While English ivy is well known as an example of the differences between juvenile and adult phases, in reality, the number of plants which, possess morphologically distinct forms is rather small More commonly it is very difficult to distinguish adult from juvenile on the basis of morphology. Flowering appears to be the only trait upon which the phase of many plants may be determined

Rooting and Maturation. One aspect of the development of maturation which is becoming clearer is the concept that phase change is not a single on/off event, but is an accumulation of events. A plant becomes mature over time, not overnight. There are numerous experimental observations demonstrating that characters which change with the phase of a plant do so over time, and at their own rate. In a practical sense, the ability to form adventitious roots may be lost long before flowers appear This type of change has been demonstrated in Douglas fir, in which flowering does not occur in the first 20 years Yet, the ability to form roots changes much earlier. In one experiment, cuttings taken from 9 year-old Douglas fir trees rooted 100%. But the rooting ability declined rapidly after then, and may be only 5% by 15 years (2). In some species of *Eucalyptus*, rooting ability is lost as early as the fourth node (7). Perhaps many of the plants we consider to be 'difficult-to-root', lose the ability to do so very early in their life cycle.

Such experimental results help us to understand the observation that a 'gradient of juvenility' from base to periphery exists in many plants, with more juvenile tissues retained at the base One apparent example of this gradient exists in the Fagaceae, where a 'cone of juvenility' is found in many species. Here, a morphological marker of the plant's phase lies in it's ability to retain leaves in the fall (actually, an inability to form the necessary abscission zone). Juvenile shoots retain the leaves throughout the winter and into the spring. Adult shoots lose the leaves as normally expected. This is a clear indication of juvenile and adult phases existing within a single plant.

Further evidence is derived from observations on the rooting of Douglas fir cuttings (12). Cuttings taken from the bottom one-third of 16 year-old trees rooted at 71%, whereas cuttings taken from the central or upper third rooted at 53 and 51%, respectively Many nurserymen and propagators have long ob-

served that shoots from the basal area of trees root more easily than those higher up in the tree.

Rejuvenation. If we assume that most trees possess at least some juvenile tissue at their base, it might be possible to induce juvenile shoots to develop, shoots which would have a high(er) rooting potential. Such rejuvenation has been induced experimentally by severely pruning or hedging plant material. Using this practice on hard-to-root Monterey pine trees, Libby *et al* (5) have been able to double the percentage of rooting (as compared to cuttings taken from normal, unhedged trees). Rooted cuttings from hedged trees had more roots per cutting and the overall root system was more symetrical and fibrous. Mazalewski (7) used a combination of pruning and cytokinin application to induce the formation of shoots of *Eucalyptus ficifolia*, which rooted at a higher percentage than normal plants. Another example of this practice is the use of stool beds for rootstock production.

There may be a question as to whether such pruning treatments are indeed causing rejuvenation of mature tissue or are inducing the production of shoots which have a high capacity for root formation. It has been generally thought that shoots arising from adventitious buds are juvenile. Whatever the physiological basis, the result is production of shoots with a greater ability to root.

Experimentally, such rejuvenation (or reversion) has also been induced by treatment with gibberellic acid, and by a combination of high temperature and low light.

Evidence is also accumulating that *in vitro* propagation of woody plants may be a rejuvenating process. Two recent findings with *Hedera* (1) and *Vitis* (8) demonstrated that *in vitro* rejuvenation occurs, in both callus and shoot tip cultures. Many propagators who use tissue culture as a propagation tool are finding reversion occurring after a number of sub-cultures. Hackett (personal communication) has suggested that a major use of tissue culture in the future will be in the propagation of 'difficult-to-root' plants, using the rejuvenation process.

SUMMARY

In summary, propagators must be aware that the phenomenon of juvenility involves a number of physiological processes, including flowering and the ability to form adventitious roots. As a general developmental process, phase change does not occur all at once, but over a long period of time. The loss of rooting ability with age may or may not coincide with the onset of flowering or even the ability to form flowers. These two characters are distinct in their physiological basis.

It is also important to remember that while these two phases are quite stable, reversion of the adult form to the juvenile can occur. With careful manipulation of the mature phase, propagators may be able to produce juvenile cuttings with a high capacity for rooting.

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INFLUENCE OF HIGH IBA CONCENTRATIONS ON ROOTING

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Abstract. Cuttings of *Acer saccharum*, *Cotoneaster acutifolius*, *Malus pumila* 'Mor Spur McIntosh', *Malus* 'Hopa', and *Taxus cuspidata* were treat-

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Abstract. Cuttings of *Acer saccharum*, *Cotoneaster acutifolius*, *Malus pumila* 'Mor Spur McIntosh', *Malus* 'Hopa', and *Taxus cuspidata* were treat-

ed (5-second dip) with 0 (control), 1,250, 2,500, 5,000, 10,000, 20,000, and 40,000 ppm indolebutyric acid (IBA) dissolved in alcohol, rooted under intermittent mist, and evaluated for percentage rooting, mean root length and mean root number *Cotoneaster acutifolius*, *Malus* 'Hopa', and *Taxus cuspidata* showed significant increases ($P = 0.01$) in rooting percentage, root length, and root number, with optimum responses in these parameters observed with IBA treatments between 10,000 and 40,000 ppm *Acer saccharum* showed a significant increase ($P = 0.05$) only in rooting percentage with maximum response occurring with the 5,000 ppm IBA treatment *Malus pumila* 'Mor Spur McIntosh' failed to root regardless of IBA treatment

The discovery in the mid-1930's that auxins were of real value in stimulating rooting of cuttings was a major milestone in the history of plant propagation (14,16). Exogenously-applied auxins and other growth regulators have been distinctly beneficial for numerous plant species, but their effects on root formation sometimes have been conflicting and, on occasions, found to be detrimental to some species, including some difficult-to-root species not ordinarily propagated by cuttings (3,14).

Ample evidence suggests that increasing age or loss of juvenility is one of the most important single factor limiting rooting ability of many difficult-to-propagate species (1,7). It has long been advised that high concentrations of growth regulators might promote rooting in these species (1). In fact, certain hard-to-root species have been successfully rooted after treatment with high concentrations of growth hormones. *Quercus robur* 'Fastigiata' cuttings rooted after treatment with 20,000 ppm indolebutyric acid (IBA) (6) Brown and Dirr (1) reported successful rooting of softwood cuttings from mature crabapple trees due to high IBA concentrations; *Malus floribunda* was most effective with 10,000-30,000 ppm IBA, and *Malus* 'Hopa', *Malus* 'Selkirk', and *Malus zumi* 'Calocarpa' with 10,000 ppm. Still (12) observed significant stimulation in rooting of cuttings from mature *Tilia* taxa with IBA treatments, especially in the range of 20,000 ppm. On the contrary, IBA concentrations of 10,000-30,000 ppm did not promote rooting of mature red oak or black walnut cuttings, although juvenile black walnut cuttings can be promoted to root by 5,000-8,000 ppm IBA treatments (11) Thus, the rooting response of species and cultivars can be expected to vary, and optimum treatment levels must be determined empirically (2,7).

Increased demand for woody landscape plants and related fruit nursery stocks have resulted in shortages of some of these planting materials. Many of these woody plants are difficult to propagate vegetatively and require a lengthy time to produce salable plants. As part of a research program, which aims to develop more effective methods and techniques for the production of woody ornamental and related fruit nursery stocks with emphasis on more difficult-to-propagate species,

this study was undertaken to study the influence of high IBA concentration on rooting of stem cuttings of selected woody species.

MATERIALS AND METHODS

Between July 10 and 13, 1979, stem cuttings of the current season's growth were removed from the following species (approximate age of source in brackets); *Acer saccharum* (20 years); *Cotoneaster acutifolius* (15 years); *Malus pumila* 'Mor Spur McIntosh' (10 years); *Malus* 'Hopa' (2 years, budded nursery stock). Length of cuttings varied between 10-15 cm depending on species. Cuttings of *Acer saccharum* were limited to two nodes. The basal portions of all cuttings were stripped of foliage. The remaining leaves on cuttings of *Acer saccharum* and *Malus pumila* 'Mor Spur McIntosh' were cut in half to reduce the surface area.

Cutting bases of each species were treated (5-second dip) with 0, 1,250, 2,500, 5,000, 10,000, 20,000, and 40,000 ppm IBA dissolved in 50% ethanol. Fifty percent ethanol served as the control. Cuttings were then stuck in a medium of 1 peatmoss: 1 perlite (v/v) in wooden boxes (44 cm long × 35 cm wide × 15 cm deep), and placed in outdoor frames under intermittent mist controlled by electronic leaf. The mist frames were shaded with lath. Captan was applied at time of sticking, followed by Captan or Benlate applied alternatively once per week.

The experimental design used was a randomized complete block with four replications and 12 cuttings per experimental treatment, except for *Acer saccharum* in which there were 10 cuttings per experimental treatment. Cuttings were evaluated for percentage rooting, mean root length, and mean root number.

On the dates, November 9, 1979 and February 19, 1980, two consecutive experiments were similarly conducted for *Taxus cuspidata* but cuttings were rooted under greenhouse conditions under intermittent mist with bottom heat of 24 ± 2°C. In experiments for *Taxus cuspidata*, six replications and 10 cuttings per experimental treatment were used. On June 21, 1980 the same experiment as described in 1979 was repeated for *Cotoneaster acutifolius*.

RESULTS AND DISCUSSION

Except for *Malus pumila* 'Mor Spur McIntosh' which failed to root regardless of IBA treatment, cuttings of the four other species rooted (Figure 1). The rooting periods (weeks) for these four species were. *Acer saccharum*, 8; *Cotoneaster acutifolius*, 5;

Malus 'Hopa', 3.5; *Taxus cuspidata*, 9. Results for *Taxus cuspidata* are shown as the average of the two experiments since data were similar for the two dates (Figure 1,2,3). On the other hand, results for *Cotoneaster acutifolius* are shown separately for experiments conducted in 1979 and in 1980 since rooting response was significantly higher ($P = 0.01$) in 1980 (Figures 1,2,3); however, the trend in rooting response of this species to increasing IBA treatments was essentially similar in both years.

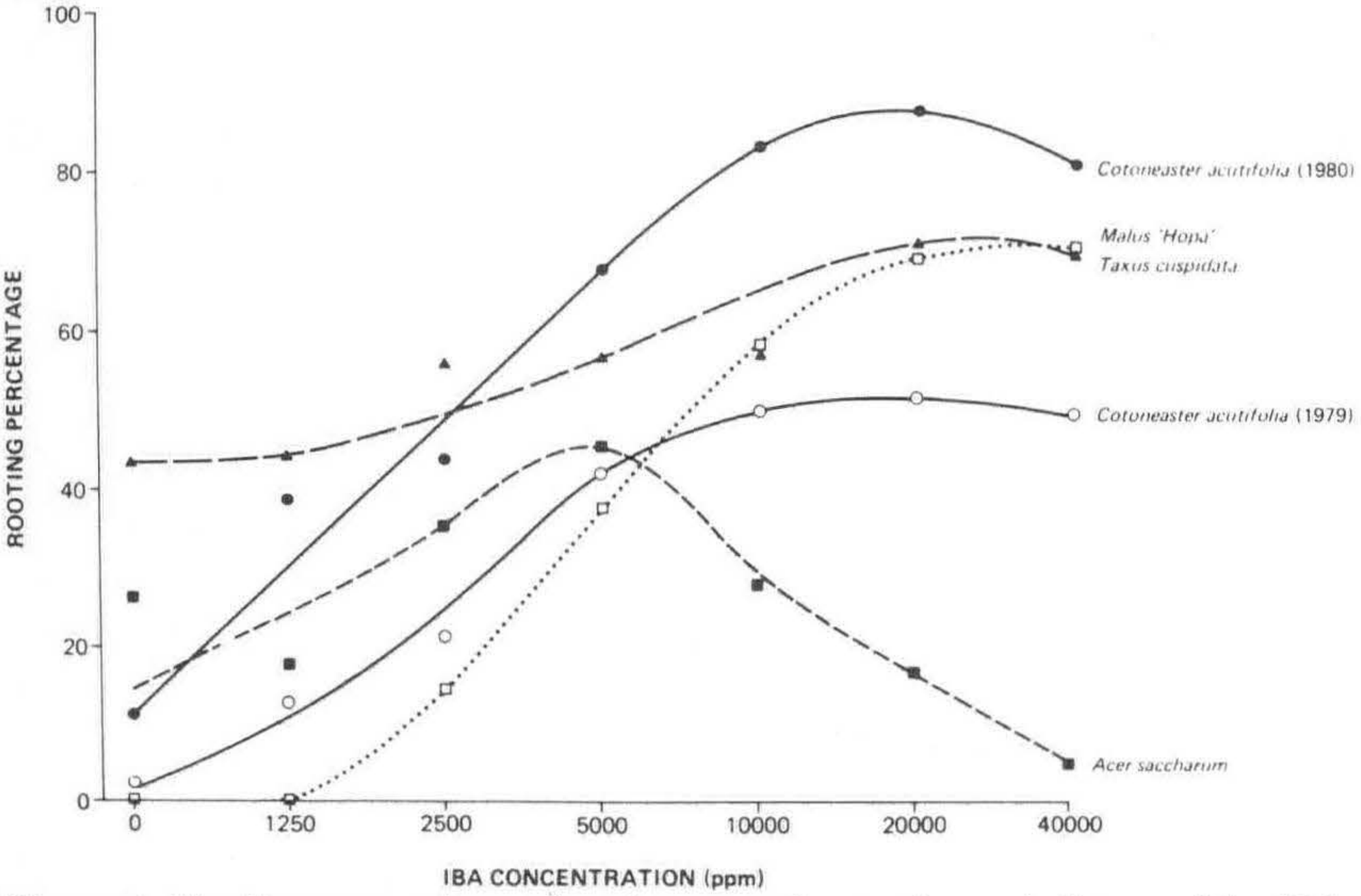

Figure 1. Rooting percentage of various woody species as influenced by IBA concentrations. LSD ($P = 0.01$): *Cotoneaster acutifolius*, 28% in 1979 and 31% in 1980; *Malus* 'Hopa', 47% *Taxus cuspidata*, 22%. LSD ($P = 0.05$); *Acer saccharum*, 22%.

Analysis of variance for rooting data of *Cotoneaster acutifolius*, *Malus* 'Hopa', and *Taxus cuspidata* showed highly significant ($P = 0.01$) and consistent increases in rooting percentage (Figure 1), root length (Figure 2), and root number (Figure 3). Percentage rooting (Figure 1) peaked or plateaued with IBA treatments of 20,000 ppm for *Cotoneaster acutifolius* (50% in 1979; 88% in 1980), 20,000 ppm for *Taxus cuspidata* (71%), and 40,000 ppm for *Malus* 'Hopa' (71%). Root length (Figure 2) peaked or plateaued with IBA treatments of 10,000 ppm for *Cotoneaster acutifolius*, 20,000 ppm for *Malus* 'Hopa', and 40,000 ppm for *Taxus cuspidata*. Root number (Figure 3) was dramatically stimulated by IBA concentrations between 10,000 and 40,000 ppm with maximum root number in all three species occurring consistently with the 40000 ppm IBA treatment. Differences in rooting percentage, root length, and root number as influenced by IBA concentrations have been reported for var-

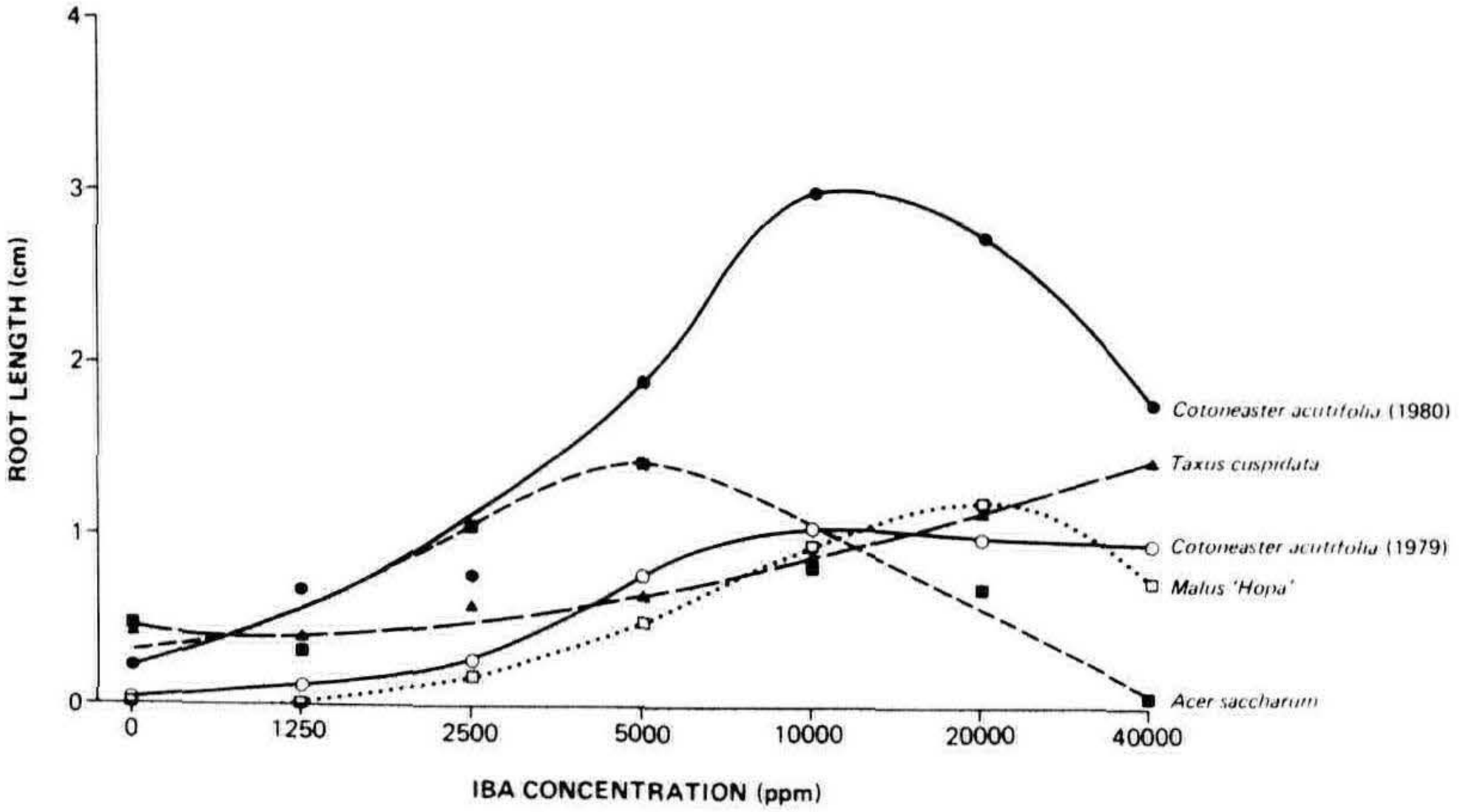

Figure 2. Root length of various woody species as influenced by IBA concentrations. LSD ($P = 0.01$): *Cotoneaster acutifolius*, 0.81 cm in 1979 and 1.32 cm in 1980; *Malus* 'Hopa', 0.91 cm; *Taxus cuspidata*, 0.81 cm. Root length was not significantly different for *Acer saccharum*.

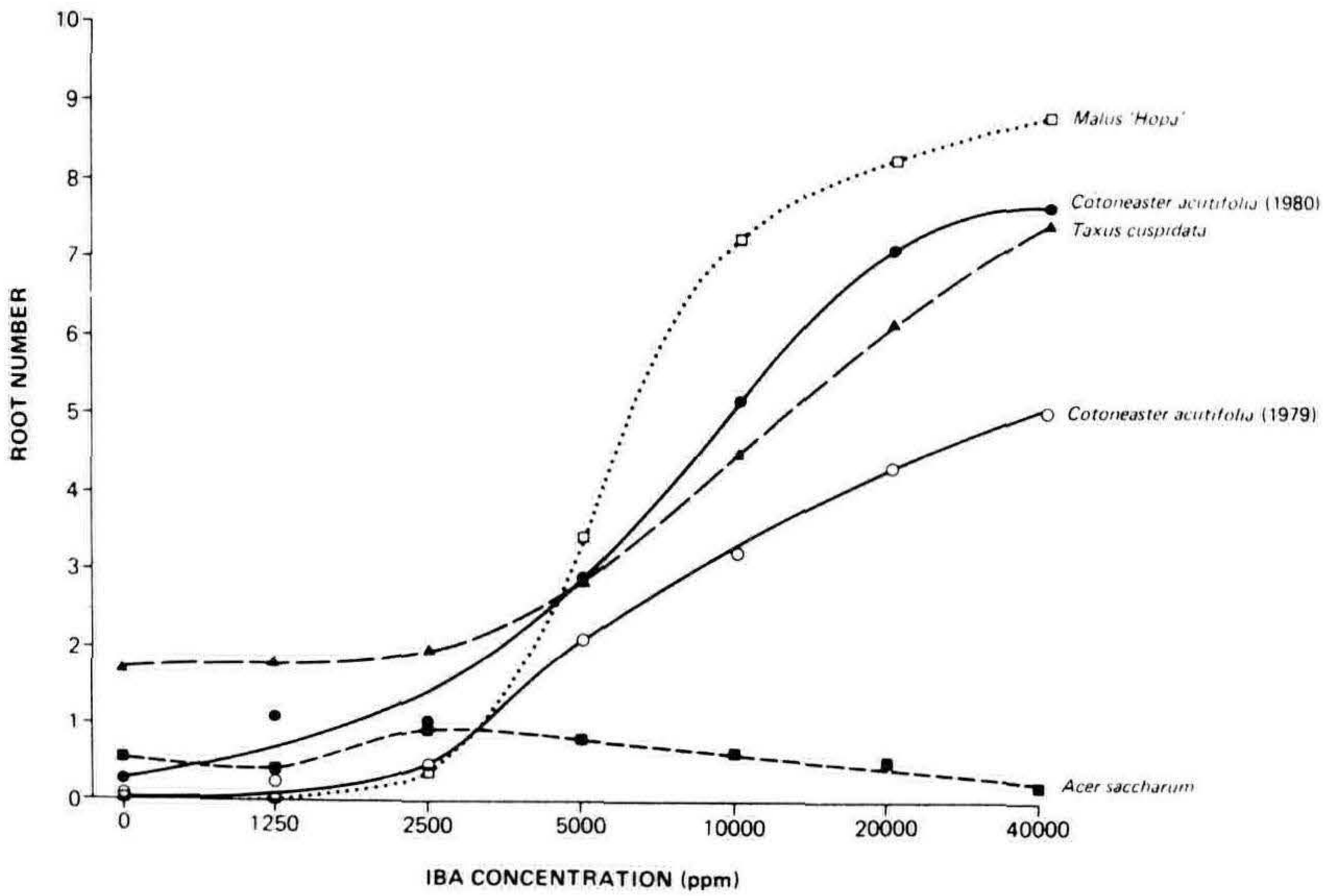

Figure 3. Root number of various woody species as influenced by IBA concentrations. LSD (P=0.01): *Cotoneaster acutifolius*, 3.5 in 1979 and 1.8 in 1980. *Malus* 'Hopa', 7.2; *Taxus cuspidata*, 3.6. Root number was not significantly different for *Acer saccharum*.

ious crabapple taxa (2) and for juvenile oak (11).

Acer saccharum showed significant increase ($P = 0.05$) only in rooting percentage, which peaked at 45% with IBA treatment of 5,000 ppm (Figure 1).

It is perhaps worth noting that further tests with IBA

during the winter of 1981 in a commercial nursery, in which *Taxus* × *media* 'Hicksii' cuttings were rooted in a greenhouse without intermittent mist but supplied with bottom heat, confirmed the results of this study (Figure 1.2,3). In another experiment conducted in 1980, cuttings of *Malus pumila* 'Mor Spur McIntosh', treated with all combinations of IBA at 2,500, 5,000, and 10,000 ppm and ethephon (2-chloroethyl phosphonic acid) at 0, 500, 1,000, and 1,500 ppm, also failed to root Many cuttings developed callus in the fall and several developed roots the following spring, after being allowed to overwinter in the mist frame. However, there was no discernible relationship of rooting with growth regulator treatments. Ethephon alone, or in conjunction with other auxins, has been shown to stimulate rooting ability of various species (4,5,13).

Root formation in cuttings is a complex phenomenon influenced by numerous factors such as physiological condition; genetic origin of donor plants; climatic effects or season in which cuttings are taken; treatment with growth regulators, nutrients, or other chemicals; misting frequency and composition; and temperature of the rooting medium (7)

High hormonal concentrations have proven to be a significant factor in the successful rooting of stem cuttings of various ornamental crabapples and a limited number of other difficult-to-root woody species as reported in this (Figure 1,2,3) and other studies (1,2,6,12). This contrasts with the difficulty in rooting stem cuttings of *Malus pumila* 'Mor Spur McIntosh' (this study), other commercial fruiting apples, and apple rootstocks (2,9,10) and certain other woody species tested in this way (11). This evidence seems to emphasize our present uncertainty in the use of growth regulators and also our lack of understanding of the sequence of rooting events which allows growth regulators to be used effectively (3,8).

Unlike easily rooted species, such as the willows, which possess preformed root primordia in their stems, root primordia must be biochemically induced in many species (8). Difficult-to-root tissues may lack the necessary active enzymes or substrates to induce a meristematic state and thus the initiation of root primordia (8).

Evidence further suggests that, like other growth processes, each step of the rooting process is controlled by delicate balances of growth hormones, both promoter and inhibitor types, in conjunction with other rooting cofactors and complexing enzymes (15,16). Thus according to Cameron and Rook (3), it seems unlikely that a single application of one growth regulator applied against the background of natural growth regulators that vary in composition with age of the plant, time

of year, and an integrated series of events will give consistent results.

Brown and Dirr (1) and Burd and Dirr (2) indicated that high concentrations of IBA between 20,000 and 30,000 ppm often resulted in defoliation, significant injury or death in crabapple taxa. In the present study, it was noted that the basal portions of cuttings treated with 20,000 and 40,000 ppm IBA also tended to be injured by these high concentrations. However, in the three species that responded positively to high IBA concentrations (Figures 1,2,3), more prolific rooting nevertheless occurred above the injured portion, as exemplified by cuttings of *Cotoneaster acutifolus* (Figure 4). At these high concentrations, IBA dissolved in 50% ethanol will usually form a precipitate after several days of storage in the refrigerator (4°C). The precipitate will clear easily after standing for several minutes in luke-warm water with occasional shaking. Dissolution of the IBA in 95% ethanol will prevent this problem.

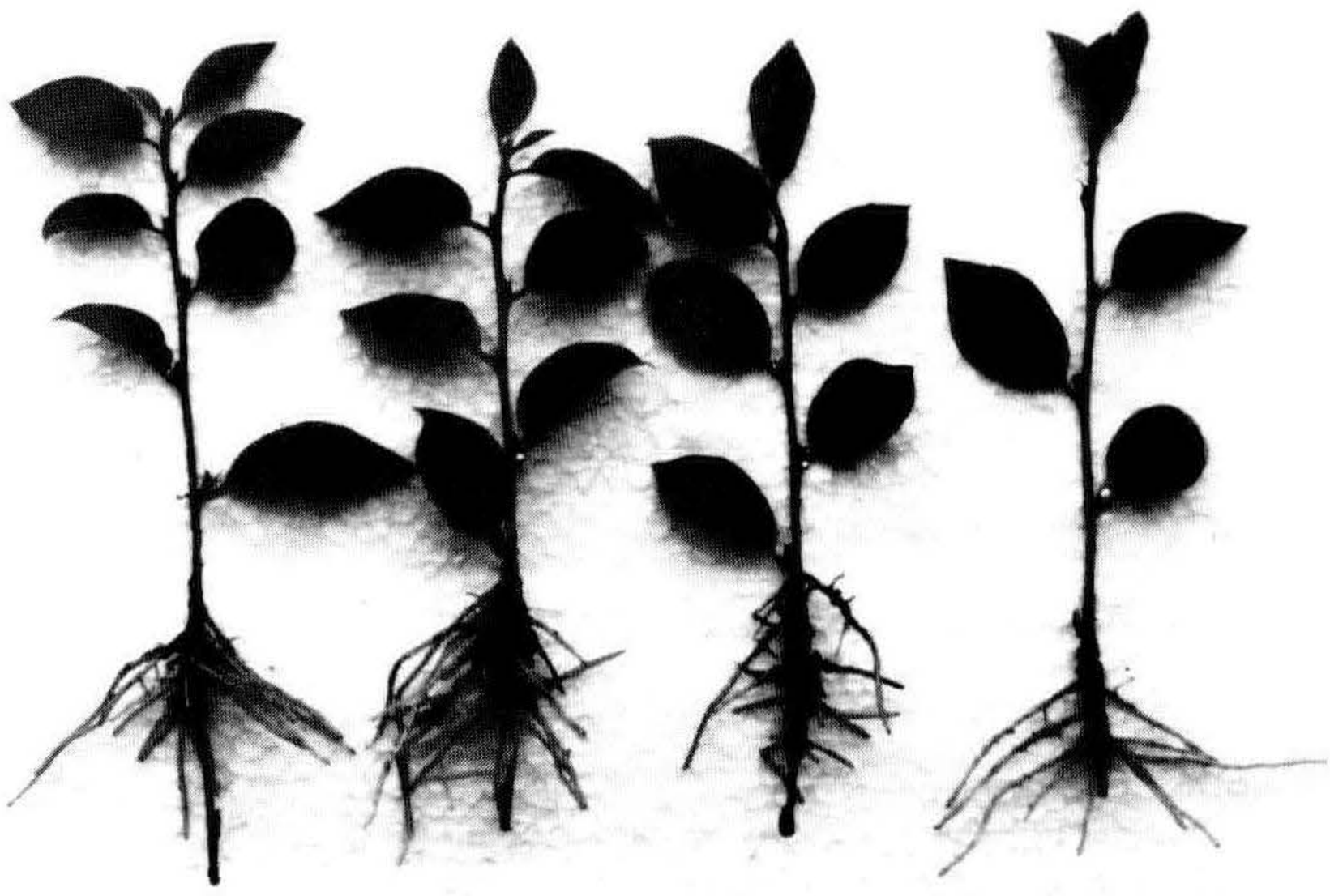

Figure 4. Prolific rooting occurs above basal portion of *Cotoneaster acutifolius* injured by high concentrations of IBA.

The results of this study, together with those of other researchers (1,2,6,12), indicate the favorable use of high IBA concentrations for stimulating rooting of certain difficult-to-root species. Further extension of this finding to other species and also use of other growth regulators in a similar way may be the key to rooting of many more difficult-to-root species.

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JOERG LEISS: What was your growth response after heavy hormone treatment? Did the heavy hormone treatment suppress growth?

CALVIN CHONG: I did not do a formal growing-on study. However we did pot a few cuttings and did not see any detrimental effects.

CARMINE RAGONESE: Please explain how to make a 20,000 ppm solution?

CALVIN CHONG: A 20,000 ppm solution is equal to 20 grams per liter or 20,000 milligrams per liter.

WILLIAM WOLFF: I have tried varying hormone strengths with a number of *Acer* species. The conclusion we came to was that high IBA concentrations act as growth inhibitors.

ADJUSTING NURSERY PRACTICES FOR PRODUCTION OF MYCORRHIZAL SEEDLINGS DURING PROPAGATION

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During the past few years, there has been a growing interest in mycorrhizal research. There are many reports citing the possible benefits mycorrhizal fungi may afford nursery crops, such as increased nutrient uptake, growth, disease resistance, cold hardiness, drought tolerance, rooting of cuttings, and fertilizer conservation. Information pertaining to these benefits has been thoroughly discussed in previous Proceedings (8,19,20) as well as for other horticultural and forestry crops (25,47).

A major requirement in developing uses for mycorrhizal fungi in the nursery industry will be to determine cost-efficient methods of producing plants infected with specific mycorrhizal fungi and no others. We feel that one of the most efficient methods of producing mycorrhizal plants will be through the inoculation of seedlings at time of propagation. During propagation, the amount of mycorrhizal inoculum required is minimal, and regulation of environmental conditions and/or cultural practices can be closely monitored and controlled.

The primary objective of this paper is to place in perspective some of the current information pertaining to mycorrhizal formation so that the propagator has a better understanding of how to develop techniques for the production of specifically infected mycorrhizal seedlings. This objective will be accomplished in three steps: first, through a review of mycorrhizal occurrences and chief characteristics; second, through a brief discussion of plant-fungus interactions and mycorrhizal formation; and third, through a discussion of how production practices may have to be adjusted and/or new ones developed to inoculate and grow mycorrhizal seedlings economically.

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Mycorrhizal occurrence and characteristics. Mycorrhizal associations are so prevalent that the nonmycorrhizal plant is more the exception than the rule (9). Consequently, it is easier to name the plant groups in which the associations do not occur or have yet to be reported: the order Centrospermae and the families Cruciferae, Cyperaceae, Fumariaceae, Commelinaceae, Urticaceae, and Polygonaceae (9). However, Gerdemann (10) has cited exceptions where endomycorrhizae have been found for several members of the order Centrosperme, family Chenopodiaceae (17,40,48) and several speices in the Cyperaceae (35) and Cruciferae (17,40). Hirrel et al. (15) and Ocampo et al. (36) found several species of Chenopodiaceae and Cruciferae to become infected to a limited extent if grown in the presence of a mycorrhizal plant, but not if grown alone.

Mycorrhizae can be divided into three anatomic classes; ecto-, endo- and ectendomycorrhizae. Of these, ecto- and endomycorrhizae are the two major classes of mycorrhizae. The three types of mycorrhizal relationships are typified by the fungal intrusion being limited to the cortical region of unsuberized roots. The association involving only unsuberized roots may in part be the result of root expansion and subsequent loss of the primary cortex in mature roots. Attempts to penetrate further into the inner layers of the root by the fungus may be overcome by defense mechanisms of the host (33).

Ectomycorrhizae are most common among forest and ornamental tree species in the families Pinaceae, Salicaceae, Betulaceae and Fagaceae as well as in some members of the Rosaceae, Leguminosae, Ericaceae and Juglandaceae (32,46). The fungal partner in an ectomycorrhiza most frequently belongs to the Basidiomycetes, primarily in Amanitaceae, Boletaceae, Cortinariaceae, Russulaceae, Tricholomataceae, Rhizopogana-ceae and Sclerodermataceae (27). Some orders of Ascomycetes, Eurotiales, Tuberales, Pezizales and Helotiales contain species that form ectomycorrhizae. Basidiomycetes include those fungi which produce mushrooms and puffballs while the major Ascomycetes which form ectomycorrhizae are the truffles, some of which are gourmet delights in many European countries.

Structurally, ectomycorrhizae can be distinguished by the presence of hyphal strands coalescing to form a thick weft or sheath around the feeder roots known as a mantle. The mantle can range from thin to profuse and the texture can vary from smooth to cottony or granular (49). The mantle replaces the root hairs with fungal strands, greatly enhancing root surface absorptive area. These hyphal strands are capable of permeating outward from the root surface several meters or more and exploring regions not accessible by root hairs Hyphae also

penetrate through the epidermis into the intercellular spaces of the cortical cells apparently replacing the middle lamella and forming an interconnecting network known as the 'Hartig Net'. Ectomycorrhizal roots are generally recognizable by their short, swollen appearance and distinctive colors of either white, black, orange, yellow and olive green which are contingent on interactions between the plant species and its fungal associate. Ectomycorrhizae are also characterized by specific branching patterns ranging from monopodial to multiforked (ramiform) or coralloid.

Ectomycorrhizal fungi can exist in the soil as spores, sclerotia and rhizomorphs. A rhizomorph is a coalesced group of hyphal strands which may extend from the ectomycorrhiza to or near the surface of the soil forming fruiting bodies containing spores that can be disseminated by wind, surface water, or animals.

Most endomycorrhizal fungi belong to the order Phycomycetes, genera *Glomus*, *Sclerocystis*, *Endogone*, *Gigaspora* and *Acaulospora* (12). These form what is known as vesicular-arbuscular (VA) mycorrhizae with plants. Endomycorrhizae are the most widely distributed of any of the mycorrhizae, being found in many herbaceous, shrub and tree species including most agronomic and horticultural crops (10). A few endomycorrhizae are formed by an association with Basidiomycetes which differ somewhat in cellular morphological structure from endomycorrhizae in having septate hyphae. Those endomycorrhizae occur primarily in the Orchidaceae, *Gentianaceae and Ericaceae.*

Endomycorrhizae differ from ectomycorrhizae in that there are essentially no discernible morphological changes in the external root structure of the host. A fungal mantle is not present, but a loose network of hyphase which radiate outward several cm or more from the root may be seen on feeder roots (38). Hyphae of endomycorrhizal fungi generally penetrate through the epidermis or root hair into the cortical cells, hence the prefix 'endo' is used. The penetrating hyphae often form specialized structures called vesicles and arbuscules. The longevity of arbuscules is short, 5 to 15 days (3), as they continually disintegrate (16), leading to the hypothesis that this process may be a valuable source of mineral nutrients to the host (9). Round or oval bodies known as vesicles are also formed in the cortex and in some instances outside the root. Little is known about vesicles; however, it has been suggested that they may function in some storage capacity (11).

Spores of endomycorrhizae are borne in small sporocaps or occur individually in the soil or in the root. The sporocarps are often not easily observed as in the Basidiomycetes and

must be extracted from the soil using wet sieving techniques (11)

Some plants are capable of forming both ecto- and endomycorrhizal associations Those include the families Salicaceae, Juglandaceae, Tiliaceae, Myrtaceae as well as some species of *Juniperus* and *Chamaecyparis* (10).

Plant-fungal interactions and mycorrhizal formation. The interactions between the fungus and host are complex and appear to be influenced by a myriad of interrelated biochemical, physiological and environmental processes. Furthermore, there also appears to be some reciprocal relationships between the fungus and the plant host, but it is difficult to interpret the exact contribution either organism lends to the association (33). We do know that the fungal symbiont must enter and maintain a parasitic relationship with its host for procurement of organic compounds required for its growth and reproduction. It is during mycorrhizal formation that we can begin to understand how the biochemical interactions between the partners develop and how these interactions may influence plant growth and development of nursery crops Most of the work on mycorrhizal formation has centered around ectomycorrhizae, where the morphological changes brought about by various biochemical influences are more easily discernible.

Plant and fungal hormones are suspected of being involved in mycorrhizal development. Auxins, cytokinins, gibberellins and vitamins have been shown to be produced by mycorrhizal fungi in pure culture (7,37,41), and the effects of these compounds on rooting of cuttings and on plant growth and development are well documented (45). Although no one has yet shown that any mycorrhizal fungus produces a growth hormone while in association with the root, Linderman and Call (18) have obtained enhanced rooting of cuttings with some mycorrhizal fungi.

The involvement of plant growth hormones such as auxin in mycorrhizal formation is further complicated by the need for simple carbohydrates (sugars) for fungal growth. Auxin has been shown to influence translocation of sugar from starch reservoirs of the plant (44) as well as the hydrolysis of starch into sugar (1,2,6). The quantity of soluble sugar in the roots may also have a direct relationship to the degree of ectomycorrhizal development (13). Bjorkman (4,5) suggested that since mycorrhizal fungi generally assimilate soluble carbohydrates, the absence or presence in small quantities of soluble carbohydrates could influence mycorrhizal formation.

The available soluble carbohydrates and the presence of plant growth hormones or other substances found in the root

are not considered solely responsible for mycorrhizal formation and maintenance of the symbiosis. Some environmental factors affecting mycorrhizal development as well as plant growth and development include light, soil conditions (moisture, mineral nutrients, pollutants) and interaction with other soil organisms

The importance of photoperiod and light intensity for mycorrhizal formation is unclear. Although light is essential for carbohydrate production and plant carbohydrate levels are known to influence mycorrhizal formation, conflicting evidence exists regarding the light intensity needed for mycorrhizal formation. Mycorrhizal formation has been found to increase at both low and high light intensities (5,14). These variations may be related to host-fungal specificity and/or to a photoperiodic response. However, additional work is needed in this area to determine the relationship between fungal-plant carbohydrate relationships and subsequent mycorrhizal formation.

Mycorrhizal formation can also be influenced by temperature. Most mycorrhizal fungi have an optimum temperature for establishment of the symbiotic relationship and the survival of the mycorrhizal condition There is, however, considerable variation in the temperature-range tolerance of individual fungi. Marx *et al.* (29) found that the fungus *Thelephora terrestris* Ehrh. ex Fr. had a considerably lower tolerance to a wide temperature range than *Pisolithus tinctorius* (Pers.) Coker & Couch. *T. terrestris* formed ectomycorrhizae on 45% of the feeder roots of loblolly pine (*Pinus taeda*) at 14, 19 and 24°C, but the percentage dropped to 30% at 29°C and none at all at 34°C. *P. tinctorius* formed mycorrhizae in increasing numbers up to a maximum of over 80% at 34°C. *P. tinctorius* has been shown even to have a good survival rate at 40°C (30). Schenck and Schroder (42) also found a temperature response by an endomycorrhizal fungus, with arbuscular development being favored at 30°C, mycelial development greatest at 28-34°C, and spore and vesicle production being greatest at 35°C.

Production of Mycorrhizal Seedlings. We recommend that production of specifically infected mycorrhizal seedlings begin at the time of plant propagation Our recommendations are based on economic considerations and understanding the ecology of these fungi. From the economic standpoint, during propagation, the least amount of inoculum would be required per volume of growing medium, and per unit area of the root system with which the inoculum can come in contact. Furthermore, mycorrhizal development occurs in the nonlignified portion of a root system, primarily the root tip, just behind the apical meristem. The newly developing root system of a cut-

ting or seedling should be receptive to mycorrhizal infection since it is initially nonlignified. Also, mycorrhizal fungi have been shown to increase the rooting of cuttings and/or increase root development during propagation (18). Finally, it may be more cost efficient to develop a mechanized inoculating system during the propagation stage than at any other stage of plant production.

Although mycorrhizal fungi occur naturally, they are often eliminated from the propagating medium through the use of soilless media, fumigation or sterilization, and pesticides. Mature mycorrhizal fungi are in competition with other soilborne organisms. However, many mycorrhizal fungi are slow growing and do not compete well with other fungi. The absence of soilborne organisms in a propagation medium leads one to hypothesize that simply adding mycorrhizal inoculum back to a "sterile" medium is all the propagator will have to do to reap the benefits of mycorrhizal fungi. Unfortunately, this may not often work. Through the years, mycorrhizal fungi have become adapted to specific environments. Successful use of mycorrhizal fungi will require identification and isolation of superior fungi, production of pathogen-free inoculum to prevent losses during propagation, development of inoculation techniques, and adjustment of current cultural practices to facilitate plant infection and maintenance of the plant-fungal association. Linderman and Call (18) were successful in increasing the rooting of some cuttings with mycorrhizal fungi. However, not all fungi used stimulated rooting.

We feel that adjusting fertilization practices will be an important factor in developing mycorrhizal technology. Most mycorrhizal fungi are adapted to low fertility levels. Current production practices often employ very heavy fertilization practices which often inhibit mycorrhizal development (9,31). The rate of fertilizer release may be a critical factor in controlling mycorrhizal formation. We have been able to produce mycorrhizal plants at an adequate or accelerated growth rate, depending on the plant and fungal species, by using slow release fertilizer (21,22,23,24,26). These results showed that recommended rates of a slow release fertilizer (4.5 Kg/m^3) were not inhibitory to formation of ectomycorrhizae by *Pisolithus tinctorius* or endomycorrhizae by *Glomus fasciculatus* on a variety of woody species. Apparently, mycorrhizal development may not always be indicative of nutritionally poor soils, but may also be dependent on a balance of nutrients.

Mycorrhizal fungi can also exhibit ecological selectivity. The ectomycorrhizal fungus *Pisolithus tinctorius* is one of a few ectomycorrhizal fungi with which a considerable amount of research work has been done *Pisolithus tinctorius* has a

broad host plant range and generally is found colonizing plants on disturbed landscape sites (28). We have been able to synthesize *P. tinctorius* mycorrhizae on a number conifer seedlings by inoculating the container medium just before direct seeding in containers (20). In growing shortleaf pine seedlings for 9 months in the greenhouse, the mycorrhizal seedlings were significantly smaller than nonmycorrhizal plants (Table 1) However, when these seedlings were planted on a surface mine site, the mycorrhizal plants outperformed the nonmycorrhizal plants.

We have also found that endomycorrhizal fungi may have deleterious side effects on plant growth, but these side effects only become manifested under certain cultural conditions. The endomycorrhizal fungi *Glomus fasciculatus* and *G. clarus* were used to inoculate container-grown sweetgum seedlings fertilized at various rates, 1.1, 2.2, 4.5 (manufacturer's recommended rate), 9.0 kg/m^3, with the slow release fertilizer 18N-2.6P-10K Osmocote (Sierra Chemical Company, Milipitas, California). The *G. clarus* isolate was isolated from a superior volunteer plant growing on an abandoned surface coal mine site. At one-fourth the recommended fertilizer rate, inoculating sweet gum seedlings with either mycorrhizal fungus significantly increased plant growth when compared to noninoculated control plants (Figure 1). However, at higher fertility rates, the *G. clarus*-inoculated seedlings had a significant inhibitory effect on plant growth, 4.5 kg/m^3 whereas, height of *G. fasciculatus* inoculated plants was similar to control plants. These results suggest that mycorrhizal fungi adapted to low fertility sites may be deleterious to plant growth at high fertility rates. Understanding the ecology of mycorrhizal fungi will be essential to developing applications for their use in production of nursery crops.

Although research is intensifying on the ecology of mycorrhizal fungi, we presently have little information on the species present in nursery cropping systems. For the immediate future most research with mycorrhizal fungi will deal with fungi that are easily cultured, e.g. the ectomycorrhizal fungi *Pisolithus tinctorius* and *Laccaria laccata* and the endomycorrhizal fungi *Glomus fasciculatus* and *G. mosseae*. Initially, these fungi will serve as models facilitating the developing of techniques for inoculation of plant material and for determining the effects specific cultural practices may have on mycorrhizal fungi. However, in order for the nursery industry to maximize the uses of mycorrhizal fungi, we will have to determine which mycorrhizal fungi are in our cropping systems and under what parameters these mycorrhizal fungi may benefit nursery crops. What influence such factors as monocropping,

crop rotation systems, winter cover crops, green manure crops, fertilization practices, and the effects of soil fumigants, herbicides, and fungicides have on mycorrhizal fungi must be determined. It is with this knowledge that we will be able to determine the role mycorrhizal fungi will play in production of nursery crops.

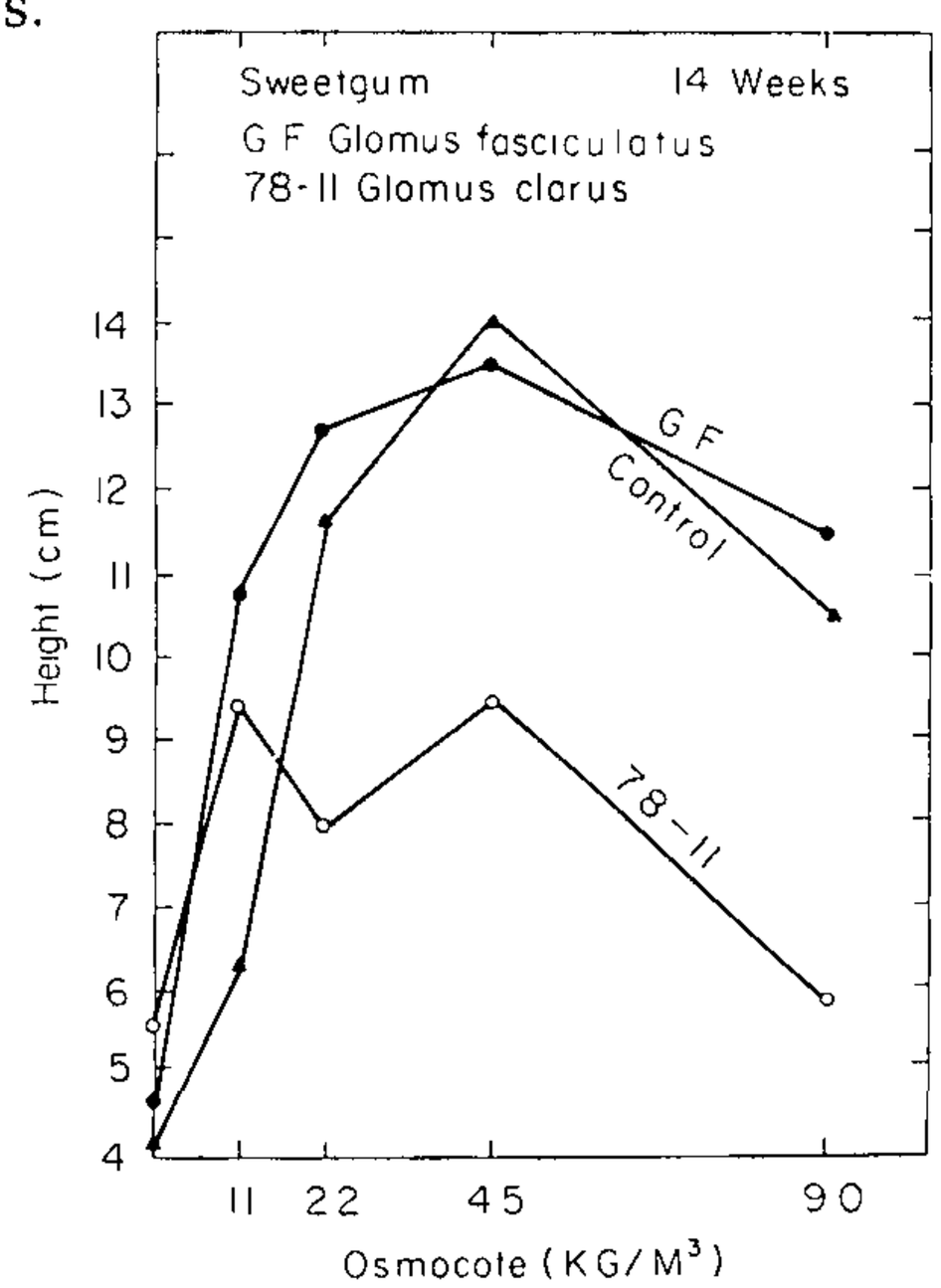

Figure 1. The effect of selected rates of 18N-2 6P-10K Osmocote and the endomycorrhizal fungi *Glomus fasciculatus* and *G. clarus* on growth of container grown sweetgum seedlings (*Liquidambar styraciflua* after 14 weeks)

Table 1. The effect of ectomycorrhizal fungus *Pisolithus tinctorius* on growth of shortleaf pine (*Pinus echinata*) seedlings after 9 months [z]

	Height	Caliper	Percent Mycorrhizae
Noninoculated control	39 6 cm	9 1 mm	0
Inoculated	32 0*	7 3**	78**

[z] All plant were fertilized with 4 5 Kg/M³ of 18N-2 6P-10K Osmocote (8 to 9 month release rate) at time of planting Means of 80 trees. Means significantly different statistically at P = 0 05 (*) or P = 0 01 (**)

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DON SHADOW: I had a problem growing b&b *Fagus sylvatica* from the West Coast. I went to our local stands of *F. grandiflora* and dug soil from under them and put it under the *F. sylvatica*. It seemed to solve the problem. Do you have any comments?

DALE MARONEK. That has been a standard practice for a lot of people *Fagus* is an ectomycorrhizal plant and it has a requirement under certain propagation systems for a mycorrhizal association

JACK DOMIN: Would you care to comment on the cost involved in inoculating on a nursery scale?

DALE MARONEK· It is feasible In fact, there are a number of nurseries in the U.S. that are inoculating their beds. There is a commercial source of mycorrhizal inoculum for sale. It sells for $16 per liter but you have to purchase 50 liters. They estimate that 50 liters will inoculate 50,000 conifer seedlings in seed beds. There are several commercial inoculators that are being utilized in commercial forest tree seedling production.

PETER VERMEULEN: Dale, could you discuss the interactions of soil sterilants with mycorrhizal fungi?

DALE MARONEK They all take their toll on mycorrhizal fungi. In some cases you can get resistance to a degree. May not destroy but can really knock it down.

ROOTING COMPOUNDS AND THEIR USE IN PLANT PROPAGATION

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A review of the pertinent literature shows that numerous chemical compounds have been tested for root-promoting activity. It is estimated that well over 10,000 chemicals show positive formative effects (17). The essence of chemical plant propagation began in 1934 with the discovery of a naturally occurring auxin, indole-3-acetic acid (IAA) (15). The demonstration that two synthetic (do not occur in higher plants) auxins, indole-3-butyric acid (IBA) and naphthaleneacetic acid (NAA), induce a greater rooting response was shown by Zimmerman and Wilcoxon in 1935 (21). In 1937, Zimmerman and Hitchcock published a paper (20) showing the comparative effectiveness of the acids, esters and salts of IAA, IBA and NAA in rooting cuttings and other growth responses. The essence of their work is described throughout this paper. I heartily recommend that nurserymen secure copies of these papers for their files.

Modern plant propagation revolves around the use of IBA, NAA, and their derivatives. Both 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP) have been used for rooting cuttings (16,18). They show potent root promoting activity but are readily translocated throughout the cutting and may delay bud break or induce other adverse effects. A nurseryman should experiment with these compounds rather than attempting wholesale use. At the recent International Plant Propagators' Society, Eastern Region, meeting in Orlando, Florida, I talked with a nurseryman who is using 2,4,5-TP in conjunction with IBA-talc to root junipers. He has had fantastic results with about 1200 to 1500 ppm 2,4,5-TP plus 0.8% IBA-talc. Both 2,4-D and 2,4,5-TP are potent weed killers, and extreme caution must be exercised when utilizing these compounds. Perhaps if IBA or NAA are not producing the desired results, then one might experiment.

Commercial preparations (3,8,19) that are/have been available to nurserymen are presented in Table 1. Many are no longer available, and the current crop of favorites includes Hormodin, Hormo-Root, Hormex, Rootone and Dip 'N Gro. The first four are talc (powder) formulations that contain IBA at various concentrations. The Hormodin 1, 2 and 3 formulations represent 0.1%, 0.3%, and 0.8% IBA or 1000, 3000 and 8000 ppm IBA, respectively. Hormo-Root A, B and C are similar in

IBA concentrations except B contains 0.4% IBA. Hormo-Root also contains 15% thiram. Rootone is offered in different talc formations, and the Rootone F contains 4.0% 1-naphthyleneacetamide and 4.0% thiram. Rootone 10 contains only 0.4% 1-naphthenacetamide. Dip 'N Gro is a liquid concentrate that is diluted according to the difficulty of the cuttings being rooted. It contains 1.0% IBA, 0.5% NAA and boron plus an organic solvent as the carrier. There may be other ingredients for it is described as possessing antibacterial and antifungal properties. Other commercial preparations that deserve a casual mention include Seradix, more or less the British equivalent of Hormodin, and Chloromone, a product containing chlorophyll extract derived from alfalfa and NAA. Jiffy Grow may no longer be available but did contain an interesting and apparently effective combination of 0.5% IBA, 0 5% NAA, 175 ppm boron, phenylmercuric acetate, and alcohol as the solvent.

Table 1. Commercial rooting preparations frequently encountered in plant propagation literature *

Auxan	Ree Root
Auxilan	Rhizopan
Chloromone**	Rootagen
Dip 'N Gro**	Rootone**
Hormex 1, 3, 8, 16, 30, 45**	Seradix
Hormodin 1, 2, 3**	Stim Root
Hormo-Root A, B, C**	Synergol (potassium salt of IBA and NAA in liquid formulation)
Hormovita	Wood's Rooting Compound
Jiffy Grow	
Proliferol	

* This list is not exhaustive
** Preparations that are commonly used in the United States

Wood's Rooting Compound is relatively new on the market and has received an EPA label. It contains 10,000 ppm IBA, 5000 ppm NAA and 20% dimethyl formamide as a carrier. The other 80% is ethyl alcohol. It is diluted (1:5, 1:10, etc.) like Dip 'N Grow to approximate the difficulty of the cutting being rooted. One propagator has indicated that it is better than straight IBA on certain plants.

The essence of all the commercial preparations centers around IBA, NAA, and their derivatives. IAA, although naturally occurring, is seldom used as a rooting compound because it is broken down by a naturally occurring enzyme (IAA oxidase) system, is destroyed by light and a bacterium, *Acetobacter* sp., that is widely distributed. This same organism has no effect on IBA or NAA. IBA can be adversely affected by exposure to strong light, but the effect is minimal. NAA seems to be entirely light stable. It should be mentioned that when pure chemicals are purchased the label prescribes storing IBA at 32 to 41°F, IAA at 32°F and NAA at room temperature which

serves as an indication of their relative heat stability. The pure chemicals of IBA and IAA usually come in a brown bottle which offers light protection.

A most confusing aspect of IBA and NAA is their designation in chemical catalogs and the literature as α, β or δ forms. I always questioned what difference the form made but in searching the literature came upon the paper by Zimmerman and Hitchcock that answered the question In short, the δ form of IBA is the most effective while the α form of NAA is 100 times more effective than the β form in promoting rooting of cuttings. There is a significant cost difference with the β form of NAA selling for 10 times as much as the α form. As a rule, IBA offers much more latitude than NAA for rooting cuttings. Cuttings of a particular species or cultivar will root over a wide range of IBA concentrations. I know of one large nursery firm that utilizes NAA exclusively for cutting propagation. When a nurseryman compares the cost of NAA to IBA, there is good reason to at least run comparative effectiveness studies between the two chemicals. Combinations of IBA and NAA are often used; the idea being to derive the best effects of both in a single treatment. The literature is full of testimonials to the combination, but there are as many studies that show no superiority of the combination over IBA alone. Mrs. Sue Burd Brogden, one of my former graduate students, conducted an extensive study on rooting cuttings of selected crabapples, 'Bradford' pear, serviceberry, paper birch and silverbell. The cuttings were sampled from May to August and treated with IBA, NAA, or a combination by the concentrated dip method at rates of 0, 2,500, 10,000, 20,000 and 30,000 ppm.

The results showed that·

(1) There were inherent differences among the crabapple taxa as to their degree of rooting.

(2) The earliest sampling date and the lowest concentrations of IBA (2,500 and 10,000 ppm) proved the most effective for rooting crabapples, although there was wide variance in rooting depending on timing, hormone and concentration.

(3) *Amelanchier arborea* and *Betula papyrifera* rooted in low percentages throughout the season although other investigators have had good success with *Amelanchier* spp.

(4) *Halesia carolina* rooted successfully on all four collection dates at low IBA and NAA levels (2,500 and 10,000 ppm).

(5) Cuttings treated with IBA showed greater rooting percentages, numbers and lengths compared to NAA and the combination-treated cuttings.

(6) There was no relationship between callus formation and rooting percentage.

(7) Cuttings which did not receive a hormonal treatment (control) showed limited rooting.

(8) The two highest concentrations (20,000 and 30,000 ppm) often resulted in defoliation or death of the cutting.

(9) Successful transplanting of rooted cuttings is strongly related to root numbers and length. Percentage should not be the sole parameter for evaluating rooting performance

(10) Percentage, root number and length offered valid indices of rooting quality. Callus formation bore no relationship to rooting and should not be used as an index.

Many nurserymen use the concentrated quick dip method. This involves dissolving the acid form of IBA or NAA in an organic solvent. IBA is soluble in ethanol while NAA is soluble at the ratio of 1 to 30 parts alcohol. This presents no problem to the nurseryman for it is doubtful he would need to exceed the solubility limits of NAA. The standard solvent is usually a 50% alcohol/water mixture, but any concentration is acceptable as long as the pure chemical dissolves Isopropyl alcohol is a suitable solvent and is available from the pharmacist. Polyethylene glycol (Carbowax) is frequently used as a solvent and carrier. DMSO, dimethyl sulfoxide, is also used; but care should be exercised. It penetrates skin as well as cuttings, and rubber gloves should be worn The basis for utilizing DMSO is that it "carries" the IBA into the tissue and, therefore, elicits a more uniform and possibly rapid rooting response. In humans, it causes bad breath, something approximating garlic.

A nurseryman can make his own concentrated IBA solution by dissolving ¼ level teaspoon of pure crystals in 3⅓ fluid ounces of 50% alcohol (5). This results in a 4000 ppm IBA solution which is suitable for a great number of woody plants. A full level teaspoon in the same volume results in a 16,000 ppm IBA solution A concentrated solution can be easily diluted to give varying strengths. It is difficult to do the same with a talc preparation because of the mess involved. See Machen (9) for a good discussion of mixing rooting substances.

In addition to the pure acids, various salts of these acids have been formulated and are available (Table 2). They are sold as the potassium or sodium salt. Their cost is comparable and perhaps slightly cheaper than the acids. The advantages are their free solubility in water yet similar effectiveness and stability (20) I recommend that nurserymen who are not interested in worrying with the acid and an alcohol solvent buy the salt. As a rule, the salts are less toxic to the cuttings than the acids.

Table 2. Suppliers of IBA, NAA and their derivatives.

Supplier	Address
Aldrich Chemical Co	940 West Saint Paul Avenue Milwaukee, WI 53233 414-273-3850
Baker, J T Chemical Co	222 Red School Lane Phillipsburg, NJ 08865 201-859-5411
ICN Pharmaceuticals, Inc K&K Labs Division	121 Express Street Plainview, NY 11803 516-433-6262
Pfaltz and Bauer, Inc	375 Fairfield Avenue Stamford, CT 06902 203-357-8700
Sigma Chemical Co.	P O Box 14508 Saint Louis, MO 63178 800-325-3010
United States Biochemical Corporation	P O Box 22400 Cleveland, OH 44122 800-321-9322

The cost of IBA and NAA from 3 suppliers is presented in Table 3. It is worth noting that the differences in price are significant.

A great controversy rages as to the relative effectiveness of talc formulations compared to quick dips (2,4,6,10,12,13,14). I prefer quick dips and use them in all my work. There is ample evidence to indicate the superiority of the quick dip over the powders. Meahl and Lanphear (11) reported that a quick dip was equal or superior to powder in the promotion of rooting. They also noted that, on an equivalent basis, 0.8% IBA powder was not as good as 0.8% IBA solution. Approximately 1500 cuttings can be treated with an ounce of the quick dip solution Supposedly, one pound of the powder treats 35,000 cuttings. My guess is that with the waste involved with powders something like 25,000 cuttings could be treated. This would approximate the number that could be treated with 16 ounces of a quick dip. Never return the powder to the can or the solution to the stock bottle. Use a small vessel for the powder or the solution. Never stick the cuttings in the original talc can or in the stock solution.

Table 3. Cost of IBA, NAA, and naphthaleneacetamide from the chemical supply companies

	Price per 5 grams		
Supplier	IBA	NAA	Naphthaleneacetamide
1	9 25	0 50	1 50
2	6 25	0 43	
3	10 20	1 30	

The general superiority of quick dips is probably related

to the uniformity of coverage and perhaps the more rapid absorption of IBA. It is reasonable to assume that IBA or NAA in solution will be more rapidly absorbed by the cutting than that applied in a powder form which has to be solubilized.

The question has been raised many times as to how the 5-second dip became standard. Earlier work (11) showed that a 5-second dip was as effective as a 160-second dip in promoting rooting. A 320-second dip decreased rooting. It was determined that the decrease was caused by the 50% alcohol and not the IBA. This may be one of the few occasions when "haste does not make waste". It should be mentioned that extremely concentrated quick dips of 20,000 to 40,000 ppm IBA or NAA will often "burn" the base of the cutting. Rooting may occur in the untreated region just above the "burn".

Another technique that has been used is a dilute IBA or NAA solution and a longer soaking period. The solution may range from 20 to 200 ppm and the soak period from 6 to 24 hours. This technique appears to be effective but involves a time lag that is not inherent in the quick dip method. Howard (7) reported that similar levels of rooting were obtained with dipping times of 5000 ppm IBA for 5 seconds, 500 ppm for 30 seconds, and 50 ppm 18 minutes. The need for 24-hour soaks in aqueous solutions is due to the low solubility of IBA in water. Howard has also shown that best rooting occurred when cuttings were dipped as shallow as possible. Most nurserymen dip the cutting about one inch, and this is perfectly acceptable

Recently, a report (1) has surfaced relative to the "Willow Rooting Substance". Dr. Max Kawase, The Ohio State University, has shown that willow extracts, in combination with IBA, show synergistic properties. Yellow birch, *Betula alleghenien-sis*, was rooted from cuttings by using the willow extract and IBA. IBA alone did not work Dr. Kawase is attempting to identify the chemical constituents of the willow extract. He mentioned that it was quite stable, has been refrigerated for six years and still retained its effectiveness. Apparently, most willow species will work with equal effectiveness. Current year stems (leaves removed) are cut into small pieces, packed into a container, and covered with water. This mixture is allowed to steep for 24 hours and is then drained off The resultant extract is used to treat the cuttings. Cuttings should be placed upright into the willow extract and allowed to absorb for 24 hours and then stuck.

Many commercial rooting products, some promising fantastic results, have come and gone since the 1940's The essence of their effectiveness, no matter how sophisticated the

name, is based on IBA, NAA and their derivatives. Perhaps some new chemicals will make in-roads into modern cutting propagation, but only time will tell. Since 1935, IBA and NAA have proven to be two of the plant propagator's most valuable tools

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Tuesday Afternoon, December 8, 1981

The afternoon session was convened at 1.30 p.m with Rick Allred serving as moderator

EFFICIENCY IN PROPAGATION

BLAIR MASTBAUM
Scarff's Nursery, Inc.
New Carlisle, Ohio 45344

Labor costs in America have steadily increased while worker productivity has in many cases declined. The survival of our businesses depends largely on our ability to increase efficiency Labor costs comprise approximately 60% of my total budget Coupled with decreasing worker productivity I feel this is the first and most logical place to work on becoming more efficient

We begin by taking an unbiased look at our operation. Are the facilities efficient? Is everyone producing an equal amount and is the amount enough? Assuming the facilities and procedures are efficient and the goals are in order then the area to concentrate on is labor efficiency. What amount of production can we reasonably expect from our workers? I think one answer lies in the use of production standards. A production

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standard is a tool used to measure the performance of a worker against premeasured production expectancies

Production standards help us not only in gauging the productivity of employees but in many other ways as well.

We can utilize standards in planning a day's activities thereby using labor effectively Standards can be used to plan labor costs for a yearly budget. By knowing what we can expect in terms of output we can accurately design our budget to accommodate the amount of production we anticipate. Standards also provide a gauge for determining where we are in our schedule

Production standards are invaluable in personnel relations. Employees want and need to know what is expected of them. By setting standards we set attainable goals for them to accomplish.

Standards initiate a healthy competition between crew members. Knowing their performance can be accurately and individually evaluated, the workers tend to try harder The use of standards thus eliminated the worker who previously got by by putting on a show of work whenever the boss was around This type of worker is extremely detrimental to a good crew. The crew sees this person as someone who shares the reward for their good work and the undermining cause for poor results. We can determine who is or is not suited for particular jobs One person may excel in taking cuttings, a fast repetitive activity, and be a complete failure at watering, a slower type activity.

The use of production standards also helps top management in evaluating supervisors. Top management can pinpoint production expectancies against schedules. This enables management to evaluate a supervisor's performance accurately and fairly.

Probably the most important aspect of using standards is increased productivity. This is what we aim for in instituting a system of standards. The other benefits we achieve by using standards might be termed bonus benefits.

With all the positive things I've said about using standards I must be fair and list a few negative aspects. The employee working to accomplish standards puts more emphasis on quantity rather than quality. This promotes a need for quality control. Perhaps this aspect isn't entirely negative. Quality control is something many of us have shelved years ago when we could sell anything and everything we produced regardless of quality Our business today is in greater competition for the consumer dollar. They expect and deserve a quality product from us.

To effectively use standards we need to accurately record performance. Keeping records takes time and time costs money. However, if this is done in an efficient manner the benefits outweigh the liabilities

The most serious problem with using standards can be the lack of nurserywide participation. The obvious problem is with those people working with standards tending to feel they work harder than those people who are not working with standards. This type of problem should be handled as a matter of departmental pride The point to stress is the department produces because the people are proud of their accomplishments regardless of what is or isn't expected of other departments.

There are many methods of setting production standards. The most effective way for me is to evaluate production records and use this as a starting point I then examine the procedure or actual mechanics of a job, much like time and motion studies. Once satisfied the procedure is correct, actual timing is made of several workers, often including myself. All this information is then reexamined and a standard is set.

The standard is never static, it is always subject to change. Standards can and should be revised from time to time. Reasons for this could be changing working conditions, employee suggestion or improved methods.

Table 1. Some examples of our propagation standards

Cuttings	Man-hours
Summer Cuttings	
Cutting	*600-1200
Preparation	*300-1500
Sticking	*600-1500
Evergreen Cuttings	
Cutting	*700-1400
Preparation	*250-1400
Sticking	*500-1400
Peat Potting Rooted Cuttings	
3" pot	125
2¼" pot	190
Pre-filling Containers	
2 gallon	150
3 gallon	125
Potting B/R	
2 gallon	95
3 gallon	63
5 gallon	40

*Depending on plant cultivar, difficulty in removing, preparing, and/or sticking the cutting

Our standard for peat potting rooted cuttings was revised twice in one week because of an employee's suggestion Daily production was increased by 30%!

In closing I wish to point out that production standards alone are not going to increase productivity The key to productivity is effective personnel management. To be effective we need to practice some very sound principles of personnel relations The people we employ are individuals who have different needs for work Their needs vary with different situations. We must be sensitive to their needs and adapt our management techniques accordingly As managers, we should treat our workers the way we would like to be treated. We need to encourage interest in the job Be receptive to their ideas. Encourage them to do their best Give praise for a job well done. Stand behind these people.

Practice these principles and you will create an atmosphere of good moral, positive attitudes and increased productivity.

PETER VERMEULEN. Do you have problems when you find your standard is too low and you try to raise it? Also have you compared your standards with piece rate?

BLAIR MASTBAUM: Yes, it can be a problem to increase standards. The direct supervisor needs to have a good relationship with his people and be open with his workers He needs to point out to them that if they are achieving above the set standards that there is no need to object because they are doing it already We time at 100% efficiency but expect only about 85%

In regard to your piece rate question, I should point out that I have a factory background and think it is a good idea. I have not, however, been able to initiate a plan when we work with crews producing 12-15,000 units per day and the great amount of interaction that occurs between different jobs. We are working on group standards.

THE PASSIVE SOLAR PROPAGATION STRUCTURE

ARTHUR J OSLACH
Ziraldo Farms and Nurseries, Inc
R.R 1, Simcoe
Ontario, Canada N3Y 4J9

The passive solar principle in greenhouse construction is to utilize solar energy in its most economical and efficient

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THE PASSIVE SOLAR PROPAGATION STRUCTURE

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The passive solar principle in greenhouse construction is to utilize solar energy in its most economical and efficient

form. The basic concept that we used had to be:

1. Of simple construction,
2 Economically feasible for commercial greenhouse production,
3 Reliable and efficient.

Therefore, a system was developed that employed a solar collector, a water storage system, and a simple form of passive energy transport. This system, when compared to an active solar system, is very inexpensive to construct and requires very little maintenance.

CONSTRUCTION DETAILS AND PRINCIPLES

1. The greenhouse is designed and built to become the complete solar collector.
   a The structure is 100 feet long and 13.6 feet wide.
   b. The whole structure is 32 inches in ground. The foundation consists of 8 inch cement blocks on a 12 inch footing. A complete system of drainage tiles inside and out removes excess water to a sump.
   c. The gable ends and north wall are fully insulated and consist of two-by-four construction, fiberglas insulation, vapour barrier, interior ¼" plywood and exterior KB board with white masonite siding.
   d. The acrylic skin of the greenhouse is S.D.P. clear plexiglass (an insulated plexiglass). The S.D.P. plexiglass is sandwiched between the 1 × 6 inch bar cap and the 2 × 6 inch cedar rafters with polybutyl sealant. A ¼ inch space is allowed on either side of the 4 × 15 feet sheets of plexiglass for expansion during hot weather. The acrylic skin is all south orientated at a 40° angle for optimum solar absorption.
   e The height of the structure is 9 feet, 6 inches above grade and 12 feet, 8 inches from floor to roof inside.
   f. Al' interior walls are painted a flat black.
2 The storage system
   a. Two hundred 25 gallon steel barrels of water (5000 gal. of water total) are located below grade and enclosed in two cement and steel greenhouse benches with plastic drapes on each side for heat retention. The 25 gallon barrels are very reasonable to purchase and can be easily replaced as needed
   b. The passive transport system consists of five thermo generators located in the peak of the house. These generators

pump hot air down and around the barrels during the daytime, thus raising the water temperature in these barrels. During the night colder air is pumped down around the barrels and this forces heat from the barrels up to heat the greenhouse.

c. A row of barrels lies between the north wall and bench. These absorb solar radiation directly.

TEMPERATURE ZONES IN RELATION TO PLANT GROWTH

During cloud-free days the 40° angle of the solar collector will raise the interior temperature very rapidly to extremes. The construction is such that these extremes are located in the peak and, as one proceeds downward, temperature becomes progressively lower until an optimum plant growth temperature is found at approximately grade level. The plant benches with their growing media are located at this level Temperature at this level will vary only ±5° of 70°F at any one time.

We used a thermograph to monitor temperature at the seven foot level and you will note extreme temperature variation at that level, but not in the plant growth area The thermograph could not be lowered last winter because of the very humid conditions at plant growth level. This is due to our automatic misting system, which is located just above the plant growth area. The greenhouse being a propagation structure requires a bench medium temperature of approximately 70°F and an air temperature from 55 to 75°F These temperatures were easily achieved with the result of an excellent crop of evergreen cuttings, grafts and other liners being produced.

Approximately 35,000 liners were produced in the structure over the 1980-81 winter. This covered about 150 species and cultivars of plant material. This production was achieved with a minimum of energy expense when compared to a conventional glass or polyhouse.

SUPPLEMENT HEATING SYSTEM

A back up system was installed consisting of an oil-fired boiler and radiators running under the benches on either side of the barrels. A thermocouple located in the medium half way down a bench regulated the boiler performance. The boiler was operated from the first of December, 1980 to the first of April, 1981, with an expenditure of approximately $748.00. Some of our coldest days and nights in several years occurred during the latter part of December and early January. During this period, it was not uncommon to record peak temperatures of over 100°F.

MODIFICATIONS OF STRUCTURE

The greenhouse structure could be extended to 20 feet wide by making the roof wider. This would accommodate three growing benches, more water storage barrels and, therefore, more strato-therms The increase in total volume of the greenhouse would store more heat from the collectors and therefore the greenhouse should become more efficient than it is now.

Table 1. Construction costs for the solar greenhouse

S D P covering	$ 4,335 00
Putty	120 00
Cement blocks, 8″	516 00
Cement bench bottoms	400 00
Steel benches	498 00
5 Strato therms	300 00
Fan	298 00
Lights, wiring, sump, etc	216 00
Excavation of footings and hole	120 00
5 yds of concrete, mason cement and sand	250 00
Lumber for construction	1,600 00
Labour for construction	2,500 00
Total Greenhouse Cost	$11,153.00

SUPPLEMENTAL MODIFIED NEARING FRAME AND LATH HOUSE

The north wall of the greenhouse, being a solid wall with white siding, allowed the construction of a modified Nearing frame against this wall. The frame is 18 inches in the ground and 96 feet long by 6 feet wide with redwood sash as a covering. The area immediately adjacent to the greenhouse north wall is totally covered by a 50 × 100 foot lath house. This provides a modification in climate which provides the necessary environment for the culture of small cuttings, seedlings and grafts. The lathhouse also covers the Nearing frame and therefore provides an excellent propagating area for summer and winter rooting of cuttings. This frame is automatically misted all summer.

By using the Nearing frame to root the species that will root cold (no energy expense), either during the summer or winter, we increase our total production by about 10,000 cuttings per year. Under conventional means these species would be rooted with bottom heat in a greenhouse over winter. Therefore, the Nearing frame becomes an intricate part of our total greenhouse system. Windows located in the north wall of the greenhouse provide ventilation in spring and summer and also provide an easy method in which the greenhouse can be emptied of its plant material. The use of rollers and green-

house flats can be employed here reducing labour considerably. The plant material can then be planted directly into the lathhouse beds or held in flats under the lath for future planting. Overhead watering in the lathhouse provides the necessary modification of environment during the handing-off process

PLANT MATERIAL PRODUCED AND THE PROBLEMS INCURRED

The operation of the structure went very smoothly over the winter of 1980-81. To test its complete propagation feasibilities, a complete cross section of plant materials was placed in the structure. Table 2 lists some of the cultivars produced in this greenhouse during the 1980-81 season.

Table 2. Partial list of plant material propagated in the passive solar propagating structure

GRAFTS	
Acer palmatum	'Crimson Queen'
Cornus florida	'White Cloud'
Juniperus chinensis	'Mountbatten'
Juniperus chinensis	'Pyramidalis'
Juniperus chinensis	'Spartan'
Juniperus procumbens	'Nana'
Juniperus scopulorum	'Blue Heaven'
Juniperus scopulorum	'Gray Gleam'
Juniperus scopulorum	'Hill's Silver'
Juniperus scopulorum	'Wichita Blue'
Juniperus virginiana	'Skyrocket'
Juniperus virginiana	'Springbank'
Picea abies	'Echiniformis'
Picea abies	'Inversa'
Picea abies	'Maxwellii'
Picea abies	'Pendula'
Picea bicolour	'Tigers tail'
Picea omorika	'Nana'
Picea omorika	'Pendula'
Picea pungens	'Globosa'
Picea pungens	'Hoopsii'
Pinus densiflora	'Pygmaea'
Pinus flexilis	'Glauca'
Pinus parviflora	'Megishi'
Psuedotsuga menziesii	'Pendula'
CUTTINGS	
Juniperus chinensis	'Gold Coast'
Juniperus chinensis	'Mint Julep'
Juniperus chinensis	'San Jose'
Juniperus chinensis	'Sea Green'
Juniperus chinensis	'Pfitzeriana Compacta'
Juniperus communis	'Suecica Majour'
Juniperus horizontalis	'Glauca'
Juniperus horizontalis	'Hughes'
Juniperus horizontalis	'Jade Spreader'
Juniperus horizontalis	'Plumosa'

Juniperus horizontalis	'Wiltonii'
Juniperus chinensis	'Hetzii' *for understock*
Juniperus sabina	'Broadmoore'
Juniperus sabina	'Buffalo'
Juniperus sabina	'Hicksii'
Juniperus scopulorum	'Table Top Blue'
Juniperus squamata	'Meyeri'
Rhododendron	25 cultivars
Platycladus orientalis	'Raffles'
Thuja occidentalis	'Ellwangerana Aurea'
Thuja occidentalis	'Holmstrup'
Thuja occidentalis	'Lutea Nana'
Thuja occidentalis	'Nigra'
Thuja occidentalis	'Pendula'
Thuja occidentalis	'Techny'

MISCELLANEOUS

Buxus cultivars
Chamaeyparis lawsoniana 'Ellwoodii'
Chamaeyparis nootkatensis 'Aurea'
Chamaeyparis obtusa 'Nana Gracilis'
Crytomeria japonica 'Pygmea'
Euonymus cultivars
Ilex cultivars
Prunus 'St Julien X' (softwood)
Taxus cuspidata 'Brownii'
Taxus cuspidata var *nana*
Vitis cultivars (softwood)

The structure proved to be too efficient during the latter part of February and March, with excessive sunlight and high interior temperatures, especially against the back wall of the house. Here we tried rooting cuttings in flats on top of the water barrels which are against the back wall; this proved only about 50% reliable because:

1. Our flats were too shallow,
2. Increase amount of water need, due to high sunlight,
3 Inaccessibility (24 inches higher than the benches).

Shading had to be applied over one half of the lower section of the house and ventilation had to be provided daily during this period. We experienced some burning on new grafts with the open bench method of callusing but none with the polytent method. All cutting material rooted quite well with the exception of some very slow to root cultivars such as *Chamaecyparis obtusa* 'Nana Gracilis', *Thuja occidentalis* 'Pendula' and *Crytomeria*. Grafts were within the range of 90% for most cultivars while others ranged from 25% to 50%. Excessive sunlight during the callusing period is a problem with this structure and we hope to experiment more with this problem this winter by using several different callusing areas within the greenhouse. This way we should find an optimum area for our callusing procedure. After the structure was emptied

about May 10, 1981, 100,000 grapevine grafts were placed in the house for callusing (callusing boxes). Here excessive temperatures played an important part in the callusing procedure. Callusing temperatures must be maintained at 86°F. (or 30°C.) day and night over a period of 3 to 4 days or until the interior of all the callusing boxes reaches the above temperatures This was accomplished by completely sealing the greenhouse for 3 days and then ventilating on the 4th day to lower the interior temperature gradually to 72°F. More shading had to be applied during this period for fear of burning the new developing vine growths

CONCLUSIONS

The structure overall proved to be very efficient for propagation. A few problems have to be worked out but these are minor when compared to the amount of fuel savings over the year. According to last winter's fuel savings, we estimate that the structure will pay for itself in fuel savings alone in about four years.

JACK ALEXANDER: Could you give us heating cost figures?

ARTHUR OSLACH. It costs us $758 in back-up fuel for last year. This same boiler was in a similar nonsolar glass structure 3 years ago and it cost $4,000 to operate. December and January are the worst months.

DAVE EMMONS. Why not use double poly which is cheaper?

ARTHUR OSLACH: I wanted something that was more permanent for propagation and also had a high R-factor to it.

EXPERIENCES IN BREEDING AZALEAS AND RHODODENDRONS

DAVID G. LEACH

1894 Hubbard Rd.
North Madison, Ohio 44057

My goal in breeding ornamental plants has been to produce hybrids which can make it commercially Some hybridizers make crosses for their own satisfaction; some do it as a joint activity with other hobbyists. But mine is a full-time occupation and I have hoped to produce new rhododendrons for very cold climates that would be profitable for commercial growers and present no problems in production. The records

about May 10, 1981, 100,000 grapevine grafts were placed in the house for callusing (callusing boxes). Here excessive temperatures played an important part in the callusing procedure. Callusing temperatures must be maintained at 86°F. (or 30°C.) day and night over a period of 3 to 4 days or until the interior of all the callusing boxes reaches the above temperatures This was accomplished by completely sealing the greenhouse for 3 days and then ventilating on the 4th day to lower the interior temperature gradually to 72°F. More shading had to be applied during this period for fear of burning the new developing vine growths

CONCLUSIONS

The structure overall proved to be very efficient for propagation. A few problems have to be worked out but these are minor when compared to the amount of fuel savings over the year. According to last winter's fuel savings, we estimate that the structure will pay for itself in fuel savings alone in about four years.

JACK ALEXANDER: Could you give us heating cost figures?

ARTHUR OSLACH. It costs us $758 in back-up fuel for last year. This same boiler was in a similar nonsolar glass structure 3 years ago and it cost $4,000 to operate. December and January are the worst months.

DAVE EMMONS. Why not use double poly which is cheaper?

ARTHUR OSLACH: I wanted something that was more permanent for propagation and also had a high R-factor to it.

EXPERIENCES IN BREEDING AZALEAS AND RHODODENDRONS

DAVID G. LEACH

1894 Hubbard Rd.
North Madison, Ohio 44057

My goal in breeding ornamental plants has been to produce hybrids which can make it commercially Some hybridizers make crosses for their own satisfaction; some do it as a joint activity with other hobbyists. But mine is a full-time occupation and I have hoped to produce new rhododendrons for very cold climates that would be profitable for commercial growers and present no problems in production. The records

show that the most cold-hardy rhododendrons are also usually the most heat-tolerant, so I am always hoping that some of my hybrids will be equally useful in the south, and some of them have proved to be so.

The rhododendron cultivar 'Roseum Elegans' is still the best seller in the northeastern United States. It was introduced in England by Anthony Waterer some time before 1851. It's a dirty magenta-pink and it grows far too large for contemporary houses and gardens. But it's hardy and it roots easily. It's one of the group of so-called "ironclads" which means that it can be grown just about anywhere that rhododendrons can be grown at all in cold climates.

My cultivar 'Spring Frolic' by contrast is a pale pink with almost exactly the same dense growth habit as 'Roseum Elegans' It bloomed after 28 degrees below zero in 1963 in the mountains of western Pennsylvania, and again in 1977 after the coldest winter the Cleveland Weather Bureau has recorded in 102 years. 'Spring Frolic' also roots very easily. It, however, won't quickly outgrow a single story house or a small garden. It makes up fast enough as a small plant to be commercially practical, but a 30 year old specimen I have is less than 6 feet tall It blooms at an earlier and better season than 'Roseum Elegans'. An array of deeper pinks with pretty much the same characteristics as 'Roseum Elegans' is available that blooms both earlier and later.

The second best seller in the cold northeast is probably 'Nova Zembla'; this was introduced in 1902 in Holland by Koster's, so it's only been on the market 80 years. Keep in mind now, if you will, that we're talking this afternoon about the hardiest category of ornamental shrubs. These rhododendrons are more bud hardy than forsythia. They're almost as hardy as lilacs. In the case of 'Nova Zembla', the color is badly flawed by blue; the plant will swamp a single story house in 15 years; and it blooms at the end of May with 99% of the other rhododendrons now in commerce.

'Sumatra' is an alternative that, in my judgement, is much better suited to the ending years of the 20th century It's a clear scarlet; it's such a dense grower that it would be a good evergreen if it never bloomed; it matures at about 3 feet, so it's an ideal foundation plant; and it blooms two weeks earlier than the hybrids now in commerce. This one, however, will always have to bring a price premium. You can't get this super-dense, twiggy growth along with the production of an 18- to 24-inch budded plant from a rooted cutting in two years. However, these dwarf scarlets have never before been available in hardy form for cold climates, and the tender counter-

parts have sold well in the mild climates of the west coast and England

Incidentally, if you're wondering how I got the dwarfness and the clear scarlet color into 'Sumatra', it came from *R. forrestii*, which was introduced from the mountains of Yunnan Province in China by George Forrest. It took 2 generations and 20 years to produce 'Sumatra', but it was worth it.

The standard white in commerce was introduced about the time of the Civil War under the Latin sounding name of 'Catawbiense Album ' It's a pretty good rhododendron, but it's not the easiest to propagate, as a young plant it is a bit slow, both in budding and in growth, and as an old plant it reaches a height of 15 feet with no trouble at all It's a good cemetery plant because it blooms right on the button at Memorial Day, or it would be a good hybrid for the purpose if it didn't grow so large

'Finlandia', however, roots like a weed, is a cleaner white, grows half the size, has a finer foliage texture, and lasts much longer in bloom because of its heavy flower substance. It's also guaranteed to be just as hardy as the 130-year-old 'Catawbiense Album.' which means that it's satisfactory in a Zone 5a climate Some of you from the relatively mild East Coast are familiar v ith the Dexter and with the Gable hybrid rhododendrons Both the Dexter and the Gable hybrids were produced in a zone 7a climate, 20° warmer in winter than the new hybrids. Their breeders didn't claim them to be, and didn't intend them to be, suitable for colder parts of the Northeast.

But there are myriad traps for the hybridizer aiming at widespread commercial distribution, and you may be interested in knowing a few of the sorts that may not be so obvious

One of my most attractive earlier hybrids was named 'Limelight'. It was one of those rhododendrons with style, a crisp flower outline, an attractive pale yellow truss and it was bud hardy to at least 20° below zero. The original plant was normal in vigor. But with some hybrids there is a difference between the selected seedling and plants propagated from it by rooted cuttings.

Propagated plants of 'Limelight' failed to produce adequate root systems. At about 18 inches they developed enough wind resistance to rock back and forth in the ground. The result was that all propagated plants died at about 18 inches. This hybrid would have to be grafted to be a successful commercial rhododendron, and there aren't many volume wholesalers left who know how to graft even if it would be commercially practical

When 'Tahiti' came along, I was rather pleased with it. It was a unique color, it was a bud hardy to about −16°F; it had

good foliage, and visitors liked it After I released it to my introducers, it became apparent that it was worthless. It propagated routinely in a Nearing frame for me, but it dropped its leaves under glass with heat in the greenhouse, and failed completely.

Another which did exactly the same thing was 'Serenata' which at the time was a novelty hardy throughout the Northeast. I hoped it would be a test as to whether the public in the East would accept a flat-topped truss. By the first of the year the greenhouse propagator had a miniature forest of naked stems in the bench.

One of the oddest faults I encountered was with a hybrid called 'Virginia Leach' This was gratifyingly different for a hardy hybrid, and seemingly a winner in every way, until I waded out through snow one cold January day, and found every leaf on the propagated plants sticking straight up in the air like rabbit ears. The original seedling was the same way. The plants presented the appearance of brown skeletons. So this one had to be discarded.

It is generally true that like does tend to beget like, so it is well to avoid the known but hidden faults of potential parents. 'Mrs. Furnival' is usually regarded as hard to root by many west coast propagators Its progeny tend to be hard to root too. A 'Mrs. Furnival' hybrid that came through −28° in 1963 and bloomed well but absolutely refused to root at the usual propagating season by any method, but it rooted fine the first week in July. Nonetheless, few commercial growers are willing to deviate from their standard propagating procedures. A sure kiss of death for a new hybrid is any difficulty with propagation

'Spellbinder' is one of the most striking rhododendrons which have appeared among my hybrids. The trusses of silvery pink flowers are huge. 'Spellbinder' is hardy as an oak and it blooms extra early, right after *R. mucronulatum* But it has not one, but two faults as a commercial rhododendron. It's hard to root, but an equal handicap is that the leaves are so large the cuttings take up too much expensive space in a greenhouse propagating bench. It is a novel hybrid in every way for the Northeast, but unless tissue propagation overcomes its drawbacks, I think 'Spellbinder' will always be a hobbyists' hybrid.

Every breeder has endless offers from hobbyists to test his productions for him. The problem is that those making the proposition are often not competent growers or are otherwise unqualified to evaluate the rhododendron performance under their conditions. All the same, for gross defects which may

appear in dissimilar climates, enthusiasts can be quite helpful. Here is a case in point 'Vernus' distinguished itself in the only batch of small seedlings I have ever bought. They came from Tony Shammarello may years ago. It has done quite well in commerce, both in the Northeast and overseas, because it is ironclad hardy, and it blooms with the dogwoods and the daffodils. But it is virtually useless in the South, because it blooms partially in the fall, so that the remainder of the buds are frozen over winter Another unseen defect, which was not apparent when I named it is that it is not tolerant of the growing site. It must have sun to remain presentable; even in light shade it becomes lanky as it grows about five feet tall. Still, it is a useful and attractive shrub in the right situation.

The most bizarre and extreme example of out of season bloom occurred with a hybrid I called 'Athens'. It was a nice, rounded, semi-dwarf which bloomed very early every spring. Seven years ago, to my astonishment, it abruptly began blooming in the fall and scarcely at all in the spring, whereas it originally held the distinction of being the first of all the broadleaved hybrids to flower In 1974 it became the last, flowering in October, so I renamed it 'Last Hurrah'. One nurseryman is promoting it as a fall blooming plant, but the problem is that its performance will probably vary with the climate, so it may well be neither fish nor fowl in some regions I think this was pretty close to the ultimate in concealed faults of new hybrids

A rhododendron I like very much is 'Party Pink'. It is as hardy as any rhododendron that grows; it is exceptionally free flowering; vigorous yet dense and sturdily branched. However, this hybrid seems to over-respond to forcing fertilizer by becoming a tall, lanky container plant, especially in the south So we have another of the hidden faults that confound the breeder and irritate the introducer However, I figure this is one for which the breeder should be excused.

A delightful dwarf variegated leaf rhododendron represents yet another problem. The contrast between the green and the yellow parts of the leaves was emphatic, and the result was striking. The plant was moved to the open field and within two weeks the yellow parts of the leaves had browned or fallen away from sunburn, and there was a drastic decline in its health. This rhododendron was produced from a cross between two of my dwarf hybrids and it did seem promising not only to me but to visitors as well. If I had propagated it in the original ground bed and distributed it, the result would have been a total failure. The moral is always to grow some plants of a new hybrid with full field exposure before deciding its worth.

Some hybrids which are conspicuously handsome plants in the north are disfigured by leaf spots in the south and on the west coast An example is a pretty little dooryard shrub which came from a cross of *R. carolinianum* with *R. hanceanum var nanum. With too much exposure, or in humid* climates, the fresh green leaves so freely produced soon become rusty and unattractive. I have noticed that glossy leaved rhododendrons tend to do this In any event, it's still another of the hidden faults that plague the breeder.

It pays to think ahead about competition when making crosses To my mind, there is an exceptionally attractive little dooryard rhododendron which resulted from a cross of *R. keleticum* with *R carolinianum*. It is faultlessly evergreen the year around but it has the misfortune to bloom in the evergreen azalea season. Visiting commercial nurserymen often say that they can produce the same ornamental effect with an azalea in a third of the time at a third of the cost. So this will be, at best, a hobbyists' rhododendron if in fact it achieves any distribution at all.

We've been talking about the faults and the misfits that bedevil the rhododendron breeder. Let's turn to the positive progress that has been made.

'Malta' is an extremely early, scaly leaved hybrid which is mature at about 6 feet 'Malta' came from 'Pioneer', self-pollinated, but to my mind it is a great improvement over its parent. Being sexually incomplete, as you can see, it sets no seeds so it covers itself with flowers every year It is emphatically evergreen, whereas 'Pioneer' is deciduous as soon as it gets any size and its color is a clear pink with white intermingled, not the bluish pink of 'Pioneer'. It is a super-performer in the North, but like practically all scaly leaved hybrids, it loses its dense habit in the South.

Before we turn from these somewhat special scaly leaved rhododendrons, I'd like to mention a couple of dooryard hybrids. These are little 18- to 24-inch miniatures, hardy versions of a tender type that is popular in Europe.

'Tow Head' is the only one that has been named. I have perhaps a half dozen of these early flowering dooryard hybrids in various colors but I've never released any of them because there seems to be very little commercial interest in them. Hobbyists, however, are enthusiastic. To the best of my knowledge, 'Tow Head' is the first hybrid of *R. ludlowii*, a diminutive species from 14,000 feet in southeastern Tibet.

Turning now to the conventional large leaved rhododendrons, there have been no hardy yellows at all for cold climates But quite a lot of progress has been made. The precur-

sor is the same for both anthocyanin and yellow pigments, and there is not a limitless supply. In most of the Northeast we probably must accept the anthocyanin along with the hardiness requirement, and this means an automatic reduction in the precursor available to produce yellow.

The cultivar 'Nile' is a denser grower and altogether a better evergreen than most this color However, it's not by any means the deepest of the yellows.

'Good Hope' is my own favorite It's an exceptionally handsome shrub out of bloom as well as in, as it grows for me, but Ted Richardson and Ted Van Veen both tell me the foliage spots for them. So it will only be good for the Northeast. If it weren't for the complete absence of any yellow rhododendrons at all in cold climates, I would think it should be discontinued.

Perhaps I should qualify the absence of yellow rhododendrons just a little bit There is a British hybrid called 'Goldsworth Yellow' which will grow in the mildest climates as far north as Boston, but it's hardly yellow, and almost all specialists agree that it's not a good garden hybrid So, if you can call it competition, this is the only one in commerce for any part of the Northeast.

One of my own goals has been to try to produce hardy versions with the same decorative garden effects as are available from tender hybrids on the West Coast and in England We have no rhododendrons with bold blotches in the cold Northeast, but an as yet unnamed cultivar [('Mrs Furnival' × 'Catglas') × G.B.M. #66-2] provides a striking contrast.

Rhododendrons with orange flowers are unknown in the Northeast, so of course that is a strong incentive to produce them. The best I have today is a cultivar 'Poppinjay' a unique color.

ED MEZITT How are you doing with your *Rhododendron yakusimanum* crosses?

DAVID LEACH. I have only had one *R yakusimanum* cross that was worth anything the first generation The results have improved in the second generation and I am getting what I want in the third.

CARMINE RAGONESE· How do you propagate your rhododendrons?

DAVID LEACH I feel old fashioned to tell you. I still use an 18 hour soak with IBA at 150 to 400 ppm and root in a Nearing propagation frame It is quite satisfactory for the quantities I require

THE GENUS CLEMATIS, PAST AND PRESENT

RAYMOND J EVISON
Treasures of Tenbury Limited
Tenbury Wells
Worcestershire WR15 8HQ England

It is fairly unusual for a business to be set up around an entire genus Normally, a person who is interested in a specific genus will specialize in one section, especially if that person is a nurseryman — he will produce the best selling species or cultivars from that genus. If a person is a private collector then usually that person becomes a fanatic specialist If a botanist becomes involved in a genus, he too, specialises, usually, along a fairly narrow pathway

What I am about to describe to you is the way in which our company has collected many different clematis species and cultivars and the way in which a concept is being carried out: that concept is a mixture of the specialist collector, the plantsman, the nurseryman, and also with the businessman's view to making money What we have tried to do is combine all of these different angles the fascination of collecting, successful cultivation, and the mass production and modern selling techniques.

During the last 25 years, clematis species and cultivars have been collected from various parts of the world. Our company now holds the National Clematis Collection for the National Council for the Conservation of Plants and Gardens. This, of course, has opened up many doorways for the collection of old cultivars and obtaining more species that have been almost lost to cultivation in gardens. From the sales point of view, this gives us a most prestigious position.

Our retail sales are divided into two. specialist, unusual plants for the collector and keen plantsman, and the sales of the more popular species and cultivars for the gardeners who are looking for a plant to produce a mass of colour with a flowering period as prolonged as possible

With regard to the wholesale side of our business, we sell clematis liners to nurserymen who grow the plants on into a larger plant to their own specification; with additional sales of clematis that go direct to garden centres, where young plants are sold with a pictorial label. Specialist packs are also put together for supermarket sales in the UK and in Europe with special presentation cases. The final portion of our wholesale sales go to mail order companies in the UK and Germany.

With this outline of our clematis sales you will be able to see that the genus is sold to a wide range of customers, from

the specialist collector to the housewife who buys the clematis in a supermarket on an impulse sale.

I am now going on to describe some of the clematis species and cultivars that have been introduced into England from the sixteenth century and that have contributed greatly to the genus as it now stands; many of these species that were introduced in the eighteenth and nineteenth centuries are still very popular.

One of the first species to be introduced into the UK was *C. viticella* which is a European species producing its flowers on current years' growth. The flowers of *C. viticella*, vary in the wild from a mauve-pink through various shades until it reaches a deep, purple-blue. Queen Elizabeth I was known as the virgin queen and *C. viticella*, introduced during her reign, was known as the virgin's bower.

This species has given rise to many small flowered hybrids, which lend themselves to many uses in the modern garden.

We prefer to allow the *C. viticella* hybrids to scramble through low growing shrubs and they are particularly ideal for scrambling over winter flowering heathers. The winter flowering heathers are allowed to flower at the normal time; dead heads of the heather are removed after flowering, allowing the clematis to produce its growth from a plant which was pruned down the previous November. The clematis come into flower from the beginning of July and flower until mid-September, all clematis stems and top growth is then removed in November when each plant is pruned down to about 6-9 inches, to allow the heathers to flower freely.

Some of the better *C. viticella* cultivars are 'Venosa Violacea', which has a purple-veined flower on a white background; 'Etoile Violette', which is a rich purple; 'Abundance', which is a wine red; 'Minuet', which has a very attractive flower with deep, rosy-pink veins on a white background, 'Royal Velours', which is a velvet-purple, and one of the most fascinating of the *C viticella* group — 'Purpurea Plena Elegans' a cultivar raised over 90 years ago that has a very attractive double, mauve-purple flower.

Another European species to be introduced into gardens quite early was the species *C integrifolia*, which is herbaceous in habit. It's flowers range from pale to deep blue and there is also a very nice sugary-pink cultivar.

C. viticella and *C. integrifolia* were the parents of the first clematis hybrid to be raised. This cultivar was named *C.* × *eriostemon* 'Hendersonii' and was raised in the late 1830's, in London.

C. recta, another herbaceous species was introduced again from Europe. This produces long stems six feet in length with clouds of tiny white flowers — this plant being a typical English, herbaceous border plant.

Another herbaceous species introduced from China was *C. heracleifolia*. Some of its better cultivars are 'Davidiana', and a slightly deeper, blue form known as 'Davidiana Wyevale'. *C. heracleifolia* was a parent of a very useful ground cover plant, *C.* × *jouiniana* 'Praecox' — the other parent being *C. vitalba*, commonly known in England as 'old man's beard'.

The American species still prove quite scarce in Europe and are still quite unknown. Species such as *C. viorna*, *C. texensis* and *C. douglasii* var. *scottiae* — the latter coming from the Rocky Mountains. These three species are almost herbaceous in habit, dying back to ground level each winter. *C. texensis* was used in a hybridization programme with one of the most popular hybrid clematis, *C.* × *jackmanii*, and also with other species such as *C. viticella*. Some of the more dramatic hybrids which were produced are *C. texensis* 'Gravetye Beauty' and *C. texensis* 'Duchess of Albany', which bear flowers like miniature tulips.

Other popular species that were introduced from Europe include the tiny, pale blue-white flowered *C. campaniflora* and *C. flammula*; both coming from Portugal. *C. flammula* is still a popular species and looks most dramatic if it is allowed to scramble through the common green holly. It produces thousands of tiny, almond-scented, white flowers during the late summer months.

Many species were introduced from the Himalayan Mountain range and, more importantly, from China. The *C. montana* group were a most important introduction due to the mass of white or pink flowers produced annually. This plant is an ideal plant for scrambling over conifers, especially pines, or for covering out-building walls. One of the best modern cultivars is *C. montana* 'Elizabeth' which is a pale pink and produces a pleasant, fragrant flower

Possibly the most dramatic clematis species is that of *C. florida* 'Sieboldii' (Syn.: *C. florida* var. *bicolor*) which was introduced from Japan in the 1830's. This species resembles the passion flower. Its growth is somewhat fragile and the plant needs to be grown through a wall-trained, evergreen shrub to produce its best.

Some of the more important clematis species, with large flowers, also came from China and Japan. A few years after *C. florida* and *C. lanuginosa* were introduced from China and *C. patens* from Japan, during the mid-nineteenth century, a great

surge of hybridization took place, which resulted in some 500 clematis hybrids being offered for sale by the end of the century. These three species and many of their cultivars have since been lost to cultivation in the western world. We are looking forward to reintroducing these three species again in the future if we are successful in obtaining seed or plants from Asia.

One of the best yellow-flowered species is *C. orientalis* Ludlow and Sherriff 13342. It was introduced from Tibet in 1947. The species, which produces flowers with very thick, fleshy sepals, is ideal for scrambling over medium sized rhododendrons and will attain a height of some 10 feet.

C. rehderana, a species from Western China, produces rather coarse foliage but with attractive, nodding, greenish-yellow flowers which are produced in clusters and are cowslip-scented, is still not commonly grown. I recently found several forms of this species in China.

C. fargesii var. *soulei* produces many inch-wide, white flowers from April onwards and looks charming if allowed to grow through an evergreen such as the common, English yew. This plant, too, deserves to be more popular.

Some of the more fascinating evergreen Australasian clematis can be grown in England with protection Of these, there is the fascinating *C. afoliata*; the plant produces a mass of stems that look like an overgrown rush with virtually no leaves. It is known as the 'rush stemmed clematis'.

C. fosteri, another New Zealand species, produces a mass of creamy-green, scented flowers during early spring. *C. paniculata* 'Lobata', another New Zealand species that is also dioecious, produces very attractive, white flowers which have pink anthers. Another of the evergreen clematis, a native of China, is the well known *C. armandii*. This plant has large, leathery-green leaves and produces an abundance of white flowers during the early spring.

Of the more hardy species (another European native) *C. alpina*, has given rise to quite a number of cultivars. These small flowered cultivars are ideal for growing through wall-trained shrubs such as the commonly grown *Chaenomeles* species and do quite well if growing on a north facing wall. They produce their flowers in England during April and early May, followed by very attractive seed heads. Some of the better cultivars are 'Ruby' which is mauve, 'Pamela Jackman' which is deep blue, and 'Columbine' which is pale blue.

The double clematis, *C. macropetala*, which also belongs to the same group as *C. alpina*, is a native of China. *C. macropetala* produces its mid-blue flowers during April/May as also

does the pink cultivar, 'Markham's Pink'

In our gardens clematis are grown in many situations. As you may have noted, we prefer to grow the species and their small flowered cultivars in a natural way through trees and shrubs and some even as ground cover plants. We also encourage our customers to grow the large flowered cultivars through wall-trained trees and shrubs, through open-ground shrubs and also to allow them to scramble along at ground level through summer bedding plants Species roses also make ideal host plants for clematis.

Some of the early, large flowered hybrids that were produced from the 1850's onwards are still popular today. One of these being the large, white clematis, *C.* × *lawsoniana* 'Henry' (Syn : *C* × *henryi*), and at the other end of the time scale, one of the newer cultivars to be introduced recently is the deep, velvet-red *C.* 'Niobe', which we acquired from Poland.

The very large flowered clematis are most suited to wall-trained shrubs where their large flowers can be given more protection from wind. The mid season, large flowered cultivars such as *C.* 'Marie Boisselot', *C lawsoniana* 'Henryi' and *C.* 'Duchess of Sutherland' are more suited to scrambling over a medium sized rhododendron or cotoneaster where their more sprawling habit can be shown to best advantage over a larger sized shrub

The unusual double and semi-double cultivars such as *C* 'Vyvyan Pennell' and *C.* 'Countess of Lovelace' or *C* × *jackmanii* 'Alba' are best grown through wall-trained shrubs where their huge double flowers cannot be damaged so easily by rain or strong winds. The compact, early, large flowered hybrids make ideal container plants for patios and for growing over low-growing, evergreen shrubs such as *Cotoneaster microphylla*. Their early, medium sized flowers are produced in a range of colours Some of the better cultivars are *C* 'Edith', which is white, *C.* 'Dawn', which is pale pink and *C.* 'Mrs. N. Thompson', which is a rich, purple-blue The later flowering hybrids which produce their flowers on the current season's growth make themselves ideal for growing through shrub and species roses These include *C.* 'Perle d'Azur', *C.* 'Victoria' and *C* × *jackmanii*.

As you will have noted, we prefer not to grow clematis against a bare wall. We feel that clematis should be allowed to grow in a more natural way, even scrambling along at ground level if required

PRODUCTION

Having grown our clematis through plants in the garden so

that our customers can see how clematis can be grown; having produced books describing this concept of growing clematis, with the writing of articles for the retail gardening press, both in the UK and in Europe, and also by exhibiting our clematis at the world famous Chelsea Flower Show, we do our utmost to publicize the genus to the retail public — encouraging direct sales of clematis from the nursery and also to publicize the genus for the wholesale sales of clematis in Europe. Having collected the species and cultivars and shown how they can be grown, and publicised them, we are then left with production.

We annually produce over 300,000 clematis liners. They are produced along the lines described in my paper given to the Eastern Region Conference, 1977, at Columbus, Ohio. Our production has changed very little since giving that paper. However, we have found it necessary to change our production slightly so that we can produce a heavier grade plant; this means the production of one crop per year. Our clematis are all grown from cuttings.

The cuttings are produced by the young, previous season's cuttings; these are potted during March, allowed to grow for 6-8 weeks when they are all pruned down. When pruning the plants down we achieve two objectives:

1. the plants are encouraged to become more bushy,
2. we produce our crop of cuttings.

The cuttings are rooted on ground level, heated beds with no mist but with 60 percent shade and with manual dampening down of foliage and the entire glasshouse floor area, as conditions dictate The cuttings are allowed to continue growing in the trays until the following March; during that period the cuttings are fed with a liquid fertilizer After the potted cuttings have been pruned they are immediately staked and tied, with tying being continued until they attain the size, grade and quality plant that we require.

Dispatch is from the beginning of August and will continue until the following March. The different outlets that take our plants naturally require the plants during different months of the autumn and winter period. Our plants are boxed 25 plants per box. These boxes are stackable, giving a more efficient packing and delivery service to our customers in the UK and in Europe.

You have seen old clematis of the past and their use as a current garden plant; a little insight into their production and I finish my paper by showing you some of the clematis species which are new to cultivation and recently collected by myself in China. These species are yet unnamed and proving what an

exciting genus clematis is and underlining how fortunate I am in being able to collect new species from the wild, grow them, display them, and make a business out of them in future years.

BRUCE BRIGGS. Would you comment on your spray program?

RAY EVISON: When our cuttings are taken they are immediately dipped in a Captan solution. When we are finished at the end of a cutting period we drench with Captan We then move in with Benlate every 2 weeks as a light drench. We had a botrytis problem this year and had to come in with another compound for that. Basically it is a Benlate program though. When potting on we use a Captan drench to start. Then we use a Benlate drench (1 lbs/100 imperial gallons) at the rate of 25 gallons to 9000 sq ft Benlate works well for wilt control.

CAMERON SMITH· How do you collect your wild plant material?

RAY EVISON: It is stored in damp moss in poly bags.

GRAFTING UPRIGHT JUNIPERS

DIXON P. HOOGENDOORN
Hoogendoorn Nurseries, Inc.
Newport, Rhode Island 02842

Grafting upright junipers is an ancient process in the field of plant propagation Many articles and papers have been published in various past IPPS Proceedings dealing with this particular subject.

We do not specialize in upright junipers, however, we do grow *Juniperus chinensis* 'Robust Green', and *J. chinensis* 'Keteleeri' to diversify our line of ball and burlap material. We have grown 'Keteleeri' for many years and like it for the simple reason that it has a full, compact growth habit right to the ground, as well as deep green foliage. 'Robust Green' has been a welcome addition over the last few years because of its dense and dark green color which compliments its irregular form. Both cultivars seem to adapt to our changeable and sometimes harsh weather conditions in New England

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exciting genus clematis is and underlining how fortunate I am in being able to collect new species from the wild, grow them, display them, and make a business out of them in future years.

BRUCE BRIGGS. Would you comment on your spray program?

RAY EVISON: When our cuttings are taken they are immediately dipped in a Captan solution. When we are finished at the end of a cutting period we drench with Captan We then move in with Benlate every 2 weeks as a light drench. We had a botrytis problem this year and had to come in with another compound for that. Basically it is a Benlate program though. When potting on we use a Captan drench to start. Then we use a Benlate drench (1 lbs/100 imperial gallons) at the rate of 25 gallons to 9000 sq ft Benlate works well for wilt control.

CAMERON SMITH· How do you collect your wild plant material?

RAY EVISON: It is stored in damp moss in poly bags.

GRAFTING UPRIGHT JUNIPERS

DIXON P. HOOGENDOORN
Hoogendoorn Nurseries, Inc.
Newport, Rhode Island 02842

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We do not specialize in upright junipers, however, we do grow *Juniperus chinensis* 'Robust Green', and *J. chinensis* 'Keteleeri' to diversify our line of ball and burlap material. We have grown 'Keteleeri' for many years and like it for the simple reason that it has a full, compact growth habit right to the ground, as well as deep green foliage. 'Robust Green' has been a welcome addition over the last few years because of its dense and dark green color which compliments its irregular form. Both cultivars seem to adapt to our changeable and sometimes harsh weather conditions in New England

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propagators search for a more dependable understock. We chose *J. chinensis* 'Hetzii' as it rooted quite readily and made an excellent understock for grafting. We take our cuttings from plants which have been planted in nursery beds for two years and planted in field rows for another two years. We choose the heaviest cuttings as they make the best understock. They are rooted in the greenhouse in the winter months and planted out the following spring in beds with very close spacing so that the root system is built up. The plants stay in beds until approximately the middle of November (after a killing frost) and are brought in, trimmed and potted in 2¼ in. pots. The understocks are then placed in a greenhouse with bottom heat (approximately 68°F) to stimulate understock rerooting prior to grafting We feel this is essential for good results.

The peat should be shredded and put into the greenhouse bench quite awhile before the actual grafting takes place in order that it may be turned over and uniformly dampened to insure good results. The peat can be put in a windrow and sealed with water until time of use. We usually start grafting these upright junipers the first week in January as they are rerooted sufficiently.

The scions are usually cut 3 to 4 days ahead of actual use. We try to cut this material during milder weather for various reasons: the employees do not want to be cutting this material under impossible conditions; and the scion (when extremely cold) has too vast a physical change to undertake. When extremely cold weather persists and material has to be cut, we usually submerge them in cold water for fifteen minutes to draw out the frost. Scion material is kept moist and stored in a cooler at approximately 35°F until needed. Scions are usually taken from production plants in the field. We try to select the heaviest scions possible in order to insure a strong plant right from the start

Scions are usually made to a length of approximately 12 in. with the bottom 3-3½ in. trimmed flush with the stem in order to allow the grafter a sufficient surface to make his cuts. The scions are dipped in a Benlate solution (1 tbls/gal H_2O) and allowed to dry in order to cut down on persistent fungus problems associated with grafting under a high humidity environment

The understock is watered one day prior to grafting to insure proper moisture levels. However, all external surfaces should be dry at the time of grafting.

The conventional side veneer graft is used in all our grafting operations. An extremely sharp knife is required for this process. The understock is trimmed back slightly at the time

of grafting We make approximately a 1½ in. long cut in the understock on the straightest side and as close to the pot as possible The scion is cut slightly more than 1½ ın on one side and slıghtly less on the parallel side in order that a fresh angle cut can be made on the scion Understocks and scıons of approximately the same caliper should be used ın order to match up the cambium layers on two sıdes However, thıs ıs not always possıble, but it ıs essential to lıne up cambium layers on one side to ınsure good results The scion is inserted into the understock with the lıp covering the outside cut. A buddıng strip (¼ × 4 ın) ıs used wıth medium tension It is applied from the top of the union down leaving enough space for callus tissue to form The bottom lip should be left completely open as this is where the majority of callus formation occurs. We use a half hitch in the final turn of the buddıng strip in order to simplify its removal at the time of planting

When a flat of grafts has been completed ıt ıs ımmediately taken to the greenhouse and the potted grafts are set on the bed The peat is leveled off and a trench ıs made so that the unıons are buried. The grafts are placed on approxımately 60° angle to ınsure that they fit under the glass sash We keep the bench temperature at 68° to 70°F Dependıng on size and fullness of the scıons we may want to open the rows a lıttle to help eliminate fungus problems Once the grafts have been set ın the bench they are syringed on sunny or brıght days and the sashes are put down A linen cloth is rolled over the sashes to protect the grafts from direct sunlight On dark days the grafts are aıred with no syringıng and the sashes put down ın place without the linen

Approximately four weeks after the grafts have been placed ın the sweat box or graftıng case, the callus should be fully developed It is now tıme to set them on top of the peat and begin hardenıng them off. As soon as they are brought up they are watered as the pots may be getting dry and also to keep some moisture around the callus tissue. The sashes are gradually left open a longer perıod each day to allow more air circulatıon. After four days we put a 2 in block under the sash After approximately 6 days they are kept completely open with syrınging 3 to 4 times a day depending on the weather. After the seventh day they are moved to a holding house in order to make room for a new crop

The understock ıs cut back slightly and the grafts are set pot to pot on a ground bench in the holding house. We do have heating pipes anchored to the cement walls approximately twelve inches off the floor and keep the temperature at 60°F. They are now watered to provide sufficient moisture in theır new environment The grafts are syrınged on sunny days

depending upon light intensity. As soon as the weather warms up in the latter part of February or the beginning of March, ventilators are opened and the grafts are aired. This is also a gradual process with ventilators being raised only slightly on the leeward side at first. It may also be necessary to apply shade to the glass at this time as the sun's rays become more intense The pots should be checked for proper moisture content periodically

As the days lengthen and the outside temperatures increase, it is necessary to gradually increase ventilation procedures until such a time that they are left completely open. I might add that the doors are also left open at this time to increase air circulation During this period syringing is gradually reduced.

The grafts remain in the holding house until the early part of June At this time the understock is completely removed as well as the budding strip. If the budding strip is not removed before planting, it will not deteriorate and serious girdling will result Grafts are now planted in nursery beds 7 in. apart with approximately 8-10 in between the rows. The grafts are planted with the top of the union approximately 1 in. below the soil surface in order to protect against breakage. The newly planted grafts remain for two years in this location After the second year they are transplanted into field rows They are planted in 3 ft rows with 2 ft. spacing between the plants in the row. After three growing seasons the plants are harvested for our ball and burlap trade

LEONARD SAVELLA: We take our *Juniperus* 'Hetzii' right out of the rooting bench and put them in a pot with good results.

DIXON HOOGENDOORN: We do not have time until November. You could do it that way.

Editor's Note. Calvin Chong at this time gave a short presentation titled "Simultaneous Grafting and Rooting of Upright Junipers"

CALVIN CHONG. During the past several years I have been investigating the simultaneous grafting and rooting procedure for speeding production of upright junipers. A literature search indicated that this technique, although not widely practiced, has been used by several members, such as Dillon in California and Teuscher in Montreal. The technique also has been described in the textbook by Hartmann and Kester I obtained encouraging results in grafting and rooting scions of upright 'Skyrocket' and 'Pathfinder' juniper to easily-rooted 'Hetzii' juniper rootstock using the "paired-cutting" technique for Douglas fir previously reported by Brix and Barker in

British Columbia. Matched cuttings of scion and rootstock species were grafted along the basal 3-4 cm and held together with a rubber band.

Results varied between 20 and 100% successful paired grafts depending on who made the grafts, but the approach did seem to have potential for practical application. More recently I developed the styrograft technique in which detached cuttings of the upright species were conventionally side-grafted to the detached rootstock cutting. These grafts were held together by inserting each set of grafted cuttings into styrofoam blocks (3 × 3 × 5 cm), prepunched in the center with a nail to facilitate entry of the rootstock. The base of the rootstock was allowed to protrude 0.5 cm out of the styroblock to facilitate growth regulator application. The styroblocks exert sufficient pressure to keep scion and rootstock together and benefited the graft union, which seemed to heal better Insertion into the styroblocks is less time consuming than tying with rubber bands Since roots penetrate quite freely through the styroblock, it is unnecessary to remove the block, a feature that would facilitate transplanting.

In view of the very large cuttings that can be used, I estimate that simultaneous grafting and rooting could save as much as 1½ to 2 years in production time, and may deserve a closer examination by propagators. A more detailed account of this procedure was published in *HortScience* 16(4)· 561-562, 1981

Tuesday Evening, December 8, 1981

The thirty-first annual banquet was held in the Grand Hall of the Holiday Inn, International Drive, Orlando, Florida.

On behalf of the Society, two graduate student awards were presented to Ms. Ann Fagan and her advisor, Dr. Michael Dirr, University of Georgia, Athens Georgia; and Bryce Lane and his advisor, Dr. Steven Still, Ohio State University, Columbus, Ohio.

The award for the best undergraduate paper was presented to Mr Scott E. Hyndman, Department of Horticulture, Purdue University, West Lafayette, Indiana, and Dr Paul Hasegawa, his advisor.

Two individuals received the Award of Merit at the annual banquet.

AWARD OF MERIT

Ray Halward presented the first award

Our first Award of Merit recipient is a member who you

all know and no doubt most have talked to through the years. He has been an active member since 1953 and has never missed an annual meeting

He graduated from the University of Missouri with a B S. in Horticulture. His work experience includes three nurseries in Missouri from 1946-65, one nursery in Nebraska from 1965-70; two nurseries in Ohio from 1970-80; and presently is working in a nursery in western Michigan. He has specialized in developing new techniques of seedage and other nursery production methods.

He has served in every capacity with the Eastern Region including President in 1967-68 and International President in 1971 and presently serves as the Historian. The Eastern Region is not the only one to benefit from our members dedication. The Southern, Western, and Great Britain and Ireland Regions have had the privilege of his participation. One can also gauge the intent of his giving by browsing through the Proceedings.

The person we honor tonight is Ralph Shugert.

Leonard Savella presented the second award.

It gives me great pleasure to announce to you that this year we have another recipient, truly deserving of the Award of Merit The second recipient of our Society's highest reward is John Peter Vermeulen.

Pete Vermeulen was born on May 27, 1919 in Carle Place, Long Island, to John and Johanna Vermeulen. Peter's father, John, emigrated from Boskoop, Holland in 1915 as a fourth generation nurseryman in a nursery-orientated town and country. Pete is a fifth generation nurseryman and presently has 3 children, Jeffrey, Nancy and Wendy who represent the sixth generation in the family-owned nursery of John Vermeulen and Son, Inc.

Peter attended elementary school in Carle Place, high school in Westbury; business school in Jamaica, New York; a short course in floriculture at Cornell; and apprenticed as a student propagator under Martin Van Hof at Rhode Island Nurseries in Middletown, Rhode Island for 2 years

In 1941 he entered the army as a volunteer recruit and in 1946 he was honorably discharged with the rank of captain. On separation Pete joined the U.S army reserve and retired in 1976 with the rank of lieutenant colonel. During World War II while on Adak Island in the Aleutian Islands of Alaska, Pete met his wife Edith Newman whom he married in 1946. Peter and his wife Edith have 5 children and 2 grandchildren.

Upon leaving the army, he joined his father's nursery

business on Long Island and together they relocated and expanded to their present location in Neshanic Station in North Central New Jersey. Peter joined the Eastern Region of the IPPS in 1955. immediately became very active in the Society and was most anxious to share his knowledge with fellow members Pete has presented several papers at Society meetings and actively participates in all our annual meetings with his questions and answers. He has been both Eastern Region and International President in our Society

Peter has been active in his state nurseryman's association since 1947 and has served as its President. He has served on the Board of Managers at the College of Agriculture and Environmental Science for 9 years and also served as President He is a member of the State Board of Agriculture for New Jersey and served as its Vice-President in 1980-81. In addition he has served as Director of the New Jersey Farm Bureau for several years, and also has been active in the local school board, Industrial Commission, County Board of Agriculture, Farmland Preservation Committee and his church as a teacher. leader, disciple and witness.

Peter is presently managing the family-owned business primarily engaged in plant propagation and container culture of the more rare and unusual plant genera, species, and cultivars used in plant beautification and environmental enhancement. His business is also heavily engage in creation. sales and distribution of bonsai plants

It is indeed an honor and a privilege to present to such a distinguished man our Society's highest award: the Award of Merit.

Thursday Morning, December 10, 1981

The Thursday morning session convened at 8:10 a.m. with William E Snyder serving as moderator.

PROPAGATION OF SHADE TREES BY SOFTWOOD CUTTINGS

DOUGLAS J. CHAPMAN and SUSAN HOOVER
Dow Gardens
Midland, Michigan 48640

The specific objectives of this investigation (a study initiated in 1979) include (1) how many different tree species can

business on Long Island and together they relocated and expanded to their present location in Neshanic Station in North Central New Jersey. Peter joined the Eastern Region of the IPPS in 1955. immediately became very active in the Society and was most anxious to share his knowledge with fellow members Pete has presented several papers at Society meetings and actively participates in all our annual meetings with his questions and answers. He has been both Eastern Region and International President in our Society

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The specific objectives of this investigation (a study initiated in 1979) include (1) how many different tree species can

be commercially propagated by softwood cuttings and when; (2) encouraging development of cultivars adapted to specific regions, e.g Great Lakes cultivars; and (3) stimulate local nurserymen to propagate regional cultivars or stimulating the establishment of local propagation firms with the above goals (1).

MATERIALS AND METHODS

Cuttings of *Acer campestre*, *A. platanoides*, *A. platanoides* 'Schwedleri,' *A. saccharum* subsp. *nigrum*, *Malus* 'Snowdrift,' *M. tschonskii*, *M.* 'Mary Potter,' *Aesculus hippocastanum*, *Quercus alba* and *Q palustris* were taken essentially at two-week intervals during 1980 and/or 1981. The various cuttings were taken and disinfected in a sodium hypochlorite solution mixed at a 1 to 20 ratio Cuttings were submersed in the above solution for 20 minutes and rinsed in water. The cuttings were then dipped in a powder mixture of 3.8% Benlate and Hormodin 3, and stuck in a medium containing 50% sphagnum peat moss and perlite by volume. The mist was set to come on for five seconds every ten minutes (1). Six weeks after sticking the cuttings were removed and evaluated for number decayed, callused, or rooted.

RESULTS AND DISCUSSION

The results (Tables 1 and 2) indicate softwood cuttings of *Acer campestre*, *A. platanoides*, *A. saccharum* subsp. *nigrum*, *Malus* 'Snowdrift,' *M.* 'Mary Potter,' and *A. hippocastanum* could be rooted in commercially acceptable percentages (75% minimum) at varying times from late May through mid-summer. The data indicate that *A. hippocastanum* could most easily be rooted in commercially acceptable percentages during late May through June. After that point, rooting percentages dropped dramatically. *A. campestre* rooted through June and July, again in commercially accepted percentages with mid-June being optimal. *A. platanoides* did not root in early July or late August but showed acceptable rooting percentages during early through mid-July. *A. saccharum* subsp. *nigrum* rooted 50% or greater mid-June through mid-July.

Table 1 Propagation response of some shade trees (1980)

	Number of cuttings		
Species and Dates Stuck	Stuck	Callused	Rooted
Acer campestre			
May 22	25	12	12
June 5	25	22	20
June 18	25	23	23
July 1	25	20	17
July 17	25	19	19

August 5	25	17	17
August 28	25	6	6
Acer platanoides			
June 10	25	20	12
June 17	25	5	4
July 2	25	21	20
July 17	25	20	20
August 5	25	12	12
August 28	25	6	6
Acer platanoides 'Schwedleri'			
June 5	25	23	12
June 18	25	17	14
July 1	25	12	10
July 17	25	16	15
August 5	25	6	6
August 28	25	6	6
Acer saccharum subsp *nigrum*			
May 22	25	0	0
June 10	25	15	15
July 3	25	15	14
July 15	25	15	13
July 29	25	6	5
August 20	25	2	1
September 9	25	0	0
Malus 'Snowdrift'			
May 30	25	8	8
June 13	25	23	23
June 26	25	17	16
July 8	25	25	25
July 23	25	24	24
August 12	25	25	22
September 4	25	8	7
Malus tschonski			
May 30	25	4	4
June 13	25	12	5
June 26	25	6	0
July 8	25	9	0
July 23	25	20	0
August 12	25	14	0
Aesculus hippocastanum			
May 23	25	16	16
June 6	25	25	18
June 25	25	11	11
July 9	25	25	18
July 23	25	17	12
August 12	25	0	0
Quercus macrocarpa			
June 10	25	5	4
July 3	25	1	0
July 15	25	3	1
July 29	25	14	0
August 20	25	0	0
September 9	25	1	0
Quercus palustris			
May 30	25	0	0
June 17	25	0	0
July 3	25	14	7
July 15	25	9	6

July 29	25	1	1
August 20	25	1	0
September 9	25	6	0

M 'Snowdrift' and *M* 'Mary Potter' rooted acceptably for a period of time from mid-June through the entire month of July. They, in fact, were so "easy to root," that one should expect nothing less than 90% rooting. Conversely, *M. tschonskii* showed only a slight tendency to root and, in fact, the above-mentioned propagation technique is not acceptable for commercial production.

The oaks were a difficult group, with *Quercus palustris*, at this point, showing the greatest promise for cuttings taken in early July. *Q. macrocarpa* and *Q. alba*, did not root. It was felt that the oak group did not root because of poor aeration in the media which encouraged decay In the future, one should consider sticking cuttings of oak in a medium of 100% perlite or quartz sand.

Little leaf linden (*Tilia cordata* 'Greenspire') showed a tendency to root when taken during late June. It was hypothesized that the decreased rooting in 1981 was the result of a slight change in the media peat moss (peat source) which seemed to decrease aeration and, therefore, increase the frequency of basal rot.

Table 2. *Propagation response of some shade trees (1981)*

	Number of cuttings		
Species and Dates Stuck	Stuck	Callused	Rooted
Acer campestre			
June 12	50	42	32
June 26	50	34	30
July 10	50	16	13
July 24	50	31	31
Malus 'Snowdrift'			
June 26	50	47	43
July 10	50	48	48
July 24	50	49	48
Malus 'Mary Potter'			
June 26	50	50	50
July 10	50	50	50
Tilia cordata 'Greenspire'			
June 24	50	16	16
July 8	50	9	9
July 23	50	9	8
Quercus alba			
July 30	50	4	0
August 13	50	3	0

A. campestre, *A. platanoides*, *A. rubrum*, *M.* 'Snowdrift,' and *M* 'Mary Potter' can be propagated in commercially acceptable percentages (in excess of 75%), depending on the tree species. Propagation of trees by softwood cuttings is a viable

concept when cuttings are taken and stuck between June to July, depending on species types. Cuttings of some trees develop basal rot when taken and stuck too early, e.g. *A. campestre*, *A. platanoides*, and *A. rubrum*. Therefore, cuttings of these trees should not be taken until after the period of rapid elongation is complete. Further, it should be stressed that porous, well-aerated media combined with the correct timing are two important factors, resulting in increased number of shade trees that can be propagated by softwood cuttage. This concept of propagation by cuttage of regionally adapted cultivars should provide a stimulus for the entire nursery industry, resulting in trees that are propagated and grown on their own roots with no graft incompatibility Further, they can be selected for environmental tolerances, e.g. tolerant to air pollutants, disease and insect resistance

LITERATURE CITED

1 Chapman, D J 1979 Propagation of *Acer campestre*, *A platanoides*, *A rubrum*, and *A ginnala* by cuttings Proc Int Plant Prop Soc 29 345-347

HUGH STEAVENSON: What do we know about the root structure as the trees get older?

DOUGLAS CHAPMAN: We have some 3 year old plants at Dow Gardens that look very good. The cuttings do not root from just one location but multiple sites.

WILLIAM WOLFF. I might be able to shed some light on the subject from another *Acer* species. I had a test comparing rooted cuttings vs. grafted 'Bloodgood' The trees were grown to a 6 to 8 ft size and we found in every case that we could not tell a difference in root structure.

ED MEZITT: We have also grown Japanese maples from cuttings and they have good root systems. We have done *A. rubrum* from cuttings but are having an overwintering problem

DON SHADOW: Was the *A. campestre* from a specific cultivar?

DOUGLAS CHAPMAN. No. From seedling trees 8 to 10 ft in height. The cuttings were taken throughout the plant. This was one of the more dependable species for rooting. Increased photoperiod can keep it growing.

PROPAGATION OF *ACER GRANDIDENTATUM* NUTT. BY LAYERING[1]

B.E. TANKERSLEY[2] and E.R. EMINO

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Abstract. Modified French and mound layering techniques were evaluated as methods of propagating *Acer grandidentatum* Nutt French layering was successful in one year Layers with greater than 0 5 cm caliper stems were successfully established in containers while less than 0 5 cm caliper layers did not survive transplanting A longer time period is required for evaluation of layering techniques Although these results are from limited observations, some success was obtained by layering, while more extensive efforts at cutting propagation were not successful

INTRODUCTION

Acer grandidentatum Nutt. (bigtooth maple) seedlings with desirable growth characteristics have been identified in a recently completed study on a seed source from Lost Maples State Natural Area, near Vanderpool, Texas (6). Less than one percent of cuttings of current season's growth from seven-year-old trees from the Vanderpool source rooted. Barker (1) noted success in propagating bigtooth maple using long cuttings of current year's growth stuck in August and treated with auxin and placed under intermittent mist. No other reports were found in the literature regarding propagation of *A. grandidentatum* by cuttings. Vertrees (8) was successful in layering *A. circinatum* after having failed in attempts to root the species using cuttings. Christensen (2) noted mature *A. grandidentatum* specimens growing in Utah often extended the root system radially as the lower branches layered in the soil surface litter. An experiment was designed to evaluate French and mound layering techniques for vegetative propagation of *A. grandidentatum* seedlings with desirable characteristics. The French or continuous layering technique is used to propagate *Acer cappadocicum*, *A. rubrum*, *A. saccharinum* and other species of ornamental plants (4). This technique produces more but smaller plants than mound layering. Mound or stool layering is recommended for plant materials that are difficult to root; for example, clonal apple rootstocks, *Prunus tenella*, *P. glandulosa*, *P. triloba*, *P. cerasifera* 'Nigra', *P. cerasifera* 'Hessei', *Chaenomeles* species and cultivars, *Cotinus oboratus* (Syn.: *C. americana*), *Cotinus coggygria*, and *Castinea sativa* (3,5).

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[1] Texas Agricultural Experiment Station Journal Article Number 17314

[2] Present Address Newell Business Park, 2501 Gravel Rd , Ft Worth, Texas 76118

MATERIALS AND METHODS

The layering bed medium consisted of 2 peat: 2 perlite: 1 sand by volume. The soil amendments and rates were 3.5 kg gypsum per m^2, 3.5 kg dolomitic limestone per m^2, 221 g Fritted Trace Element #503 per m^2, 0.7 Kg superphosphate per m^2, and 3.3 kg Osmocote 19-6-10 plus iron per m^2. The medium was placed in a raised bed to a firmed depth of 20 cm over a layer of coarse gravel. A windbreak was used to slow prevailing winds.

The procedures for French layering technique followed that given by McMillan-Browse (4). Nine one-year-old plants in 15 cm pots were transplanted with the stem parallel and in contact with the soil, and the root balls covered with mounded soil in February 1980. The stems were pegged to the ground to insure contact. The lateral terminals were mulched with weathered sawdust in April, May, and July to maintain a moist, well-aerated environment suitable for adventitious root formation. The total height of the sawdust after all additions was 10 cm. No wounding, girdling, or hormone treatments were used. Data was collected in January, 1981, and the rooted layers were placed in nursery cans in the same medium used for the layer beds. Survival data was collected in April, 1981.

The procedure for the mound layering technique followed the outlines described by McMillan-Browse (3), and by Hartmann and Kester (5). Eleven one-year-plants were removed from the greenhouse on February 1, 1980, and planted in a raised bed. The plants were covered with weathered sawdust as with the French layering study, and no wounding, girdling, or hormone treatments were initiated. In January, 1981, the plants were pruned back severely to encourage growth from the crown.

RESULTS

Seven plants in the French layering study received sufficient chilling to break lateral buds. The plants averaged 3.1 laterals per stem. Rooting occurred only on the previous season's growth and varied with the vigor of the plant (Table 1). Plant accession #106 with four laterals was classified as heavy rooting, having three or more roots per lateral (Figure 1). Plant #34 (3 laterals) and #6 (1 lateral) were classified as moderate rooting with 2-3 roots per lateral. Plants #111 and #22 (4 laterals each) produced only 1-2 roots per lateral. Plants #17 and #11 (3 laterals each) did not initiate any roots. Survival of the rooted layers apparently was related to stem caliper. All transplanted layers with a stem caliper less than 0.5 cm at 1.5 cm above the soil level on past seasons growth died by April, 1981.

Table 1. French layering results.

Accession No.	No. Laterals Formed	No. Laterals Rooted	No. Roots/ Lateral	Class	Caliper (cm)	Survived
106	4	3	3+	Heavy	0.677	Yes
					0.248	No
34	3	2	2-3	Moderate	0.433	No
6	1	1	2-3	Moderate	0.696	Yes
111	4	4	1-2	Slight	0.335	No
22	4	2	1-2	Slight	0.298	No
17	3	0	0	None	—	—
11	3	0	0	None	—	—

Ten plants used in the mound layering study received sufficient chilling to break dormancy. Two of the ten had established adventitious roots with the potential for one propagule each within one year. The rooting was slight with one root per stem. Additional evaluation of both techniques will be necessary.

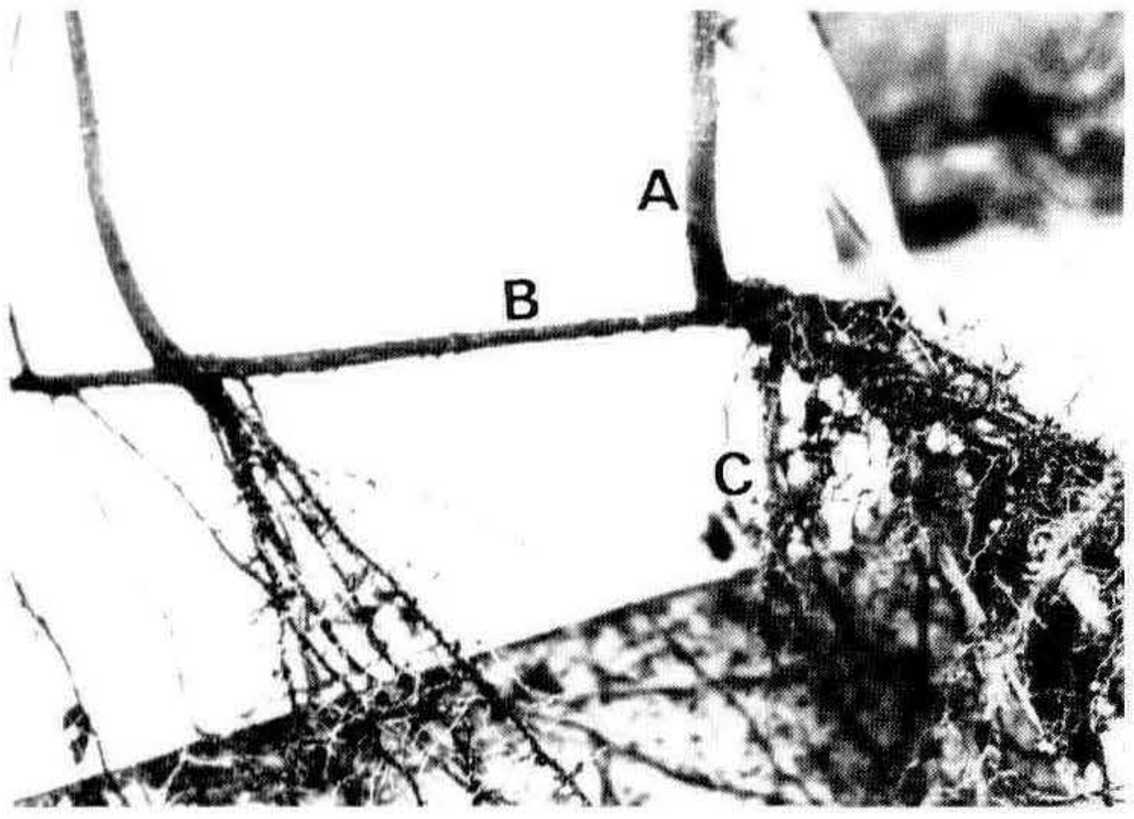

Figure 1. Rooting on French layered seedlings of *A. grandidentatum*. The roots were formed only on the two-year-old wood that was pegged horizontally. A = one-year-old wood; B = two-year-old wood; C = roots.

DISCUSSION

The French layering technique was more effective in producing rooted layers within one year after transplanting than mound layering. The survival data indicates the small laterals formed on the French layered plants may initiate roots, but will not survive transplanting if the stem caliper is less than 0.5 cm. The caliper of small layers might be increased by establishing the parental stock in the layering beds for one year before layering is attempted. Success was obtained with French layering technique facilitating the development of clones. Seedlings may now be selected, cloned, and further evaluated for other desirable traits such as improved growth rates and fall color.

The demonstrated layering technique is intended to be used primarily for clonal evaluations of *A. grandidentatum*.

The technique is uneconomical for commercial application but it is the most reliable vegetative technique known at this time. Other propagation methods are being studied for commercial use

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8 Vertrees, J D 1975 Observation on *Acer circinatum* Pursh *The Plant Prop* 21(4) 11-12

FRANK GOUIN: Did you check the sugar levels during rooting?

B.E. TANKERSLEY: We looked at the starch level and it was not related. We did not look at sugars.

PROPAGATION OF SYRINGA RETICULATA AND ITS FORMS

JOERG LEISS

Sheridan Nurseries Limited
Oakville, Ontario, Canada

Up to a few years ago the Japanese tree lilac had been known as *Syringa amurensis* var. *japonica* in the trade. The confusion in naming comes from the many botanists that described the tree.

Blume described it in 1855 as *Ligustrum reticulata*. Maximowicz in 1875 used the name *Syringa amurense* var. *japonica*. This name was also used by Franchet and Savatier in 1879. However, Hara is to be credited with the now valid name, *Syringa reticulata*.

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In 1876 Dr. W.S. Clark of the Agricultural School in Sapporo, Hokkeido, Japan sent seeds to the Arnold Arboretum where it was grown under the Accession #1111. One can surmise that considerable seed was sent because within 8 years nurseries such as Ellwanger and Barry of Rochester and H.H. Berger of San Francisco besides various nurseries in Europe listed the tree for sale. It is a small tree growing to 10 m. with a peeling shiny bark similar to cherry. It is usually multi-stemmed and flowers toward the end of June with immense, terminal white flower clusters 50 to 60 cm long and 40 to 50 cm wide.

Since it is found in the wild along stream banks, it grows well under moist conditions unlike most lilacs. Sheridan Nurseries grows the tree single stemmed or as an unpruned bush. We found it to be variable in growth and some plants exhibited extreme chlorosis. To grow a more uniform tree and one that would grow without chlorosis we selected a number of plants, of which the best was named 'Ivory Silk'. When budded onto *Syringa reticulata* seedlings it produces an upright 2 to 3m tree within 3 years after budding. The tree calipers well and makes a more oblong crown than the round headed seed form. It flowers after 6 to 8 years and has the further advantage of being hardy as far north as Edmonton, Alberta. *Syringa reticulata* is quite adaptable to city conditions and is used as a street tree in our area. Herbicides such as Simazine are to be avoided as with *Oleaceae*.

PROPAGATION

Seeding. The seed ripens towards the middle of October and is best picked early in the morning or when the weather is damp to prevent shattering. It is cleaned and fall seeded in beds covered with a layer of sand 2 cm to 4 cm thick and mulched with straw. There are 3000 seeds per 100 grams. Germination does not occur until August of the following year and little growth beyond the cotyledons happens in that year. Despite their tender appearance, the seedlings will survive the first winter with only a straw cover Modifications to the seed treatment, such as additional warm-cool periods, have not shown earlier germination.

For the second year a high nitrogen fertilizer, at the rate of 37 kg. of nitrogen per hectare applied each month from May to August, should produce a 25 cm. seedling 2-4 mm thick. As this is not of budding size, the seedling is transplanted for another year when it should develop into a 40 to 50 cm, 5-8 mm plant at the end of the third season after seeding.

Budding of *Syringa* 'Ivory Silk'. The 3 year seedling is lined out into field rows at a spacing of 120 cm × 45 cm.

Budding by T-bud is done in July when growth has hardened. We like to place the bud in the direction of the prevailing wind. Rubber strips are used as ties. These are cut off when union has taken place. In the spring of the following year, the understock is reduced to 10 cm above the bud. The bud is tied to the understock as soon as it reaches 10 cm. The bud does grow straight without staking up to 180 cm. Very seldom does it branch during the first year. The second year after budding any side branches are reduced to 20 cm along the stem and a light head is produced. In late summer, all side branches are removed from the stem. The third year a good head develops and the stem is kept clean. The tree is ready for sale by fall. Transplanting is easy because of the fibrous root system.

Cuttings. The trend in modern tree nurseries is to produce tree cultivars on their own root. We tried to root *Syringa* 'Ivory Silk' because seedlings take as much as 4 years to be buddable and any reduction of this time would be valuable Further the resulting tree grown from cuttings might be more uniform We therefore, ran a trial of 1000 cuttings treated with Hormodin 3 powder on July 12, 1980. Cuttings were 20 to 25 cm long with tips left on. They were placed on a greenhouse bench, in a sand and perlite medium, with misting for 5 seconds every 10 minutes. In October 87% were rooted when dug. The cuttings were placed into cold storage until spring 1981 and planted out into beds. As 80% of the plants flowered, the flowers were removed to stimulate growth. The size of these cuttings was 40 cm at the end of this season. On June 23, 1981, 9000 cuttings were made and 2560 of these rooted. Because of the larger space requirement, these cuttings were made in a shaded outside mist bed. After 6 weeks, not enough root action was observed and we felt the soil temperature was too low. We removed the cuttings, retreated them with Hormodin 3 and placed them in a greenhouse. At this time the results would indicate that our best course of action is to root these cuttings in a greenhouse We can now produce a field liner of the cultivar wanted in 2 summers instead of the 4 years from seed to understock Of course we also eliminated the work of budding. I hope that my talk will help to fill a gap because the demand for this tree far out-distances the supply I am indebted to the Royal Botanical Garden, Hamilton, staff for nomenclature information.

JIM KING: How do you overwinter the rooted cuttings?

JOERG LEISS: The rooted cuttings are removed from the greenhouse in the middle of October and heeled in until No-

vember when the leaves drop. The cuttings are then packaged in a sausage roll. We cut plastic into strips and put sphagnum moss on it and roll the cuttings up in it We have a package that can be easily taken out in the spring and planted. The cold storage is kept at 28 to 30°F over winter We have found that late planting, the first or second week of May, produces more growth than early planting.

MICHAEL DIRR· How do you handle double breaks and does it hinder growing a straight trunk?

JOERG LEISS: In our case the terminal breaks are flowers, so we end up with the shoots from the second node. We normally do what we do when we graft — just knock one break back. Growing a straight tree is the easiest thing.

PROPAGATION OF SOUTHERN PINES BY CUTTINGS

THOMAS M. MARINO

International Paper Co.
Natchez Forest Research Center
Natchez, Mississippi 39120

For the past 30 years, forestry in the southeastern United States has been devoted to genetic improvement of pine trees (21). Major interest in tree improvement has concerned loblolly pine (*Pinus taeda* L.) though longleaf (*Pinus palustris* Mill.), slash (*Pinus elliottii* Engelm. var. *elliottii*) and shortleaf (*Pinus echinata* Mill.) pines are also important. Straightness of bole, branching characteristics and large volume are a few of the traits being examined. Improvement of these desired traits has been through the process of sexual propagation; that is, through controlled breeding to produce improved progeny for successive generations (15). Recently, there has been an increased effort among research foresters to capture these desired traits through asexual propagation by rooting. Since pines in general are difficult to root (18), obstacles have been encountered.

Asexual propagation by rooting allows for a greater recovery of the genetic potential of a tree more quickly than through sexual propagation. As a result of this advantage, research in the area of improving the rootability of the southern pines is being pursued. Grigsby (5) was the first to report rooting success with loblolly pine, but he could not successfully repeat his results. Subsequent research has revealed that quantity of mist, use of fungicides, adjustment of hormone concentrations in rooting powders and girdling prior to remov-

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al of cuttings from the ortet were important for attaining repeatable rooting success (4,6,8,9,16,20) Important factors in rooting southern pines (specifically loblolly pine) to be discussed in this report include age of ortet from which the cuttings are obtained, time of year of rooting, environment during rooting, pretreatment of the branch to be cut and cuttings prior to sticking, and treatment of the cuttings during rooting.

Age of ortet. The age of the ortet from which the cutting is obtained is extremely important. In other conifers such as *Tsuga diversifolia*, *Abies concolor* (water controls only), *Pinus strobus* and *Pinus radiata* (10,12,18), it has been observed that rooting declines as the age of the ortet increases. Results (unpublished) within International Paper Company demonstrated similar trends in southern pines Cuttings from one- to two-year-old ortets had rooting percentages from 60-80. They exhibited vigorous root systems averaging three or more main roots per rooted cutting. After three years of age, rooting percentages declined to 30-50 percent of cuttings along with the quality of the root system. Usually 1-3 main roots occurred per rooted cutting.

Time of Year. Seasonal variation in rooting southern pine has been investigated but discrepancies exist. Reines and Bamping (14) showed that optimal rooting of slash and loblolly pine occurred from September through January. They suggested that carbohydrate levels during that period play an important role in the rooting process. In work reported by Bower and van Buijtenen (1), cuttings collected in May from both greenhouse- and field-grown ortets rooted best. Work at International Paper Company has shown optimal rooting of cuttings to occur from early October through early February. Cuttings stuck earlier than October or later than February will receive daytime temperatures that can be detrimental. With the exception of the results of Bower and van Buijtenen (1), cuttings stuck during the dormant season have rooted best.

Although rooting appears to be more successful during the winter months, a problem can occur with growth of the propagules produced during this time. Cuttings rooted during the winter months and receiving and 18-20 h photoperiod will undergo an out-of-phase dormancy change when placed in natural day lengths the following spring (3). This induced quiescence is unavoidable, and it can affect subsequent growth and development for a year or more following outplanting.

Environment. Environment is another very important parameter affecting rooting. A chamber to maintain high humidity conditions around the cuttings was developed by Hare (8) and later modified by van Buijtenen (20) These chambers are

equipped with nozzles to provide the cuttings with a fine intermittent mist at fairly precise intervals.

Mist quantity and distribution within the rooting bed affects cutting survival and rootability (4). The following formula has been developed to calibrate mist fall where volume = volume collected in a circular cylinder in milliliters, $\pi = 3.14$, r^2 = the square of the radius of the container, and time = mist collection time in minutes:

$$\text{millimeters/hour} = \frac{600 \bullet \text{volume}}{\pi r^2 \bullet \text{time}}$$

When mist fall is quantified using the above formula and correlated with rooting, optimum rooting has been obtained with a mist precipitation rate around 0.1mm/hour. This quantity is very close to that reported by Grigsby (5).

Other environmental parameters are important to the rooting process and are listed in Table 1. Supplemental CO_2 and extended photoperiod have not been determined as essential, and further work should be pursued to establish their effect on rooting.

Table 1. Summary of techniques for successful rooting of southern pines

Environment	1	Mist chamber — polyvinyl, roof not essential, sides may be essential
	2	CO_2 supplement — 1500-2000 ppm
	3	Intermittent mist — 0 1mm/hour
	4	Medium — 1 1 perlite-vermiculite
	5	Bottom heat — 80°F.
	6	Air temperature — maintain as close as possible to 80°F day and 62°F night
	7	Supplemental light — incandescent light used to extend natural day length to 18-20 hours
Age of Ortet	1	Young material roots better than old material, cuttings from ortets 0-3 years old root around 60%, cuttings from greater than or equal to 4-year-old ortets root around 35%.
Pretreatment Before Sticking	1	Hedging — used to increase cutting material and possibly slow down maturation
	2	Girdling ortet — two months before collecting
	3	Cytokinins — increase axillary bud induction
	4	Hare's rooting powder before sticking
	5	Rooting is optimum from October 1 through February 1 — further work needed
Treatment During Rooting*	1	Hoagland's nutrient solution — every other day until foliar run-off
	2	$AgNO_3$ — 250ppm biweekly

*Rooting time is around 3-4 months

Pretreatments. There are several mechanical as well as chemical pretreatments that can be applied to improve rooting.

In slash pine, Hare (9) showed that girdling in mid-summer can significantly improve rooting from cuttings obtained that fall; however, throughout the season girdled cuttings always rooted better than non-girdled cuttings. It may be that the effect of girdling on rooting is similar to the cause for seasonal rooting observed by Reines and Bamping (14); that is, both effects result from increased carbohydrates in the stem.

Hare (8) developed a pretreatment rooting powder that significantly influenced subsequent pine rooting behavior. The ingredients in the powder consist of two forms of auxin, a fungicide, an anti-gibberellin, and sucrose. The influence of the components of Hare's powder on growth of resulting rooted cuttings has not yet been tested. Also, the exact combination of ingredients causing improved rooting has not been fully tested. Greenwood *et al.* (4) found that cuttings from trees more than four years old rooted better with one-half strength formulation of Hare's powder. Thielges and Hoitink (16) observed in eastern white pine an increase in rooting by the use of fungicides alone.

Hedging, another pretreatment technique, has been suggested to improve rooting by arresting or slowing down maturation (10,13). This could be an essential technique for genetic improvement of pine through asexual propagation. Many timber-growing companies now seek to make selections of superior trees at age 5 in order to speed up the genetic improvement process. After the selections are made, scion material from these selections are grafted into specially designated clone banks. If hedging begins on this grafted material immediately after banking, maturation should be slowed down or arrested with stabilized rooting percentages. Despite the appeal that hedging may have, it has not been fully established whether maturation is actually affected by hedging in southern pines. Regardless of whether or not hedging is affected, hedging is a reasonable practice from the standpoint of accessibility of cuttings.

Hedging can also be used as an ortet pretreatment to induce outgrowth of axillary buds in the base of each needle fascicle bundle. This process can produce virtually unlimited cutting material from a single genotype. Besides hedging, foliar sprays of cytokinins and other plant growth regulators have been effective in inducing axillary bud outgrowth (2,7,11,19).

Treatment during rooting. There are several treatments which improve cutting survival during rooting. One treatment is the use of nutrient amendments. For southern pines, Hoagland's solution in the concentration shown in Table 2 is a widely used nutrient amendment.

Another useful treatment to maintain sanitary conditions in the bed is silver nitrate (4). When 250 ppm silver nitrate is used biweekly, it can be effective in reducing large algal accumulation However, when mist is adjusted properly, algal growth should not be a serious problem.

Table 2 Hoagland's solution for vegetative propagation of southern pine by cuttings

Macronutrients	in 4 liters
$Ca(NO_3)_2 \cdot 4\ H_2O$	2 35 grams
KNO_3	1 01 grams
$MgSO_4 \cdot 7\ H_2O$	0 99 grams
KH_2PO_4	0 27 grams
NH_4Cl	0 54 grams
Micronutrients[1]	4ml of stock solution
Iron chelate[2]	4ml of stock solution
[1] Micronutrient Stock Solution	grams per 1 liter
H_3BO_3	2 86
$MnCl_2 \cdot 4\ H_2O$ (manganous chloride)	1 81
$ZnSO_4 \cdot 7\ H_2O$ (zinc sulfate)	0 22
$CuSO_4 \cdot 5\ H_2O$ (cupric sulfate)	0 08
$H_2MoO_4 \cdot H_2O$ (molybdic acid)	0 02
[2] Iron Chelate Stock Stolution	
Sequestrene 330 Fe	13 0

CONCLUSIONS

With the increased effort to improve southern pine genetics and to reforest with this improved stock, vegetative propagation by means of rooted cuttings is attractive. Since rooting percentages are low, further work to increase rootability is needed. With the information provided here, one should have the basic techniques to obtain rooting percentages of 30-50 from cuttings of southern pine trees greater than three years old. Since the rooting response of southern pine is slow (requiring two to three months) compared with more easily rooted plant species, the need exists for more careful environmental control than is common with many plant cultivars of horticultural interest.

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CAMERON SMITH: Could you explain Hare's rooting powder?

THOMAS MARINO: IBA at 1% is the auxin. The powder also contains PPZ, Algar 85 as an anti-gibberellin; sucrose and captan 10W as the fungicide. If you want the formula I will send it to you.

BILL SNYDER: Are the roots on one side or distributed around the cutting?

THOMAS MARINO: It is variable The older the cutting the more prone the roots are to be on one side.

BRUCE BRIGGS. Did you remove any of the needles when you put the cuttings in? Did you do a leaching experiment for 12-24 hours? In Japan they have obtained a good rooting response with some pines after leaching

THOMAS MARINO: We left the needles intact and, no, we have not tried leaching.

PROPAGATION AND PRODUCTION OF *RHUS TYPHINA* 'LACINIATA', CUTLEAF STAGHORN SUMAC

RICHARD E. CROSS, SR

Cross Nurseries, Inc
Lakeville, Minnesota 55044

The cutleaf staghorn sumac is a very hardy form with bright green leaves, deeply cut foliage and good fall coloration. It is sometimes referred to as fern leafed sumac.

The propagation and growing of this attractive plant is not a very common practice in midwestern nurseries. This creates a good demand and we are always sold out before our season is over. There are only a few nurseries who grow it.

The procedures described are our own methods and derived from a trial and error procedure over a period of more than ten years. We have found it to be a somewhat difficult and inconsistent subject but by using large numbers and being persistent, we have always had a crop of plants for sale.

Growing conditions. It is one deciduous item we can grow and produce to saleable sizes in one season's growth. Our growing season in Southern Minnesota is normally about 115 days with precipitation averages of nearly 30 inches per year.

Our soils are a silt-loam type and very moisture retentive We do not irrigate them or use any herbicide or chemical fertilizers during the growth period. We try to apply cattle manure to our nursery about every other year.

We harvest this crop in early November when they are completely dormant They are taken to the root cellar and stored until we can grade them, usually in December. The plants will grade out into four sizes, from 9-12 inches to 3-4 foot.

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Propagation. While grading, we get our root pieces for propagation. Most of the plants have abundant root systems about 2 feet long. From these we take as much root as safely possible without harming the plants for sale. We collect the roots and put them in baskets until we have all we need. Last year we cut fifteen bushels of root pieces. The roots we cut are usually one to two feet long. We then put some sphagnum moss over them and put the baskets of roots in the root cellar where it is cool. The moss should not be wet but only slightly moist. They are kept there until worked into cuttings which is usually during January

At that time they are cut into cuttings about four inches long using sharp snips. The roots are slightly tapered; and it is important to arrange the cuttings with the upper ends all pointing in the same direction. Any side roots are removed at this time for ease in planting.

The cuttings are then tied into bundles of 50 with the lower ends being dipped in rooting powder. We use a 0.3 percent IBA in talc (Hormex 3 or Hormodin 2). The treated cuttings are then packed into boxes or baskets with the tops upward and packed well with slightly moistened sphagnum moss.

While working with the cuttings I have the workers use a heavy hand cream or lotion for protection from the sumac sap.

The boxes are then covered with poly and placed in a cool greenhouse 50 to 60°F under benches and left for about 10 days. While here they get some sap moving and begin to callus. This is about the same procedure we use on *Malus* (apple) bench grafts. After this period they are taken back to the root cellar where they are stored until planting time in May. It is important to protect them from water or freezing. The temperature in the root cellar is 35°F.

We like to remove them from the root cellar several days in advance before going to the field to warm them up before planting.

Field planting. We do our planting in the first part of May when the soil has warmed somewhat. We select a field that was weed free the previous year. The soil is worked well to make planting easier and also destroys any seedling weeds. The cutting boxes are taken to the field and unpacked as they are needed. We use a mechnical transplanter to plant the root cuttings. They are spaced 8 to 9 inches apart and in rows 44 inches apart. The cuttings are set upright with their tops even or slightly above the soil surface. A crew member walks behind the planting machine and straightens any tipped cuttings and also tramps the soil on both sides of the cutting. Some are

not packed well enough with the machine and may dry out if this is not done carefully. After planting is completed they are cultivated very carefully and the soil is loosened to keep from crusting. Usually in about 2 weeks they are cultivated again very slowly and carefully to control moisture At this time it is difficult to see the rows, therefore, stakes are placed in the rows to guide the operator.

Sprouts start to show in about a month after planting. Cutleaf staghorn sumac sprouts very slow and erratically. Some will take as long as 2 months to come up. After most have sprouted we cultivate once with hand scratchers very carefully, this loosens the soil around them and removes any weeds. If a hoe is used it may damage too many as there are still some under the surface.

The sprouted cuttings are very soft and fragile when small. About half of our 1980 crop in one field was lost in a June hail storm just as they were emerging. Because this plant is so fragile, we try to plant it in two fields several miles apart for protection from hail and severe storms.

The cultivation and weeding process is continued until growth is well established and too tall to go over without causing tractor damage. This is usually about mid-August. From then on the plants are left on their own. Most of the one year plants have a single stem or cane. If left for two years they are two and three cane plants but grow so large they are difficult to store and ship.

Harvest and storage procedures. After coloring beautifully in September and October the plants lose their leaves and ripen quickly during the hard frosts of late October. In early November they are dug using the Kelley type side-mounted digger and taken into the root cellar before severe weather arrives They are stored under high humidity at about 35°F until grading time in December. It is important that they are not allowed to get too wet as this will cause mold and bacterial rot.

RESULTS

This I consider to be the most important part of any propagation — the yield of saleable plants. This varies from year to year. It has run from 50 to 90%. This year we harvested over 6,000 plants and our yield was over 76% saleable plants.

OTHERS METHODS OF PROPAGATION

Cutleaf staghorn sumac is not grown from stem cuttings by any commercial nurserymen that I know of. We find root

cuttings a most satisfactory method. This technique should be used on a lot more deciduous plant materials.

REMINISCENCE ABOUT THE PAST

When I attended my first Plant Propagators Meeting it was held in Cleveland and I have only missed a few meetings since. That was twenty years or more ago. There was Case Hoogendorn, Martin Van Hoff, Leslie Hancock, Roy Nordine, Vince Bailey, and many others who became my good friends. And yes, even Bill Snyder was there, but we all looked a little different then.

I believe this is my last meeting. They tell me at the nursery that "I'm being put out to pasture," after having grown and sold plants commercially for over 50 years. Florence and I plan on an active retirement in Cass County, Minnesota, where it is beautiful, green and cool.

PETER DEL TREDICI: What about taking root cuttings early in the spring before growth and planting them out immediately to avoid some of the pretreatments? I grew *Comptonia peregrina* both ways with equal success.

RICHARD CROSS: It probably would be fine but it does not fit our schedule

VOICE: My dad did *Rhus* propagation and he always said it was important to dry them after cutting. Did you say you did that?

RICHARD CROSS: We do not dry them. However, putting them in moss in the greenhouse at 50°F probably does that.

PROPAGATING DWARF CITRUS WITH HYDRONIC RADIANT HEATED BENCHES

DONALD F. DILLON

Four Winds Growers
Fremont, California 94538

At Four Winds we produce over 30 citrus cultivars which are useful to the home gardener for their fruit production, their beauty as an evergreen, and for their flavors and aromas. Cultivars are chosen to ripen at many different times of the year, offering the home owner a great variety in choices.

Our trees are produced by a method called twig-grafting, developed originally by Halma and Frolick at UCLA a good

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Our trees are produced by a method called twig-grafting, developed originally by Halma and Frolick at UCLA a good

many years ago. The details of our production methods, our history and our greenhouse operations are covered in an earlier paper at a Western Region meeting in San Dimas in October of 1962. At this time we'll attempt only to give a brief review of things that have occurred from 1962 to the present date, and some changes that we have found necessary. Our production involves the use of fresh new twigs — those that first appear from the spring flush and are hardened off to the point where we begin our work in May or June. Cuttings are taken from both scion and understock mother plants and brought into a propagation room which we attempt to maintain in a condition of at least kitchen cleanliness. The plant material of course is highly susceptible to infection by various pathogens while it's in process and until such time as it has been rooted and the graft healed. The scions and understocks are each prepared with a long sloping cut without a tongue. The scion and understock are then matched up and fastened together with a single strand of rubber band. From this point on the two mated pieces are handled as through they were a single cutting. These cuttings are stuck in flats containing vermiculite, the coarsest grade possible. We use a rooting hormone roughly equivalent to Hormodin #3.

Due to the fact that the scion has no contact with the rooting medium, it is, of course, necessary to produce the plants in conditions of extremely high humidity until callus has sealed the graft union. We use a Monarch fog nozzle F 110 C-2.0-120° under 125 pounds pressure which produces roughly 2.2 gallons of fine mist per hour if allowed to run continuously. Our misting period will run from 7 to 15 seconds at time intervals from 1½ to 5 minutes. The heads are located above the benches in such a fashion that when they are not in operation any drip falls free and clear of the flats below and drops into the aisle The mist produced creates a fog which completely fills the house between mistings. It is not our intent to really irrigate the understocks and the rooting medium, merely to keep the humidity as high as possible. Nevertheless, a substantial amount of moisture does accumulate in the flats and in the room, and conditions are overall quite wet.

Our source for bottom heat, which we consider essential to swift rooting, has for 25 years been provided through electric heating cables in benches. With heat we get roots, without it we don't, even after 4 weeks in the same mist house. We learned through one of our more sensitive employees whenever we had an electrical short she complained about getting a mild shock as she stuck the twig grafts in the flat. When we checked with a voltage meter, we registered 3 or 4 volts in the leaves. With 220 volts and the wet conditions, I have been

concerned over the years that someone was going to get hurt sooner or later, even though the house was safety checked by a competent electrician each year. The electric heating cable worked more or less satisfactorily but we decided some changes were in order in 1979

Bruce Usury, president of the Western Region of IPPS and vice-president of propagation and production at Monrovia Nursery in Azusa, California, in a report to the California Association of Nurserymen refresher course, which was reprinted in *American Nurseryman* in September 1, 1981, showed that, in their experiences with electric heating cables, that while they were relatively inexpensive and easy to install, they did corrode and break easily. After about 5 years only about half of their system would still work. Our experience has been much the same.

In the course of a Society field trip in 1977, we observed ground beds complete with hot circulating water in CPVC plastic pipes through a bed filled with scoria. We understand, however, that the plastic pipe can expand 12 to 18 inches over a 100 foot length and that it is necessary to keep the top of the bed loaded with flats to avoid having it pop up out of the lava rock. The beds were equipped, as well, with mist heads. The entire operation was conducted out-of-doors rather than in an enclosed greenhouse. We were intrigued by it, but felt that our situation, requiring the retention of high humidity for the benefit of the scion, would necessitate that we continue with production inside a greenhouse. Additionally, ground benches seemed to lend themselves to being walked on, and a strong chance to spread disease. We believed that we should continue with benches.

Our inquiries led us to another large grower in northern California where indoor benches of concrete using polyethylene tubing to circulate hot water were being used. We were satisfied that this was the way we should go. A contractor gave us some preliminary cost estimates. Frankly, they were staggering We inquired what cost so much and he said, "After all, you're attempting to grow plants on a raised bench with concrete and copper tubing. The benches should last 30 or 40 years and therefore should be quite inexpensive in the long run". We inquired whether or not it might be possible to eliminate the copper and use CPVC or polyethylene tubing as a conduit for the hot water in the benches He looked me squarely in the eye and said, "If you want to use that stuff, get somebody else. Those materials are bound to deteriorate over a period of time and we simply won't guarantee the job." Needless to say, we proceeded following his direction and paid the price.

In January, 1979, we started work. Our first effort was to create concrete walks inside an existing greenhouse. Having completed that, we proceeded to build legs for the benches. After much deliberation we finally settled on the individual masonry blocks. We're fortunate in having a manufacturer of these blocks nearby and were able to acquire blocks that were "seconds" at a very reasonable price Their only defect seemed to be that they were slightly off color. Each leg is built from four 8″×5″×8″ blocks. We set two legs every four feet. The legs cost $1.12 per sq ft of bench.

The next big problem was how to hold the wet concrete in place after it was poured until it set up The only solution seemed to be to use plywood. We finally settled on ¾″ exterior ply This added another $0.36/sq ft of bench — total $1.48 for legs and bench bottom This added $1,776 00 to the cost of a modest area of 1200 sq ft of benches. We believe we have more than recovered the cost through relatively disease-free production after only 3 years The benches should last 15 to 20 years. We've talked to a number of people trying to learn how it might be possible to remove the plywood for re-use as we developed additional benches. No one seemed to have a good suggestion so we decided to just simply leave it there, figuring that in time even if it rotted out, the benches would still be intact Our conractor designed the system and supplied the material. The whole installation was accomplished by our own work force. The tubes are approximately 9″ apart. There are four ¾″ tubes running in the bench which is 36 feet long.

We poured the cement using a concrete pump, figuring that it was a lot easier to pump in the concrete rather than to carry it in wheelbarrows, etc.

The top of the bench is 27 inches above the walk. They are 4½ inches thick along the aisle, sloping to 3½ inches thick at the rear of the bench to allow surplus water to drain away from the walk.

We built ten benches — each 120 sq ft. Each bench has its own thermostat and zone control valve. No energy is being used where the slab is holding its temperature. We can vary the temperature for different rootstocks or turn them off completely when hardening off.

The benches, together with the prorated share of the boiler, built by A.O. Smith with 160,000 btu's — cost, then, $3.94 per sq ft. We believe that a boiler this size would be able to accommodate at least 40 such benches, inasmuch as not all of them are on at the same time because of the long heat retention of the concrete. In order to raise the temperature of 1 cubic foot of concrete 1°F it takes aproximately 32 btu. Our system is capable of raising each bench 4°F per hour at a flow

rate of 1 gallon per minute. This allows maximum heat exchange to the concrete.

Between each crop the benches are given a thorough coat of copper naphthenate which works great. We have tried spraying it on with a Hudson sprayer but this causes too much vapor

Our twig grafts were stuck in fumigated flats on November 4, 1981. By November 24, 1981, we find more than half of them had two or more roots of 1 to 1½ inches in length. We expect that they will be well rooted and healed (80 to 85%) in 6 to 10 weeks and be ready to be hardened off before planting directly into a one-gallon container.

As mentioned earlier, Monrovia Nursery had built their new beds in early 1981. Theirs is a magnificent propagation facility on the ground In all, it occupies approximately 2½ acres. Each of their beds is approximately 14×110 feet long They have ½" copper pipe spaced in each bed at 9" intervals. The hot water is pumped at 2 gpm (twice our 1 gpm), because of the long length of the bed It enters at 110°F and exits 110 feet away, having lost 2°F, at 108°F. They attempt to maintain a temperature in the flats of about 72°F. Each of these beds are 1540 sq ft, and can hold approximately 800 flats or 178,000 cuttings. Each bed cost them $5,314 to install which, exclusive of their mist system, amounts to about $3 per square foot. This is only about 3¢ per cutting on just one crop The important point seems to be that under their previous propagation methods their results varied from about a 50 to 55% success rate to, up now to, 70 to 75% with the plants now growing uniformly and free of disease. In contrast to our tiny little water heater, producing 160,000 btu, Monrovia has two 150-horsepower boilers which produce 5,021,250 btu each Of course, these supply hot water to their new 2½-acre propagation beds in addition to their greenhouses

All of us who use mist in greenhouses generally have problems with algae build-ups on walks and on the benches. I had observed blue color on the walks at Monrovia and had inquired what treatment they were using. The answer was copper sulfate. I decided to deal with our problem in much the same way and applied copper sulfate — just a wettable powder — at the rate of about 1 lb per 30 square feet which I simply spread with a broom, making sort of a slurry with the moisture on the walks. I can report that our walks turned a lovely blue and after five months there is no apparent algae build-up thus far. I have no idea how long it will be before retreatment will be necessary. I similarly treated adjoining walks with Consan at the rate of 10 oz/gal. These walks required retreatment in approximately three weeks. They now have been

treated with copper sulfate and it appears to be holding up very nicely

I checked back with the nursery where we had first seen the concrete benches, built in 1974, using polyethylene tubing instead of copper tubing. I was told that the polytubing has disintegrated to a point where the benches are totally inoperative. They looked so beautiful and had inspired us to build ours. I think we had good advice. It seems that the high initial cost of concrete benches containing copper tubing with circulating hot water would appear to provide us a propagation facility which is durable, safe, sanitary, low maintenance and economical to operate. While more costly to install initially than electric heating cables, they can be operated with an energy cost that is about ¼, using natural gas, than would be the case using electricity. As energy costs seem destined to continue to rise, we will consider use of solar panel boosters.

We are able to produce disease-free plants which come out at 80 to 85%. We've had these benches in operation now through three crops and have put through almost 375,000 trees, bringing the capital cost per cutting down to only about 2½¢ each in only three years. In considering that these benches will probably last 25 or 30 years, the investment appears to be warranted.

Thursday Afternoon, December 10, 1981

The Thursday afternoon session convened at 2:30 p.m., with Hugh Steavenson serving as Moderator.

COMMON SENSE IN PLANT PROPAGATION

PAUL L. SMEAL and JAMES S. COARTNEY
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

It has been 20 years since attending my first Plant Propagator's meeting in Washington, D.C., and, after attending some 16 IPPS meetings and over 100 nurserymen's short courses, nursery tours and trade shows, the same question always asked is "what's new?" Plant propagators and nurserymen are always looking for that new chemical which gives 100 percent rooting, or the new fertilizer or pesticide that solves all problems, or the machine that ends all labor. One hates to disap-

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point the inquirer, but the magic chemical or the magic machine still has not been found The successful propagator must continue to rely on "common sense" to solve plant propagation problems.

Prior to propagating any plant, there are questions or things to consider in the planning stage. First, what plants to propagate? Then, how many to propagate, how much propagation space is required, equipment and supplies needed, and the time involved? After these questions have been answered, then one has to decide if it is to their advantage to propagate or to buy seedlings, cuttings, liners or grafts. Only the owner or nursery manager with input from the plant propagator can answer these questions If the decision is to propagate, then more and more planning is required as to when to propagate, and what propagation medium and growth regulator to use

Knowing when and how to propagate a given plant can be found in various plant propagation books, IPPS publications, scientific and trade journals, and from other nurserymen and plant propagators. In gathering information, get all the available facts, and don't try to take short cuts. Any one change in procedure can affect other parameters and the result may be failure. Next assemble a list of supplies and chemicals needed for propagation and be sure they are on-hand before starting to propagate.

Another aspect that requires common sense is selection of propagation material Is the propagation material coming from stock plants, plants grown for sale, or from other nurseries or botanical gardens? In all cases, the plants must be properly identified; healthy, growing under proper nutrition, and disease, insect and weed free. Only quality plants and not left-over plants should be used for propagation. A common problem of many small greenhouse or bedding plant growers is propagating from plants not sold instead of selecting from the best plants When a grower does this over a couple of years, the entire crop may be of poor quality and the grower wonders why. If a stock block is developed, it should be near the propagation area where it can be properly cared for and not miles away

The propagating structures, greenhouse, cold frames, or outside beds should be properly constructed to make maximum use of the propagation space. The misting equipment, heating and ventilation controls should be all checked out to insure that they function properly. If bottom heat is used, is it working and is there uniform heat throughout the propagation medium? Use a thermometer to check the temperature in several places Cleanliness is a must, and this includes freedom of insects, diseases and weeds. Prior to propagation, the

medium and containers must be sterilized or disinfected. Clorox makes an excellent disinfectant when mixed 1 part Clorox to 9 parts water

The propagation medium should have all those desirable characteristics you already know such as: well-drained, holds moisture, porous, uniform, readily available, free of disease, insects and weeds, pH compatible to plant propagated, and one that can be sterilized without changing composition. Lack of a well-aerated or porous medium can be a major problem especially if very fine sand or other fine inert material is used. Water remains on top of the medium and contributes toward an abundance of algae.

The use of chemicals, rooting substances, fertilizers and pesticides are required for successful propagation In selecting a rooting hormone, a commercially prepared material may be purchased or one can buy the active ingredient, such as IBA and make their own solutions Select a rooting hormone that has been used successfully and at the recommended strength. A common problem is trying to use a concentration which is too strong and which injures the cutting Fertilization may not hasten root initiation, but will improve the subsequent growth of the rooted cutting. Fertilization may be by injection through the mist system or by using a slow release fertilizer in the rooting medium If used in the mist, remember that fertilizer is extremely corrosive to metal Perhaps it is human nature, but there is a tendency to believe that the more chemical used, the better the results. This is not so, as more cuttings, seedlings and liners are killed from too much fertilizer than from too little.

The propagation of cuttings using benches versus ground beds and flats versus pots depends upon the individual nursery. All methods have advantages and disadvantages. The decision depends on space, labor, costs and the overall method of production It appears that more nurseries are going to flats for rooting and growing liners as it is easier and therefore, cheaper to handle large numbers of plants as a unit. A critical point in inserting cuttings and potting of rooted cuttings, is not to put them too deeply into the medium. Results of planting too deep are readily seen by the development of a second root system near the surface.

Successful plant propagation does not come easily. It requires the knowledge of the why and how of plant propagation, knowledge of how plants grow and reproduce, and constant evaluation and re-evaluation of propagation practices. The most successful propagators are the ones who are the most careful about details and observe "common sense" in the propagation.

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PRODUCTION OF CONIFER SEEDLINGS

HANS HESS

Hess' Nurseries, Inc
Cedarville, New Jersey 08311

There are many different things to consider in the production of evergreens from seed. I believe one of the more important is the source of the seed you buy For example, Douglas fir seed from the Rocky Mountain area of Colorado is hardy and has a medium growth rate. Seed of the same species coming from Oregon and Washington at elevations of 500 to 600 feet is much less hardy and has a far more rapid growth rate

Juniperus virginiana from mid western sources will be crossed with *Juniper scopulorum* and will not resemble the true eastern red cedar. White pine is available from New York the lake states and the south, for planting in northern areas New York and lake states seed is the most desirable.

A seedling business that is going to be successful should provide a continuing supply of seed selections each year. This can be a problem if you buy seed on a year to year basis and there is a no crop situation on one or more plants. To prevent this problem a grower should provide himself with some sort of refrigerated storage, then he can keep a year's supply of seed on hand to prevent shortages. Conifer seed in dry refrigerated storage of 34°F will retain its viability for several years.

Soil type is a very important consideration in conifer production. A well drained, light sandy loam soil is best for most conifers. This soil type provides for rapid drainage during wet periods and encourages the development of a more fibrous root system, an essential for survival when transplanting.

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Preparation of the seed bed area must receive careful attention Sufficient land should be available to allow for a two year cover crop, three years is even better. A good permanent grass can be used or, a rotation of Sudan grass in summer and a rye grass for winter These should be fertilized and limed if necessary for a pH of 5 5 to 6, since most conifers prefer a somewhat acid soil. The area to be seeded should be plowed in August to permit the cover crop to break down somewhat. Disc as needed and then fumigate with methyl bromide or other soil fumigants to eliminate nematodes and as many weed seeds as possible When methyl bromide is used the material is injected at about 8 to 10 inches and covered with plastic. This remains in place for 72 hours before being removed When the plastic cover has been removed the ground should be cultivated to allow the remaining gas to escape. After 10 to 14 days the area is safe for planting.

We use a raised bed for planting and to get this a bed maker is used. This has two disks which throw soil to the middle which is leveled by two angled planks and a mica harrow. The resulting bed is 42 inches wide with a three foot path between the beds

The seeding at our nursery is a hand operation. The seed is broadcast by hand, one person on each side of the bed. We have purchased a seeder and, are experimenting with this and hope to have it working satisfactorily in the near future. After a bed has been seeded it is rolled to press the seeds into the soil. After this is completed a sanding machine spreads an even layer of sand on top of the bed about ½ inch deep for most cultivars. We put a marsh grass known as salt hay on top of the sand and hold this in place with erosion cloth pinned down with 6-inch staples. This prevents the erosion of the beds from heavy rains. Seeding is done in late October and early November. Although you can also get good results planting early March on most cultivars.

Birds, especially the wrens and sparrows, are very fond of pine and spruce seed and will destroy the entire crop as it germinates and the seed is still on the cotyledons. They pull the seed and the cotyledons off leaving just the stem. To prevent this problem we coat the seed with a very thin layer of linseed oil and then apply powdered red lead prior to planting and not one seedling is touched.

Seed germination takes place in our areas (which is zone 7) during March and April. Seeds of *Cedrus deodara* and other *Cedrus* species and cultivars are first to germinate, usually about March 10th to March 15th. Pine and spruce seed germinates in late March and April, and *Taxus* germinates usually in late April and early May.

As soon as germination begins the erosion cloth and salt hay are removed. Evergreen seedlings need shade to prevent damage from the sun and we immediately punch 2×2 pointed stakes on the outside of the bed on top of which we stretch wire held on the stake by a staple, and the wire is drawn tight on each end and the lath shading rolled out on top.

Our soil being a light sandy loam requires plenty of water and fertilizer for good growth. Irrigation mains are put in place soon after germination and remain for the entire season. We apply, if there is no rain, 1½ inches of water per week and 200 lbs of 20-10-10 fertilizer per acre every two weeks. The fertilizer is applied by plane since a tractor can not go over the lath shading. Fertilizing is shut down by mid August so that the plants can harden for winter. In mid-September we remove the shading from the seedlings except for a few cultivars which need the shade for winter proteciton. These would include *Cedrus* and fir species.

The growth response is quite good. *Taxus* and hemlocks are 2-4 inches in height, most pines 3-6 inches, *Platycladus orientalis* (Syn.: *Thuja orientalis*), 6-8 inches and, *Cedrus deodara*, 8-12 inches. We sell the *Cedrus deodara* as one year plants. Many of them are of sufficient caliper to be used as grafting understock A few pines are also sold as one year plants for potting to prepare for spring field planting.

The majority of the evergreen cultivars are not ready for sale until the end of their second year. During the second year we use a combination of 20-10-10 and Osmocote 14-14-14, a slow release fertilizer. This combination is applied every 3 weeks during the growing season. The first application is applied in March and the last in mid-August. Water is applied at the same rate of 1½ inches per week during the growing season. Our two year seedlings are of good caliper and height. *Abies concolor* 6-10 in, Douglas fir 10-15 in, *Pinus strobus* 6-8 in, Japanese black pine 10-15 in, *Taxus cuspidata* (Syn.: *T capitata*), 6-8 in and, *Tsuga canadensis* 8-12 in.

WOODY TREE AND SHRUB SEEDLING PRODUCTION

WAYNE LOVELACE
Forrest Keeling Nursery
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Production of tree and shrub seedlings in open field beds presents many management factors not present in more controlled seedling production programs such as greenhouses, coldframes, and other protected structures. It represents one of

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the more intense types of field production often exceeding 200,000 plants per acre. An investment with this potential requires as much pre-planning and technical management as possible in order to produce the desired size and quality seedling at the least possible cost Many factors affect this production, presenting opportunities for profit when properly implemented

SITE SELECTION AND LONG RANGE PLANNING

We are located on the first hills adjacent to the Mississippi River. These rolling hills are capped with a deep layer of windblown, well drained loess soil, which is particularly suited for seedling production. They are also higher than the surrounding countryside giving good air drainage, thus good protection against late spring frosts Inherently these are timber soils suggesting a most suitable soil for our production of 100 selections of deciduous tree and shrub seedlings.

Future production areas are established to a heavy sod pasture grass, predominately improved strains of Kentucky fescue, to begin a long range soil buildup. During this period, ideally 4 to 5 years, these areas are grazed intensively by a cow-calf herd, the objective being to convert the forage produced to organic matter (manure) An optimum fertility level is maintained during this phase of soil building, making certain we are adding more to the fertility level than we are removing.

Following 4 to 5 years of sod culture the pasture is chisel plowed keeping a high percentage of organic matter produced from the sod in the upper 6 to 8 inches of the soil. The soil is then fallowed for 1 to 2 months to break-up life cycles of weeds. An application of approximately 1,000 lbs of inorganic fertilizer (28-14-14 analysis) is applied followed by 30 tons of chicken manure per acre. A seedbed is prepared and hybrid Sudan grass is planted for green manure production After reaching about 6 feet tall it is cut with a rotary mower and chopped as much as possible. Regrowth occurs very rapidly and the mowing process is repeated again. We are able to mow as many as 3 to 5 times before fall. The combination of chicken manure and Sudan grass promotes a maximum of biological, physical, and organic properties that aid greatly to the seedling crop to be produced. Since we embarked on the use of chicken maure we observe a profusion of mycorrhiza present on roots of most species we grow Other beneficial results derived from the use of chicken manure have been observed in connection with improved seed germination. These will be discussed later.

SEED SOURCE AND PROCUREMENT

The value and source of good viable seed cannot be stressed enough in seedling propagation. A history as to origin, adaptability, hardiness, and any other pertinent information is important when a species is added to our production program. Where possible we have established seed rows in the nursery to insure our own supply of many items we grow. We prefer to produce our own seed whenever possible Many species do not seed well locally so alterate sources must be established to insure a supply. A good dependable source of seed is invaluable to the seedling grower. Close contact should be maintained with those sources as to crop outlook and availability. Records should be maintained as to true-to-name, stands secured, growth rates, and other pertinent information so you know what to expect from this same source in future crops. Many species do not bear fruit annually. They might bear crops of seed biennially or, in some cases, as long as 10 years lapse between good seed crops. Here good seed storage facilities become necessary. A future supply can be stored in a good crop year to insure an annual supply of seed until another crop occurs Under ideal storage conditions, usually about 0 to −10°F and sealed in air tight containers, seeds of many species can be stored for a period of years with very little loss of viability. The length of storage and temperatures vary from species to species so one should research each specific species before attemtping extended storage.

We collect approximately ½ of our seed. Collection is essentially a hand operation. Fruits can be hand picked from the parent plants, or nearing natural dispersal time, they can be flailed onto a plastic tarp or net. Larger seed such as acorns, walnuts, or pecans or simply picked from the ground after they fall and before the rodents store them for winter

Species bearing seed enclosed within a fleshy fruit must be separated and cleaned, then dried prior to seeding. Most of these fruits contain inhibitors that impair to some extent seed germination. Fruit can be removed in a number of ways. Our quantities are large enough to justify use of mechnical macerators that are commercially available They are designed to remove the pulp as water is applied acting as a cushion preventing injury to the seed and to float the pulp away. On more stubborn species a conventional hammermill will suffice, using water again and a slow speed. A hammermill will also clean seeds of many species such as redbud as well as other species normally born in dry pods. There are many other methods of cleaning small lots of seed mostly by hand rubbing and screening on up to very sophisticated machinery; however the above methods are predominately used.

Upon completing the cleaning and drying (if required) many species need further treatments. Those having impermeable seed coats require some form of scarification. We use essentially four approaches to this problem. They are:

1 Mechanical. Using this method seed are blasted under pressure on an abrasive surface physically scratching the seed coat.

2. Acid soak Soaking the seed in concentrated sulfuric acid until the seed coat is burned about ½ way through

3. Hot water. Soaking in hot water bringing the temperature to the boiling point, then adding the seed and letting soak until the water cools.

4. Biological. Early planting to allow more time for natural seedcoat breakdown in the seedbed.

PREPARATION OF THE SEEDBED

Following the soil building program outlined earlier, and the necessary seed pretreatments, preparation for planting begins. We use 1000 lbs per acre of 28-14-14 analysis commercial fertilizer, applied to the production areas to be seeded. Seedbeds are then formed with a commercial bedformer. They are raised 4 to 6 inches high, 48 inches wide, with a 2 foot pathway on either side making them 6 foot center to center. This spacing will accommodate any standard row-crop machinery thus getting away from specialized equipment. By concentrating the top soil in a raised bed much improved drainage and aeration occurs, essential to good seed germination and subsequent growth. Also organic matter produced in the soil building program is concentrated in the seedbed further improving the physical and biological makeup.

SEEDING

Determining the number of seedlings to produce per square foot becomes most important We find under our conditions and for our market we produce our best quality seedling at a density of 5 to 10 per square foot, depending on the specific species and its ultimate use. The number of seed to plant per square foot in order to get the desired density becomes extremely important A sample of each seed lot is weighed to determine the actual number of seed per pound. Then a cutting test is made to determine as close as possible the percentage of sound viable seed in the lot. At this point past records are studied and good judgment and experience is called upon. The above information combined with the projected production quotas indicate the number of bed feet to be planted. A majority of our planting is done by hand. A skilled,

experienced, seeder can evenly distribute the desired number of seed over the bed area. We do some mechanical seeding, but find the diversity of size and shape of various species to be an almost unmanageable problem in our situation. We do both broadcast seeding and row seeding Usually species having larger seed such as oaks, walnuts, chestnuts, filberts are planted in rows and also certain species that have a tendency to dry out such as some of the maples. After sowing, the bed area is rolled with a cultipacker pressing the seed into the bed surface. Then a mixture of sawdust and hardwood bark is applied for a mulch. The bark tends to stabilize the sawdust and hold it on the surface of the seedbed. Also we feel we are deriving additional pathological benefits from the use of hardwood bark.

Timing of our seeding depends upon the length of after-ripening required for the species we are growing. Some species such as certain viburnums are seeded as early as mid-June, remaining in the ground for 9 to 10 months before emergence. This method of production was made possible mostly with the advent of the knock-down herbicides, Paraquat and Roundup, so weeds can be controlled by repeated sprayings. Since we depend on most of our after-ripening to occur in the field beds, we find ourselves seeding virtually every month of the year that our soil can be tilled.

SEEDLING GERMINATION AND GROWTH

Since embarking on our soil building program, we observe much improved seed germination. Improved aeration with the added accumulation of organic matter has been a prime factor. Beyond this we feel the increased biological activity is helping in the breakdown of seed coats on most species, thus markedly improving our germination percentages Over the last few years under this program we have reduced our average sow rates up to 50%. We are convinced this saving is tied to our soil program

After emergence occurs we shift our emphasis to cultural practices aimed at producing maximum growth in one season As soon as true leaves appear on the young seedlings, Dacthal herbicide is applied at 6 pounds per acre to aid in weed control. Also fertilizing begins with an initial application of 300 pounds of 28-14-14 applied per acre. An additional 1,000 to 1,500 pounds per acre will be applied periodically throughout the remainder of the growing season. Coupled with sufficient water supplied through our solid set irrigation system our goal becomes getting maximum growth in one year Size for size a one-year seedling is far superior to a two-year or older seedling as to survival and growth after transplanting. For this

reason we take every step to push our seedlings to maximum size in a single growing season

Good seedling production practices must continue until the crop is harvested, graded, stored and shipped making certain a minimum amount of stress is placed on the plant material. Great care is exercised to apply a protective spray in the field as soon as the seedlings are dug and placed in pallets. The pallets are tarped for additional protection while transported to the storage buildings. They are held in high humidity storage (98 to 100% relative humidity) during the storage period, which begins in November and extends through the following May for a portion of the crop. When grown properly and handled carefully, one can approach a near perfect stand when the seedlings are transplanted to the nursery for future production.

SIGNIFICANT ENVIRONMENTAL AND BIOCHEMICAL FACTORS IN SEED GERMINATION OF *LIRIOPE MUSCARI* AND TWO RELATED TAXA

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Liriope muscari (Decne.) Bailey, big blue liriope, is one of the most commercially important groundcovers in the southeastern landscape, and is also widely used in the southwest and California. Hardy to Zone 6, it could be used in additional geographic areas. The 1 to 2 foot grass-like evergreen foliage; lilac-purple flowers borne on a spike above the foliage; sun and shade tolerance; and adaptability to a wide range of soil types are traits contributing to its popularity. *Liriope* displays a high degree of salt tolerance which makes it particularly useful in coastal landscapes (5,20).

Abundant blue-black, single-seeded berries are produced on upright spikes in the fall. Seeds are globose and the embryo is surrounded by copious, hard endosperm A deep blue-black skin envelopes a purple, pulpy inner matrix (collectively called pulp). Seed appears to be a logical method of propagation, although division, which is not only time consuming but expensive, is the only method referred to in the literature (1,5,20).

Dormancy mechanisms in other members of the Liliaceae, specifically *Trillium grandiflorum* (Michx.) Salisb. (3), *Polygonatum biflorum* (Walt) Ell. (3) and *Lilium* (2) species posed ques-

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tions as to the germination requirement of *Lirope muscari* The subsequent studies were designed to determine the endogenous and/or exogenous factors that are necessary for seed germination in *Liriope muscari*. It was hoped that a commercially feasible recommendation for seed propagation could be established.

Additionally, similar fruit morphology and paucity of information pertaining to their seed germination prompted germination studies of two related taxa. The taxa included· 1) *Liriope muscari* L 'Variegata', variegated liriope, similar to *L. muscari* in morphological and cultural requirements, with the exception of leaves having two white marginal stripes and a central green band, and 2) *Ophiopogon japonicus* (Thunb) Ker., mondo grass, a member of a closely allied liliacious genus. *Ophiopogon* resembles liriope in gross morphology, differing mainly in its shorter height (16 to 37 cm), narrower leaves (0 2 cm), reduced cold hardiness (Zones 8 to 10), and a flower scape that does not exceed the height of the foliage. These two grasslike perennials are also valuable groundcovers in the southeast, and are commonly propagated by division, with no documentation of the specifics of seed propagation present in the literature (1,5,9)

The work is divided into three parts· 1. determining the effects of stratification, depulping, and growth regulators on *Liriope muscari* seed germination, 2 seed germination of *Liriope muscari* 'Variegata' and *Ophiopogon japonicus*, based on the most successful methods with *Liriope muscari*, and 3. characterization of substances inhibitory to seed germination in the fruit pulp of *Liriope muscari*

1. Fruit of *Liriope muscari* was collected on November 3, 1979 at the University of Georgia Botanical Garden, Athens, and stored dry for 120 days at 5°C Intact fruits were: (a.) soaked for 24 hr in distilled water, placed in a 0 5% sodium hypochlorite solution for 15 min , rinsed in distilled-deionized water; or (b) given only the 0 5% sodium hypochlorite sterilization treatment. Both groups were then placed in polyethylene bags with moist sphagnum peat and held at 21°C in a Precision Scientific incubator. For each treatment 150 seeds were used.

Depulped seeds were either soaked for 24 hr in water (control), or the following growth regulators. gibberellic acid (GA_3), 30, 60, 90 ppm; kinetin, 30, 60, 90 ppm, and GA_3 + kinetin, 30:60, 45 45, 60:30 ppm. The seeds were then rinsed, treated with sodium hypochlorite, rinsed with distilled-deionized H_2O and placed in polyethylene bags with moist sphagnum peat at 21°C All treatments for intact and depulped seeds were duplicated and placed in cold stratification at 5°C to

determine whether the species needs a chilling requirement prior to germination. When a majority of the seeds germinated (after 6 weeks) in warm stratification, evaluations were made of percent germination, radicle length, and presence of shoots. The experiment was conducted in a completely randomized design with 13 treatments All treatments were replicated 6 times with 10 seeds per replicate. Analyses of variance and chi-square tests were performed according to Ott (13).

Radicle emergence from depulped seeds was evident after 3 weeks. At the end of the 6th week in warm stratification, radicle emergence in excess of 90% and shoot emergence ranging from 68-88% were observed in the depulped treatments (Table 1). Germination percentages for both radicle and shoot emergence among all depulped treatments were not significantly different. However, seeds soaked in water had shorter radicles and less shoot development compared to those receiving growth regulator treatments. Among the various growth regulator treatments, GA_3 at the various concentrations produced longer roots with secondary branching and shoots in excess of 40mm. GA_3 + kinetin treatments produced roots of similar size to GA_3 alone but shoot development was noticeably less. Kinetin produced shoots and radicles intermediate between GA_3 and GA_3 + kinetin.

Table 1. Effect of stratification, depulping, and growth regulator pretreatments on the germination of *Liriope muscari* seed

Treatment	Conc (ppm)	Germination (percent)	
		Radicle emergence	Shoot emergence
Depulped			
Cold stratification		0 a[z]	0 a
Warm stratification		90 b	68 b
GA_3	30	100 b	88 b
	60	95 b	83 b
	90	97 b	88 b
Kinetin	30	92 b	75 b
	60	95 b	80 b
	90	93 b	77 b
GA_3 + kinetin	45 + 45	87 b	70 b
	30 + 60	98 b	87 b
	60 + 30	97 b	88 b
Intact			
Warm stratification			
Water soak	38 c	23 c	
Non-soak	25 d	7 d	

[z] Mean separation within colums by X^2 test, 5% level

In contrast, intact fruits showed limited germination and, after 6 weeks, soaked and non-soaked seeds germinated (radicle emergence) 38 and 25%, respectively. Shoot emergence was

also reduced, being 23 and 7% for soaked and non-soaked, respectively.

2. Fruits of *Liriope muscari* 'Variegata' and *Ophiopogon japonicus* were collected from plantings on the University of Georgia campus, Athens, in early December, 1980. Fruits were mechanically depulped by placing them with an equal volume of distilled-deionized water in a blender (blades masked), dusted with Captan® 50% WP (replacing the sodium hypochlorite treatment) and placed in polyethylene bags for warm stratification (3). Depulping was compared to the control treatment in which fruits were left intact. Both treatments for each taxa were warm stratified in a Precision Scientific lighted incubator (18μEm^{-2}sec^{-1}, 24°C). Each treatment was replicated five times, with 60 seeds per replicate The experimental design was completely randomized. After 6 weeks in warm stratification, seeds were evaluated for germination. Radicle and shoot emergence were used as the germination indices. Seedlings were then transplanted and grown under greenhouse conditions (13°C night, 24°C day). Differences in germination percentages between depulped and intact treatments were statistically analyzed by a t-test according to Ott (13). Seedlings of variegated liriope were evaluated as to type of leaf variegation pattern after 6 weeks in the greenhouse.

Germination percentages for depulped seeds and intact fruit of *Liriope muscari* 'Variegata' and *Ophiopogon japonicus* are shown in Table 2 In both taxa, depulped seeds germinated at higher percentages than controls. Radical emergence percentages were 77 and 74% for variegated liriope and mondo grass seeds respectively. Intact fruits of both taxa showed negligible shoot emergence (3%) after 6 weeks in stratification. Seeds continued to germinate sporadically in the greenhouse.

Table 2. The effect of depulping on germination of *Liriope muscari* 'Variegata' and *Ophiopogon japonicus* seed

Taxa	Treatment	Percent germination[z] Radicle emergence[y]		Shoot emergence	
Lirope muscari 'Variegata'	Intact (control)	25%	a[x]	3%	a
	Depulped	77	b	33	b
Ophiopogon japonicus	Intact	28	a	3	a
	Depulped	74	b	54	b

[z] Mean of five replications

[x] Mean separation between treatments by t-test, 5% level

[y] After six weeks warm stratification

Sixty-five percent of *L. muscari* 'Variegata' seedlings exhibited some form of variegation: 49% of these seedlings had the typical white-margined variegation pattern, 9% contained

several heterogenous stripes, and 7% were half white/half green (Table 3) Of the remaining seedlings, 20% were achlorophyllous (albino), and 15% were either solid yellow or green. Generally, albino seedlings did not survive more than 2 weeks under greenhouse conditions

Table 3. Variegation patterns and their percent distribution in seedlings of *Liriope muscari* 'Variegata'

Variegation pattern	Percent
White marginal stripes	49%[z,y]
Several heterogeneous stripes	9
Half green/half white	7
Albino	20
Not variegated	15

[z] Total seedlings observed = 141

[y] Observed after six weeks under greenhouse conditions (12 weeks past sowing)

3 The aforementioned work with seed of *Liriope muscari* showed that removal of the pulp significantly enhanced germination. Water extractions of the pulp applied to cucumber seeds indicated the presence of a water soluble inhibitor. These water extracts take on the intense blue-black color of the fruit skin and pulpy matrix (collectively termed the pulp) at a neutral pH. No information as to which compound(s) impart the distinctive deep blue color or the inhibitory properties is available for this species.

Germination inhibitors are mostly non-specific, i.e., one inhibitor will prevent germination of seeds of several speices, the sensitivity of various species varying with concentrations applied. A bioassay is a common procedure for determining the presence of germination inhibitors in plant tissue. Test seeds are allowed to imbibe the plant juice/sap or a partially purified plant extract directly (9,12,17). Any high quality seed that will germinate 90 to 100% can be used as the test material. It should be noted that the bioassay is a crude indication of the presence or absence of an inhibitor and tells nothing of either their chemical nature or mode of action. Individual components of the plant extract need to be isolated and identified prior to use in a bioassay and before any specific inhibitor can be named.

The following lines of evidence suggested that the fruit pulp should be examined for phenolic compounds (including anthocyanins) as a prerequisite for characterizing its inhibitory nature· (a.) the crude pulp solution was blue at pH 5-6, red at pH 4; (b.) the inhibitor was present in water extracts, and thus is apparently water soluble; (c.) boiling of the extract did not decrease inhibition, which suggests the inhibitor is not a pro-

tein, whereas, anthocyanic inhibitors retain their activity after boiling (11); (d.) the addition of polyvinylpyrrolidone (Poly-ClarAT^R), a phenol-complexing agent caused partial decrease of inhibition in cucumber bioassays; and (e) a paper-chromatographic survey revealed high concentrations of anthocyanins and phenolic acids.

Liriope muscari fruit was collected in January, 1981, on the University of Georgia campus, Athens. Pulp was mechanically removed as previously described, air dried for 48 hr and finely ground in a Wiley mill Dried pulp was extracted in distilled/deionized water for three 12 hr rinses. The rinses were combined and taken to dryness *in vacuo* Eighty mg of dried crude extract was dissolved in 10% MeOH/H_2O and applied to a 40 × 8 cm Sephadex R(25-100μm) column for bulk isolation of component fractions in liriope pulp. The individual fractions would be applied to a bioassay to test for germination inhibition.

A graded series of increasing percentages of neutral MeOH in water (10% MeOH, 20% . . . 100%) served as the column chromatography solvent. UV/visible bands were collected as fractions, evaporated to dryness and weighed. The resulting fractions were monitored using 2D paper chromatography (PC) to determine the presence of anthocyanins, other flavonoids, and phenolic acids in each. The solvent in the first dimension was *tertiary*-butanol/acetic acid/water, 3:1:1 (TBA); and acetic acid/water, 15:85 (HOAC) in the second dimension. Each fraction was also subjected to UV/visible spectrophotometry on a Beckman DBG spectrophotometer. Rf values, color reactions and spectral data were used to identify PC spots as to phenolic class. Further purification of the fractions was not attempted. Each pre-weighed crude fraction was dissolved in 10 ml of water or MeOH, depending on its solubility (fractions that came off the column first were readily soluble in water, whereas later fractions were more soluble in MeOH). Since the number of seeds and quantity of pulp used to make the crude water extract was known, uniform dilution of each column fraction gave concentrations approximating that found in one *Liriope* fruit. Water soluble fractions were applied directly in 2 ml aliquots to a cucumber seed bioassay consisting of 10 *Cucumis sativus* 'Poinsett' (Poinsett cucumber) seeds placed on a double layer of pre-moistened Whatman #2 filter paper in a petri dish. The dishes were covered and placed in a 24°C lighted Precision Scientific incubator. Each fraction was applied to three replicate petri dishes. For water insoluble fractions (dissolved in MeOH), 30 cucumber seeds were tied in a single layer of cheesecloth and suspended in the alcoholic solutions for 30 seconds. The seed bundles were then suspend-

ed in air to completely dry (methanol evaporated), leaving a relatively uniform coating of the dissolved fraction on each seed. The seeds were then divided into three replications of 10 cucumber seeds each and treated identically to the water fractions. Water and plain MeOH were used as controls for each of the above procedures. After four days in incubation, germination percentages in terms of radicle and shoot emergence were obtained

Fractions affecting the greatest inhibition were combined to determine whether some synergism between several substances contributed to a greater degree of inhibition, as would be evidenced in an intact fruit Pair wise and collective combinations were made (1 ml. 1 ml, v/v) and applied to three replicate petri dishes each. These were also incubated for 4 days at 24°C and evaluated for extent of inhibition.

Significant differences in mean germination percentages among the fraction treatments were determined by means of Duncan's multiple range test.

To tentatively identify the phenolic acids present, several known standards were chromatographed in TBA and HOAC and their Rf values and color reactions compared to phenolic acid-like spots appearing in the individual fraction chromatograms.

Nine distinct bands from *Liriope muscari* pulp were eluted as crude fractions from the Sephadex® column by a graded series of neutral MeOH solvents. Germination percentages resulting from the application of each fraction to a cucumber seed bioassay are shown in Table 4. A decrease in radicle and shoot emergence, and in general radicle length, was observed in all of the pulp-fraction treatments as compared to the controls. However, radicle emergence was significantly reduced by five fractions and shoot emergence by seven (Table 5). When considering radicle and shoot emergence together, fractions 1, 5, and 7 gave the most pronounced inhibition Percent radicle emergence for these three fractions was 50, 46.7, and 53.3% respectively, in contrast to 85% in control treatments. Shoot emergence was more markedly affected; fractions 1, 5, and 7 averaging 18% shoot emergence while controls had 60%. Fractions 3 and 4 were not inhibitory to radicle emergence, but did significantly inhibit shoot development.

The effects of three combination treatments are seen in Table 6. When fractions 1 and 2 were combined, higher germination percentages resulted than when either were applied alone. Chromatographically, both 1 and 2 contained the same compounds, those in 2 being less concentrated. Therefore, it is believed that the higher germination seen is a dilution effect,

Table 4. The effect of nine *Liriope muscari* pulp fractions on the germination of 'Poinsett' cucumber seeds

Fraction	Mean[z] percent Radicle emergence		Mean[z] percent Shoot emergence		Mean Radicle length
H_2O control	87	a[y]	60	a	3 8 cm
MeOH control	83	a	59	a	2 9
1	50	b	17	b	0 9
2	53	b	27	b	0 8
3	64	a	27	b	2 2
4	67	a	30	b	2 2
5	46	b	17	b	2 0
6	67	a	50	a	2 9
7	53	b	20	b	2 4
8	67	a	40	a	3 3
9	60	b	30	b	3 0

[z] Mean over three replications
[z] Mean separation within columns by Duncan's multiple range test, 5% level

Table 5. Significant inhibition of 'Poinsett' cucumber seed germiantion among *Liriope muscari* pulp fractions

Fraction	Significant inhibition Radicle emergence	Significant inhibition Shoot emergence
1	●●[z]	●●
2	●	●
3		●
4		●
5	●●	●●
6		
7	●●	●●
8		
9	●	●

[z] ● = significant inhibition, ●● = excessive inhibition

the toxicity of compounds being found in 1 and 2 being diluted in half as a consequence of this combination. Fraction 2 was not included in the collective fraction combination (1 + 5 + 7) due to this apparent dilution affect with 1. Radicle emergence in seeds treated with fraction 5 + 7 was low, with percentages similar to those seen in each singularly In addition, shoot emergence was notably lacking in this combination. This suggests that different, independently toxic compounds are present in these two fractions, which upon combination, have an additive effect that exceeds a dilution effect, to express significant inhibition When fractions 1, 5, and 7 were combined, the inhibition appeared to be synergistic. Radicle emergence was reduced to 20% and no shoots developed. The effects of fractions 1, 5, and 7 in combination suppressed germination to below levels seen in any of the three fractions applied alone

Table 6. The effect of three pulp fraction combinations on the germination of 'Poinsett' cucumber seeds

Fractions	Mean[z] percent		Mean
	Radicle emergence	Shoot emergence	Radicle length (cm)
1 + 2	70 a[y]	23 a	1 0
5 + 7	57 b	0 b	0 4
1 + 5 + 7	20 c	0 b	0 1

[z] Mean over three replications
[y] Mean separation within columns by Duncan's multiple range test, 5% level

Based on chromatographic data (Rf values and color reactions), the relative composition of each fraction is seen in Table 7 Classes of compounds identifiable among the various fractions are. anthocyanins, phenolic acids, anthoxanthins, and a spot that suggests a polyphenol such as a tannin. It is evident that more than one of each type of compound is present in liriope pulp. Fractions 2 and 6 contain different anthocyanins; at least four different anthoxanthins are seen between fractions 6, 7, and 8; and not less than five unique phenolic acid spots are found between fractions 5 and 7. Fractions 5 and 7, in addition to anthocyanins and anthoxanthins, contain the highest preponderance of phenolic acids. Fractions 2, 3 and more so 1 and 5 contain the tannin-like substance. Spectral data substantiated these findings and indicated that the anthocyanins were of the delphinidin type.

Comparison of Rf values and color reactions of known phenolic acids on paper chromatograms (also run in TBA and HOAC) led to the tentative identification of pyrogallol and caffeic acid as phenolic acids present in fraction 1 and 1 and 7, respectively.

Table 7. Presence of various phenolic compounds within each *Liriope muscari* pulp fraction

Fraction	Anthocyanins	Phenolic Acids	Anthoxanthins	Polyphenol (tannin)
1	X[z]			X
2	X			X
3			X	X
4			XXX	
5	X	XXX		X
6	X		XX	
7	X	XX	XX	
8			XXXX	
9			X	

[z] X = presence of compounds, multiple X's for each distinct number evidenced

Removal of the pulp significantly enhanced the percentage and rate of germination of *Liriope muscari*. This suggested that

one or more inhibitors may be present in the pulp (pericarp wall) Since water soaking of intact seeds resulted in higher germination percentages (38%) than non-soaked (25%), it appeared that the inhibitor(s) might be water soluble.

It should be noted that seeds of all treatments placed in cold stratification (5°C) showed no germination after 6 weeks. These seeds did germinate when sown in flats and maintained at 21°C. The germination percentages were similar to the warm stratified seeds. This indicated a moist, cold period is not a prerequisite for *Liriope* seed germination.

Regulation of seed dormancy in *Liriope muscari* does not appear to be as complex as *Trillium*, *Polygonatum*, and other liliaceous species (2,3,4,18). If the pericarp wall is removed, uniform germination will occur after 6 weeks in warm stratification (21°C) or a similar environment.

Successful germination of variegated liriope and mondo grass seed indicates that their germination requirements are indeed similar to those of *Liriope muscari*. Although germination percentages did not reach the 90% of *L. muscari* in six weeks, they were sufficiently high that the authors feel seed propagation should be considered a feasible method of commercial production for all three taxa. Variegated liriope seed produces seedlings with heterogenous leaf variegation patterns, but if properly identified as such, might readily be marketed in the trade when production time and cost are factors. Variegation patterns of established vegetatively propagated liriope plantings on the University of Georgia campus were examined It was evident that some plant to plant and even within-plant variation in leaf variegation patterns does exist, going undetected in the overall appearance of a large planting A reliable method of seed propagation permits breeding and selection for superior types.

The similarity in response of *Ophiopogon japonicus* to *Liriope muscari* is not surprising, since they are so clearly associated morphologically as to have been considered members of the same genus (1,19) The genera have been confused in the trade, and much of what is grown as *Ophiopogon jaburan* 'Variegatus' is actually *Liriope muscari* 'Variegata' (20). *Ophiopogon* bears 3 to 6 viable fruits per spike on a mature plant, compared to the 15 to 30 of *Liriope* species observed, but in view of its inherently slower rate of stoloniferous multiplication, seed propagation would seem as economical or more so than the division methods commonly practiced.

Several classes of phenolic compounds are present in liriope pulp, flavonoids (anthocyanins and anthoxanthins), phenolic acids and a tannin-like polyphenol. It appears that certain classes of these phenolic compounds (especially phenolic

acids and tannin-types) when present in the individual pulp fractions, impart a greater degree of toxicity toward seed germination (Table 7). The greatest germination inhibition is seen in those fractions containing both anthocyanins and phenolic acids or the tannin-like substance. Fractions containing only anthocyanins are less toxic than those with phenolic acids or tannins, but more toxic than those containing anthoxanthins alone (anthoxanthins being non-charged flavonoid compounds). It appears that no one phenolic compound is solely responsible for the inhibition of seed germination by liriope pulp, but rather synergistic, or at least collective effects, of several potent phenolics. Indeed, caffeic acid, found in two of the most toxic pulp fractions, has been isolated as a primary germination inhibitor from tomato juice (6,8,11). Anthocyanins and tannins are also well known for their potent inhibition in several biological systems (10,11,15,16)

The mode of action for the particular phenolic inhibition cannot be determined from our study, but the participation of phenolics is not surprising as nearly all naturally occurring phenolic compounds possess some biological or pharmacological activity. This propensity is related to the phenolic $-OH$ group's strong affinity for proteins and therefore enzymes (11). Phenolic interference may take the form of disruption of enzyme activation, from which the enzyme-dependent (e g. α-amylase, proteinase) seed germination processes are not immune Several investigators have noted the interaction between phenolic compounds and various growth regulators, some strongly allied to seed germination (gibberellic acid, cytokinins) (8,11) Of interest in the results of this experiment is the fact that shoot emergence was more severely inhibited than radicle emergence, implying a separation in the physiological controls of these two processes.

The presence of water soluble inhibitors in the fruit pulp of *Liriope muscari* may have ecological significance Endogenous inhibitors have been known to prevent germination in unsuitable environmental conditions and act in successional preference (14) Since *Liriope* fruits mature in the late fall, presence of an inhibitor might insure seedling emergence in spring, when climatic conditions are more amenable to survival. Also possible are exogenous allelopathic or phytoalexin-like properties that may affect the surrounding microenvironment as these phenolic compounds are released during pulp degradation in the soil (24)

While limited by time constraints, these data provide *prima facie* evidence for the endotoxic effects of phenolic compounds on the germination of *Liriope* seeds. Ultimate refinement would, of course, require isolation and identification

of each of the individual phenolics to provide specific knowledge of their contribution to the toxicity.

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QUESTION BOX

The Question Box session was convened at 3 50 p m. with Ralph Shugert, Bruce Briggs, and Hudson Hartmann serving as moderators.

MODERATOR BRIGGS. Why shouldn't methanol be used to make an IBA solution?

MICHAEL DIRR: Methanol has been mentioned as a solvent for a lot of the auxins. You could use it if you want, however, I would shy away from it because it is wood alcohol Wood alcohol can cause blindness if ingested.

MODERATOR BRIGGS: What is Synergol?

MICHAEL DIRR. It is an English product that is an IBA-NAA COMBINATION.

ED LOSELY. I believe that the K salt of IBA is one of the primary ingredients in Synergol.

MODERATOR BRIGGS What are some sources of IBA and NAA?

MICHAEL DIRR My paper in the Proceedings will contain a list.

MODERATOR BRIGGS. What effect does sugar have on rooting of plants?

RICHARD ZIMMERMAN: My only experience is with tissue culture. In tissue culture we must have it. The amount is not important Ed Bunker has reported that with *Grevillea* they take very soft cuttings and drop them in a bucket of water containing ½ cup sugar per 2 gallons of water. The cuttings are left in for 30 minutes and then wrapped in newspaper overnight. He reported less wilting with the sugar treated cuttings.

GREG LLOYD. At Yoder Brothers it is standard practice to put sugar on the stock plants before they are harvested.

LEN STOLTZ: I have infiltrated mum cuttings with sugar and found no promotive effect. I would see sugar as adding a source of food for microorganisms in your rooting bed.

MODERATOR BRIGGS Question for Len Savella. How do you pot up your blue spruce cuttings and over-winter them? Are you still using this procedure?

LEN SAVELLA. After the cuttings have been rooted we plant them in flats containing a peat and sand (1:1) medium. The cuttings are returned to the mist for 2 weeks The rooted cuttings remain in the flats for 2 years and are then transferred to beds for approximatley 2 additional years before field planting. We are still using this method with the cultivar *Picea* 'Koster'.

MODERATOR BRIGGS: Has anyone used PVC pipe for bottom heat with the same results as Don Dillion?

TOM WOOD: A number of growers are using a low density PVC pipe in England with high speed hot water It does not degrade and lasts for years. I am not sure, however, if it is the same type as yours.

BRUCE BRIGGS. If you are using household PVC pipe be sure to keep the temperature below 120°F. Above that your pipe begins to swell.

DICK HENLEY. Black poly pipe has been used extensively in Florida. By the time they add on the cost of the stainless steel clamps it turns out that ½ inch PVC pipe is cheaper.

MODERATOR HARTMANN: What is the best way to propagate *Ptelea trifoliata*?

CAMERON SMITH· No problem. Collect the seed in the fall, store it in a refrigerator in damp peat, and plant in the spring

MODERATOR HARTMANN· Has anyone had success rooting cuttings of *Amelanchier canadensis*?

JIM MERCHANT: It has not been a problem with us. We propagate them outside under mist.

MODERATOR HARTMANN. Has anyone had luck rooting female selections of *Myrica pensylvanica*?

ELWIN ORTON. I have no problem rooting them in August with Hormodin 3.

MODERATOR HARTMANN: We have had problems grafting *Larix leptolepsis* and *L. decidua*. The understock dies. Does anyone have an idea why?

ROGER STOEL. They need dry feet in the greenhouse.

MODERATOR HARTMANN. What is a good method of rooting × *Cupressocyparis leylandii* cuttings?

TOM WOOD· In England there are specialist growers that root them every month of the year. The key is proper wood selection. As the wood is maturing it goes from green to straw to brown. If you take your cutting with ½ inch of the straw brown area you will get roots in about 6 weeks. From an energy point of view, March is the best month because you heat a bit for the first 6 weeks, and then natural warm temperatures occur. A fairly strong hormone is required.

MODERATOR SHUGERT. Using water from an open pond for softwood propagation can result in an algae problem What can be used to safely eliminate the algae?

HANS HESS: We had that problem and used a large industrial filter to cure it

MODERATOR SHUGERT· Is there any update on verticillium wilt research?

WILLIAM WOLFF· I asked the question because of my special interest in Japanese maples. Some nurserymen use wood chips and I am concerned about the potential spread of that disease Some years back I had a sugar maple that was diagnosed as containing the disease. I ground up the tree and test applied the wood chips to 25 container Japanese maples and successfully infected 18 of them. Needless to say, now I use only pine bark

MODERATOR SHUGERT· What is a good and safe herbicide to use on container Japanese maples?

RALPH SHUGERT: On a very modest number of plants I would recommend Ronstar at or slightly below label rate.

CLAYTON FULLER· We used a Devrinol and Ronstar combination without any toxicity this year.

MODERATOR SHUGERT· What effects do fumes from kerosene stoves have in propagation houses?

CLAYTON FULLER· Based on limited experienced after the first year, we threw them away One, during April, backfired and did not fire properly in a storage house. All the plants had come into soft leaf and the next day all the leaves were off

RALPH SHUGERT. Ethylene gas in an enclosed area is dangerous.

PETER VERMEULEN. We had damage from Tree Heet when used in an enclosed area to a large number of different plants.

MODERATOR SHUGERT: Is there a safe herbicide that can be used around *Tilia*?

AL MANBECK· Roundup or Paraquat is OK as long as you keep them off the tree We are also using Princep, Dimet, Dacthol, and Devrinol

MODERATOR BRIGGS. Has anyone had experience rooting cuttings with willow extract?

MAKATO KAWASE· We have found that willow contains a very strong unknown root promoting substance. It is still in an experimental stage and I can not make recommendations to the nurserymen In the crude form it has a synergistic reaction with IBA.

MODERATOR BRIGGS. What is the trick to successfully overwintering *Berberis thunbergii* 'Crimson Pygmy'?

DICK CROSS. We root them in the summer and by November they are well rooted After they drop their leaves we

dig and store bare root in bunches. The bunches are stored in boxes of slightly moist sand in a root cellar.The boxes are brought up in February-March and placed in a cool greenhouse at 50-60°F under benches and moistened everyday. After 10 to 14 days the buds start to swell. At this time the rooted cuttings are potted. In Iowa I saw a firm that rooted them in a bench and left them overwinter until they started to bud and then potted the plants.

MODERATOR BRIGGS: Has anyone rooted *Tsuga canadensis* from cuttings?

PETER DEL TREDICI: Clonal variation is very great. Some root very well as hardwood cuttings in January while others, such as *T.c.* 'Sargentii', can be rooted in the summer. IBA at 10,000 ppm works very well. Some respond better to NAA.

BRUCE BRIGGS: Do not expose the cuttings to too much light or you will burn them.

MODERATOR BRIGGS: Does anyone have a good method for rooting *Hibiscus rosa-sinensis* cuttings?

PETER KOSSOUDJI. We just make cuttings off stock plants, direct stick in a 2½ inch rose pot containing sphagnum and perlite (1:1), and place them under mist.

MODERATOR HARTMANN: Could someone describe the green leaf budding technique used with nut trees?

LEN STOLTZ: It is similar to T-budding except you do not make the cross-T. Instead you apply pressure to the stem after lossening the flaps. The shield is then first pushed down and then up When you let up, the shield is locked up tight. The bud is next wrapped tight. I have obtained 98% success with the technique.

MODERATOR HARTMANN: In irradiating several species of woody plants, both seeds and seedlings, to get mutations, what is the best X-ray dosage?

CHARLES HEUSER: I would suggest that a dosage curve be run for each species.

ELWIN ORTON: This type of treatment is not of value if the plant already has a large amount of variation. Large populations of seedlings might be better than messing around with radiation.

DAVE BAKKER: One should write to Agriculture Canada because they have already done some of this work.

MODERATOR HARTMANN: Assuming a seedbed area has been fumigated with Vapam, to what extent and how quickly would this fumigated area be reinfected with mycorrhizal fungi by natural processes?

DALE MARONEK. It depends on the location of your nursery. Many nurseries that are located in prairie areas with no natural stands of trees have to depend on inoculating their seed beds themselves. They can not depend on natural wind infection. With ectomycorrhizal fungi if you have a population of native species, chances are within the first year your seedlings will show some mycorrhizal development. With endomycorrhizal fungi this not the case. You have to depend on resistant spores in the soil that may take a full growing season for the roots to go down below the fumigation level and pull it back up. Actual dates are hard to pin down.

MODERATOR HARTMANN: Does anyone have information on how best to pasteurize peat moss?

ED MEZITT: I asked this question because when we stick *Kalmia* cuttings, the lower part sometimes turns black in about 3 days. Our Extension Service has come up with the theory that most peat is badly infected

ADRIAN BOWDEN: We sterilize it in a concrete mixer

CARMINE RAGONESE. Drench it with Benlate before inserting the cuttings.

HUDSON HARTMANN: There have been a number of articles in past issues of the Proceedings on pathogens in peat moss

MODERATOR SHUGERT: What is the minimum temperature for azaleas the first winter after rooting?

FRANK GOUIN: From root temperature studies we have found that the primary root will kill out at 18°F in azaleas. Also if the cambium at soil level is not mature at the first frost you often get stem splitting.

DAVE RICHARDS. Last year we put our azaleas in an unheated house for the first time. They were covered with microfoam in a poly house We lost about half with most damage along the edge. This year we are going back to using a low temperature heat at about 35°F. We expect the temperature to go down to about 20°F.

VOICE: The type of covering, clear vs white, will make a difference. In New Jersey we normally pot into a 3 inch pot in the fall and take them through the winter in a clear plastic house at about 35 to 40°F. Three years ago we direct stuck some material in late July in 1½ gallon containers. They were not touched and went through −14°F with no trouble. They had no heat but were in white poly houses I think we need to take a better look at no heat storage.

PETER VERMEULEN: We have two houses where the temperature is controlled. Both are clear poly and one is held

at 35°F and the other has the temperature maintained in the root zone at 20°F In both cases we have overwintered rooted evergreen azalea cuttings

MODERATOR SHUGERT. What future does the poly bag container have in the U S.?

FRANK GOUIN· The problem has been to get a good poly bag on the market. Machinery is a problem for automatic potting. My work has shown that you get better growth in the poly bag because as the soil loses water and shrinks the bag also shrinks. You get much more uniform moisture. Once we get a bag that will stand up over time and drain properly the cost of poly will dictate wider use. Few people handle the plants by the container so that is not a problem.

BEN DAVIS: At the Texas nursery meeting I visited a California company that is using the poly bag and has potting equipment to handle the bags

MODERATOR SHUGERT· How can I propagate *Fothergilla*?

MICHAEL DIRR. Very easy from cuttings taken in June or July and treated with 1% IBA as a quick dip. Watch when you overwinter them. Do not disturb until they have completed a normal dormant cycle

Friday Morning, December 11, 1981

Leonard Stoltz served as moderator of the morning session

TISSUE CULTURE FOR THE PRACTICAL PLANT PROPAGATOR — STATE OF THE ART

RICHARD H. ZIMMERMAN

Agricultural Research Service
U S. Department of Agriculture
Beltsville, Maryland 20705

Tissue culture has become an important tool for use by the commercial plant propagator. This technique offers a number of advantages including easier production of many difficult to propagate plants, rapid increase of newly introduced cultivars and the ability to propagate desired plants continuously or at any time throughout the year. When the micropropagation aspects of tissue culture are combined with appropriate indexing and explant establishment techniques, then tissue

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culture provides the opportunity of producing large quantities of vigorous, uniform plants free of known diseases.

Establishing a tissue culture production facility requires a considerable investment in time and money although methods for minimizing these costs have been described (6). In addition, the unit cost of micropropagated plants can be higher, sometimes considerably higher, than the cost of conventionally propagated plants. This cost may be acceptable, depending upon the purpose for which the plants are being propagated, but the propagator must be aware of the costs involved in this technique.

The first requirement for every commercial nursery is that it must be a profit-making operation to remain in business. A decision on whether or not to use tissue culture technology as a part of the overall nursery operation must take into account this requirement for profitability. In some cases, the plants propagated in tissue culture have unique characteristics, e.g. freedom from disease, new cultivar unobtainable by other means, etc., so that a high cost per plant can be acceptable. However, when using micropropagation as an alternative method for propagating plants for sale, care must be taken so that the cost of propagating the plant does not exceed its sales value. I have visited laboratories where I suspect the tissue culture produced plants are being sold at little or no profit or at a loss. This situation probably results from inadequate cost accounting procedures and an overly optimistic view of laboratory efficiency. Little information has been published on unit costs of tissue culture propagated plants (3,7) but that which has suggested that unit costs may be relatively high, particularly for plants which do not proliferate rapidly or root readily.

One result of the relatively high cost per micropropagated plant has been a shift in emphasis to micropropagating plants that have a higher value. Thus, some laboratories in Italy have greatly reduced the number of strawberries being micropropagated for direct field planting and have substituted rootstocks for various fruit trees, the per plant value of which is much greater Similar changes are occurring in North America, where higher value ornamental trees are starting to be micropropagated preferentially over fruit tree rootstocks. This change is also a result of laboratory operators attempting to broaden their product line in order to maximize the utilization of their facilities. Operators of independent laboratories appear to rely mostly on contract orders. This method of operation seems to work out well given the reluctance of many nurserymen to make the investment required for setting up and operating their own tissue culture laboratory.

A striking feature of micropropagation of horticultural

crops, particularly certain woody ornamentals such as rhododendron, is the rapid development of the technique by commercial laboratories. While the basis for micropropagating rhododendrons was developed by research scientists, particularly Anderson (1,2). several commercial nurseries have pressed forward very rapidly with the application of these methods and now have more than 70 cultivars of rhododendron in production as well as a number of azalea cultivars. This progress has required considerable development and refinement in the technique by the operators of these laboratories but the research they have done is now paying off in the production of vigorous, uniform plants. As a result, the commercial application of tissue culture to some of these crops has moved far ahead of the academic research on the same ones. Most of the information developed by the commercial laboratories is unpublished so that direct communication with the persons actually doing the work is the only way to keep abreast of this rapidly changing field.

One potential problem arising as a result of these rapid developments is whether the micropropagated plants are being adequately tested for genetic stability. Most plants being micropropagated will probably prove to be phenotypically stable but some testing is required to ensure that this is the case (5,8,9). When the micropropagated plant is grown for its flowering or fruiting characteristics, then a large enough sample of the plants must be grown to guarantee that the population, as a whole, is phenotypically stable. Failure to do this could have serious consequences. If buyers even think that they are getting off-type plants from micropropagation. the economic impact will be severe, not only for those plants showing some instabilities, but also for those which are phenotypically stable

The requirements for setting up a tissue culture laboratory have been thoroughly described by Damiano (4) but within the general requirements, many alternatives are possible The alternatives selected depend upon many factors including resources available, crops to be propagated, users of the plants produced, and whether the laboratory is independent or part of a nursery.

The many successful laboratories now in operation illustrate the use of a wide range of laboratory plans. specific equipment, and management practices These laboratories range from 2-3 person operations with a single work station for transferring cultures to those having 10 times as many employees with more than 20 work stations for transferring cultures, sometimes working more than one shift per day. Sterilization of media is accomplished using equipment ranging from sim-

ple pressure cookers to large autoclaves costing more than $50,000. Transfer hoods range from simple, home-built units circulating only filtered laboratory air to laminar flow hoods providing a sterile work environment for as many as 4 workers at a single hood Similar differences exist in types of culture containers, growing media, and acclimatization procedures. The point to be made, however, is that each problem, each step in the procedure, has a number of solutions which work equally well. The problem becomes one of selecting a course of action for setting up a laboratory, or for establishing the details of propagating a particular plant once the laboratory is set up, and following that course through to a successful conclusion. Successfully solving the problem hinges on effective management. No amount of investment in equipment, facilities, or personnel can replace it.

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PROBLEMS POSED BY MICROPLANT MORPHOLOGY

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Micropropagation by *in vitro* techniques has the potential of replacing conventional methods of propagation for many horticultural crops But several serious problems must be solved before micropropagation becomes profitable on a large commercial scale. One serious problem is the high rate of loss of cultured plants of many species when they are transferred to the greenhouse or to the field. These plants are characterized by rapid and severe desiccation unless they are nurtured in a protective environment for the first 1 to 2 weeks after they are removed from culture. Studies indicate that abnormalities in the morphology of cultured plants may cause this desiccation by blocking water flow through the plant Morphological abnormalities of the root-shoot junction, leaf anatomy, and the cuticular surface have special relevance to the problem of desiccation

The root-shoot junction has been shown to be morphologically abnormal in cultured plants in several species. In *Pelargonium* × *hortorum* vascular cylinders of multiple shoots converged inside a small knob of callus at the base of the shoots (8). The vasculature became interconnected, forming knots and blocked passageways. A complete disjunction of shoots and roots has been reported in primary explants of *Asparagus officinalis* (1) causing them to wilt severely upon transfer to the greenhouse. In cultured cauliflower plants vascular connections were narrow and ill-formed at the time the plants were transferred to the greenhouse (5) After three weeks in the greenhouse, the vascular connections were greater in number and size. Significantly greater water flow occurred from the roots to the shoots at this time compared to the water flow when the plants were first removed from culture. Thus, any hinderance to water flow between roots and shoots contributes to decreased survival rate since water stress in the leaves increases, and the plants wilt and often die.

The leaf anatomy of cultured plants also has been shown to be abnormal in several cases In *Asparagus officinalis* (6) leaves on cultured plants did not exhibit ferning characteristic of the species and survival of the transferred plants was very low Increasing the light intensity *in vitro* to 10,000 lux prior to transplanting resulted in normal leaf formation and an increase to 95-100 percent survival when plants were transferred to the greenhouse.

The leaves of cultured plants often resemble those grown in shade and those under low water stress. Brainerd *et al.* (3) measured smaller palisade cells, larger intercellular spaces and decreased stomatal frequency in cultured plum plants compared to their counterparts grown in the greenhouse and in the field. Further studies indicated that the leaves of some species were functionally, as well as structurally, anomalous. Leaves of cauliflower (12) and apple (2) had impaired stomatal functioning, with stomates remaining open under conditions of high water stress. They also had reduced photosynthetic capacity (5). These leaves would be more likely to be rapidly injured under the conditions of stress to which plants are exposed when transferred from culture to greenhouse.

Leaves of several species in culture also had altered surface wax characteristics compared to those of plants grown in the greenhouse or in a growth chamber. In cauliflower, cabbage, carnation and other normally glaucous plants, the leaves in culture were glossy rather than glaucous. Under the scan-

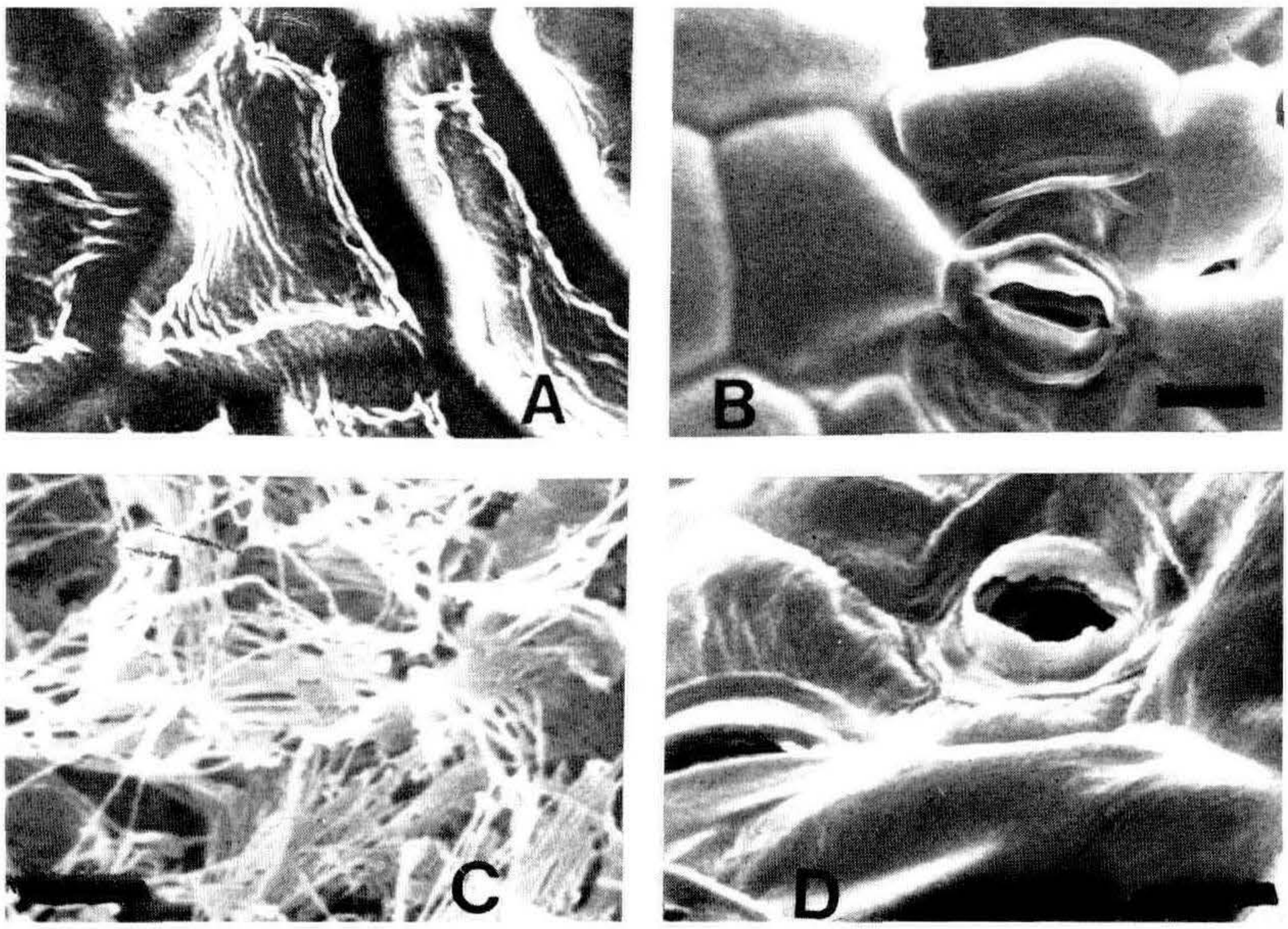

Figure 1. A. Abaxial leaf surface of *Dieffenbachia* 'Perfection Compacta' grown in the greenhouse. Ridges on surface are presumably wax. Bar = 20 μm.
B. Abaxial leaf surface of *Dieffenbachia* 'Perfection Compacta' grown in culture. Bar = 20 μm.
C. Adaxial surface of cabbage plant grown in the greenhouse. Wax covers the stomates. Bar = 5 μm.
D. Adaxial surface of cabbage plant grown in culture. Bar = 10 μm.

ning electron microscope (SEM) the cuticular surfaces were smooth, lacking the typical crystalline structure of plants grown in the greenhouse (Figure 1) (4,11,12). In a few cases wax has been observed on cultured plants of carnation (11) and cabbage (10) This wax had an abnormal crystalline structure which may indicate an alteration in chemical composition as well (7).

Measurements of the amounts of surface wax supported observations using SEM, with plants in culture having significantly less wax than those in the greenhouse (10). After transfer to the greenhouse new leaves formed normal amounts of wax with typical crystalline structure. The leaves formed in culture, however, showed reduced wax and altered crystalline structure as long as they remained on the plants.

Implications of reduced wax formation are severe Since it is the wax component that determines water flow through the cuticle (9) lack of wax would be expected to result in greater water loss. This was shown to be the case in cultured plants of cabbage (10). As the plants became hardened off, their rate of water loss decreased, approaching that of plants grown in a growth chamber

Thus, there are several morphological problems that demand attention because they adversely affect the survival of cultured plants when they are transferred to the greenhouse. Presently, these problems are being dealt with at the time the plants are transferred to the greenhouse. Cultural conditions are adapted to the morphology and physiology of the cultured plants in order to reduce stress resulting from lower relative humidity and increased light intensity Such measures as shade, mist benches and humidity tents greatly increase the survival rate of plants transferred to the greenhouse.

More effort is needed to determine the conditions that can be altered in the culture environment that will result in plants more adapted to growth in the greenhouse. The proper selection of nutrient components and growth regulators can often reduce or entirely eliminate the callus formed between roots and shoots. Direct vascular connections would allow unimpeded water flow to the leaves Altering environmental conditions in the culture room could induce the formation of leaves more suitable for growth in conditions of high light intensity and low relative humidity Presently some measures cannot be used. For example, increasing the light levels often causes damage to the plants while still in culture. Efforts should be directed to develop techniques to lower the relative humidity *in vitro* without increasing contamination since it was shown that lowering the relative humidity restores normal stomatal functioning (2) and induces the formation of wax (10). These

measures must be adopted to commercial production if the potential of mass propagation by *in vitro* techniques is to be realized

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QUESTION AND ANSWER SESSION

MICHAEL DIRR: Has *Pyrus calleryana* been propagated by tissue culture?

DICK ZIMMERMAN: I believe that Microplant Nurseries in Oregon is doing it.

LEN STOLTZ: I have been working with *Pyrus calleryana* 'Aristocrat' and our multiplication rate has not been satisfactory. Rooting and greenhouse establishment are also problem areas

BRUCE BRIGGS· Question for Ellen Sutter. Have you had an occasion, as we do in the lab, to take the lids off the tubes and expose the plantlets to air for 4 to 5 days before planting? The plants harden off and do better. Is wax forming, or are the stomates working better?

ELLEN SUTTER. I have not done that; however, other research has shown that stomates function normally after 4 to 5 days. I am sure that wax starts to form very early

CHARLES HEUSER. Question for Ellen Sutter. Have you tried high agar during the rooting process and does it modify the cuticle?

ELLEN SUTTER· We tried that and the plants did not do too well. We are trying PEG as an osmoticum. We put mums in the greenhouse after being on PEG and they died faster than the controls.

PAUL READ: We have looked at the root morphology as the agar concentration is increased and have observed changes. This may account for the better success we and other people have had with direct sticking micropropagated plants.

VOICE: Is it feasible to do tissue culture on a small scale and if so what about the availability of supplies?

PAUL READ· It is certainly possible on a small scale Len Stoltz made a presentation in St. Louis a couple of years ago which suggests that it was possible to get started on a small scale with a minimal cost (Editor's Note. See *Proc. Inter. Plant Prop. Soc.* 29· 375-381, 1979). When starting, I recommend starting slow to learn the process You can buy prepackaged recipes from companies such as GIBCO and Flow Labs, to name two.

RANDALL STRODE We have gone through an evolution. Initially we started with prepackaged media. We now have better trained people and prepare our own media from scratch. There is nothing wrong with the prepackaged media. They are very good. I should point out that we initially began our operation in a pilot lab and then progressed to a 2000 sq ft operation

BEN DAVIS: Where does one obtain training in tissue culture?

PAUL READ· You need to learn it from a good person. That might be at your nearby university or the course at the Cell Science Center in Lake Placid.

PETER VERMEULEN: Is it possible to publish a digest of literature that has been done and is now ongoing? Also what is being done with coniferous evergreens?

PAUL READ: Tissue culture is a field that is developing so rapidly that I find it impossible to keep up with what is happening. This also raises the question of whether you, as a nurseryman, should have a tissue culture lab. Currently many nurserymen do not propagate all their plants. Maybe on a cost effective basis, tissue culture propagation should be left to selected producers.

DICK ZIMMERMAN: It is not enough to know the literature but also who is doing it on a commercial scale because their results are not in the scientific literature.

STEVE McCULLOCH: Referring to the question that Peter Vermeulen asked I would like to refer him to an abstract by Dr. McCown at the American Society for Horticultural Science Meeting at Atlanta last year. It was one of the first attempts to propagate a wide range of conifers. At present he has been successful with *Thuja*. We have also done *Thuja* and it comes quite easy.

PROGRESS IN BREEDING AROIDS

R.J. HENNY
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We have been conducting breeding studies within the genera *Dieffenbachia* and *Aglaonema*, which are both members of the *Araceae* family. Two goals of this program are: A) development of new and better cultivars for commercial production in Florida and; B) to study the biology of their reproductive mechanisms and how it relates to other tropical plants. Our studies have included more than 50 distinct types of dieffenbachia and 15 different aglaonemas. The following discussion will center on the more important factors we have discovered which affect the breeding potential within these genera.

Stock plants are grown in greenhouses or shaded slat sheds with light intensities of 1500-2500 foot candles and a temperature regime of 65-95°F. Under these conditions, most dieffenbachia tend to produce a seasonal flush of blooms from April through June. Aglaonemas usually begin to flower in May and continue through June. However, some plants that we wanted to hybridize never seemed to bloom concurrently.

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As a result, studies were initiated using gibberellic acid (GA_3) in an attempt to stimulate flowering in dieffenbachia. A single foliar spray with GA_3 at 250, 500. or 1000 ppm not only induced flowering but also increased the number of blooms per plant (2) It is now possible to flower dieffenbachia at any time of the year which greatly reduces the time between seed generations and also allows us to have plants in bloom simultaneously which would not otherwise happen Similar results also occurred with aglaonemas. The effect of the GA_3 treatments turned out to be especially important since studies with pollen storage showed that dieffenbachia pollen could not be stored for any significant period of time. Even at optimum storage conditions of cool temperature (40°F) and high relative humidity (90%) pollen was capable of only poor germination after 2 days and no germination after 5 days of storage (1)

A brief description of the hybridization method follows. The dieffenbachia and aglaonema inflorescence is made up of a spadix and a spathe. The spadix consists of an upright central axis covered with several minute petalless flowers. Staminate (male) flowers cover the upper half of the spadix and pistillate (female) flowers are located on the basal half. Pistillate flowers consist of a stigma, style, and ovary while the staminate flowers are made up of the anther and filament.

The spathe covers the spadix until anthesis (the day of flower opening) at which time it unfurls and exposes the staminate portion of the spadix. Usually the spathe unfurls during the night so flowering plants should be checked each morning for newly opened inflorescences; subsequent pollinations may be made any time during the day of anthesis. The staminate flowers of dieffenbachia do not produce pollen until 2-3 days after the spathe unfurls at which time the stigmas are no longer receptive, thus preventing self-pollination in the wild.

When making a pollination, a camel hair brush may be used to transfer pollen to the stigmatic surface of the pistillate flowers. The brush will pick up pollen readily if it is first brushed lightly across the moist sticky surface of the stigma. The stigmatic surfaces of the pistillate flowers may be identified by their golden yellow color and there may be 40-80 pistillate flowers per dieffenbachia inflorescence, and 5-25 pistillate flowers per aglaonema inflorescence. The pistillate flowers of dieffenbachia are surrounded by white apendages termed staminoidia which often extend higher than the stigmatic surface. Staminoidia are sterile and serve no function during pollination.

Initially, poor seed set hampered breeding efforts; however, recent studies concerning environmental effects on seed

production in dieffenbachia have led to methods of increasing seed yield Tests have shown that a critical factor affecting seed production in dieffenbachia is the relative humidity level at the time of pollination (3). Seeds were rarely produced on inflorescences pollinated at a low relative humidity (40-50%), whereas a high percentage of inflorescences pollinated at a high relative humidity (near 100%) produced seed. Pollen failed to germinate on stigmas pollinated at a relative humdity less than 50%. As a result of these studies, following pollination the pistillate portion of the spadix is wrapped with a wet paper towel and the entire inflorescences enclosed in a plastic bag for 24 hours Increasing the relative humidity in this manner greatly increased the percentage of pollen germination and seed set. Using this method we have been able to obtain consistent seed production from some cultivars which had never yielded seed before. Preliminary studies have shown that aglaonemas may not be as sensitive to low relative humidity at the time of pollination as dieffenbachia.

In 3 to 4 weeks following a successful pollination, the pistillate flowers (or fruits) will turn green and begin to enlarge During this period the stigmas and the staminoidia will have deteriorated and disappeared. As the fruits enlarge they change color from green to cream-colored to orange to bright red when mature, approximately 4-5 months after pollination. The fruits will not immediately fall off the spadix after they have turned red, although it is best to harvest them quickly.

Once harvested, mature fruit should be planted as soon as possible Each dieffenbachia and aglaonema fruit generally contains 1 seed and it is very important not to let the seeds dry or they will lose viability rapidly. We removed the fleshy outer covering from the fruit before planting to help prevent development of bacteria or fungi After cleaning, seeds are soaked in a 10% Clorox solution for 5-10 minutes followed by a dip in a Benlate® solution Seeds are then placed in small plastic trays on top of shallow depressions made in a moistened medium consisting of 1 part German peat and 1 part perlite by volume and amended with 3 lbs/yd^3 dolomite and 1 lb/yd^3 Perk (a micronutrient source). Each container is enclosed in a plastic bag to maintain the high relative humidity around the seeds The trays are placed under fluorescent lights which are on 12 hours daily in growth rooms held at 80°F. In 3-4 weeks the seeds have germinated and the plastic cover is removed When seedlings have produced 4-5 leaves they are transplanted into 5-inch pots and grown in the greenhouse for evaluation

To date, there has been no evidence of any sexual incompatibility present in any dieffenbachias or aglaonemas. Most F_1

dieffenbachia hybrids have been fertile. Data from aglaonema hybrids will be available in the spring of 1982. This information combined with the great deal of natural variation within these genera lead to a great deal of optimism concerning the development of new and better cultivars for the future

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INFLUENCE OF EXTENDED PHOTOPERIOD AND FERTILIZATION ON ROOTING *ACER RUBRUM* L. 'RED SUNSET' CUTTINGS

BRYCE H. LANE and STEVE STILL

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Abstract. Terminal unbranched *Acer rubrum* L 'Red Sunset' cuttings were propagated in June, July and August, 1980 Cuttings were stuck in an Osmocote 18-6-12, 5 4 kg/m^3 amended medium, a 20-20-20 (200 ppm N) liquid fertilizer applied to the medium, or a control medium containing no fertilizer, and placed under a 4 hour extended or natural photoperiod The cuttings had higher rooting percentages when they were propagated in June and July under an extended photoperiod, regardless of fertility Cuttings propagated in August had significantly lower rooting percentages for all treatments There were no differences observed in rooting percentages, or root dry weights, due to fertilizer in the rooting medium for cuttings propagated in a natural photoperiod Cuttings had greatest root dry weights when they were rooted in an Osmocote-amended medium, and under an extended photoperiod

Acer rubrum L cultivars are most commonly propagated by budding onto seedling understcok of the same species. However, this practice has recently come under review because of graft incompatibility problems. Schwab (14) reported *Acer rubrum* graft incompatibility losses of 50% the first year after budding, and an additional 10 to 20% during the second growing season. The graft incompatibility losses necessitate that an alternative vegetative propagation method be developed.

Softwood *Acer rubrum* cuttings have been successfully rooted (1,5,13,14,15,20) However the actual propagation procedure varies greatly. May through September cutting dates have

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Softwood *Acer rubrum* cuttings have been successfully rooted (1,5,13,14,15,20) However the actual propagation procedure varies greatly. May through September cutting dates have

been tried (1,13,14,15). It is important to determine the best cutting date for specific *Acer rubrum* cultivars in order to produce a quality plant.

Supplemental lighting (9,11,13,19) applied to softwood cuttings, and nutrients applied to the propagation medium (4,6,8,10,16,22,23) are two possible methods for increasing rooting of *Acer rubrum* cuttings Nutrient mist has reduced nutrient loss from the plants and increased rooting percentage and root quality (3,21,22,23). However, nutrient mist encourages surface algae growth which may reduce aeration and drainage (2). To overcome possible algae problems and still obtain increased root growth from added nutrients, additions of Osmocote or other slow release fertilizers have been researched (3,4,6,8,10,17,18). Since there is little research on the effects of Osmocote on deciduous shade tree cuttings, it is important to determine the Osmocote response on cuttings of red maple

Photoperiod is another factor that may influence red maple propagation by cuttings. Extended photoperiods have promoted rooting of many woody plants (7,9,11,12,13,19,20). In these studies long days during rooting decreased time to root initiation and/or increased the root system development It is important to determine whether cultivars of *Acer rubrum* will respond to an increased photoperiod during propagation.

This study used *Acer rubrum* 'Red Sunset' cuttings to determine the optimum time to take cuttings, the effect(s) of fertilizers applied to the medium during rooting, and the effect of supplemental lighting on rooting of cuttings

The first terminal cuttings were taken from 6 cm caliper nursery grown trees on June 16, 1980. The terminal bud and first node of each cutting were removed, bases wounded on two sides below each axillary bud, and the basal 4 cm was dipped in a 6000 ppm indolebutyric acid (IBA) (50% water/ 50% ethyl alcohol) solution for 5 sec. Each cutting was stuck in a separate .3 liter container filled with 3.1 (by vol) perlite/ peat rooting medium Overhead mist was set to give 6 sec. mist every 3 minutes from 8.00 AM to 7·30 PM. One half of the cuttings received natural light and the remaining plants received 4 hours (10.00 PM to 2·00 AM) of 75 watt supplementary incandescent light. Incandescent bulbs were placed 1 m apart and 1 m above the propagation bench The light intensity recorded at cutting height was approximately 20 foot candles (215 lux)

Within a photoperiod treatment, cuttings were rooted in one of the following amended media. (1) Osmocote 18-6-12 (9 month formulation) incorporated in the rooting medium at a rate of 5.4 kg/m^3 one week before cuttings were stuck, (2) a

Peter's brand 20-20-20 liquid solution (200 ppm N) applied to the rooting medium after rooting began, and then applied at 3 day intervals; (3) no fertilizer (control medium). A random complete block design was used, with 7, 5 plant reps. Similarly, cuttings were collected and treated on July 23 and August 28 After a 5 week rooting period, cuttings were harvested and percent rooting, root dry weights, percent bud break, and shoot length of the longest broken bud were recorded.

Cuttings taken on June 16 had similar rooting percentages when rooted under the same photoperiod treatment (Table 1). However, within the extended photoperiod regime cuttings rooted in the Osmocote amended medium or control medium had significantly higher rooting percentages than cuttings that received the same fertility treatment, but rooted under natural light. Extended photoperiod alone had a positive effect on rooting percentage for cuttings taken in mid-June These results agree with Lanphear and Meahl (9), who reported increased rooting percentages of *Juniperus horizontalis* 'Plumosa' cuttings when rooted under 18 hour photoperiods Fertility in the rooting medium had no effect on rooting percentages when cuttings were placed under the same photoperiod treatment.

Table 1. Effects of fertility-photoperiod treatments on mean rooting percent, root dry weight, percent bud break, and shoot length of *Acer rubrum* 'Red Sunset' cuttings propagated June 16, July 23, and August 28, 1980

	June 16				July 23[y]		August 28[y]	
Treatment	Rooting percentage	Root Wt (g)	Percent Bud Break	Shoot Length (mm)	Rooting Percentage	Root Wt (g)	Rooting Percentage	Root Wt (g)
Extended photoperiod 4 hrs light (10 PM-2 AM)								
Osmocote	[z]91 4a	2 93a	51 4a	20 57a	91 4a	1 82a	54 2a	46a
Liq Fert	82 8ab	1 84bc	20 0b	3 57b	88 4a	1 23bc	60 0a	38a
Control	94 3a	1 90b	11 4b	5 40b	82 8ab	0 89bcd	48 4a	31ab
Natural Photoperiod								
Osmocote	60 0c	1 49bc	20 0b	5 20b	57 2c	1 32b	25 7b	27ab
Liq Fert	74 3bc	1 13bc	8 6b	1 30b	74 2abc	0 80cd	20 0b	13b
Control	57 1c	0 93c	5 7b	1 14b	65 6bc	0 62d	25 7b	11b

[z] Mean separation in columns by Duncan's multiple range test 5% level Values with the same letters are not significantly different

[y] No bud break or shoot growth was observed for cuttings taken on July 23, or August 28

Cuttings rooted in the Osmocote amended medium and under an extended photoperiod had a significantly greater mean root dry weight than cuttings rooted in the same amended medium but under natural light (Table 1) The mean dry weight was more than twice the dry weight of cuttings rooted in the Osmocote amended medium and under natural light (Table 1 and Fig. 1). Cuttings rooted under an extended photoperiod and without any fertilizer (control medium) also had a

significantly greater mean root dry weight than cuttings rooted in the same medium but under natural light (Table 1). This result agrees with others (7,9,13,19). The increased root volume might be due to earlier rooting (9). Cuttings receiving Osmocote in addition to a long photoperiod would have longer periods of time for growth with a continuous supply of nutrients available as well. Within the extended photoperiod regime, cutting rooted in an Osmocote treated medium had a significantly greater mean root dry weight than cuttings receiving different fertility treatments (Table 1). However, within the natural light regime, there were no significant differences due to fertility treatment. Osmocote incorporation significantly increased root weight only when supplemental light was employed. This result disagrees with Johnson and Hamilton (8) who reported increased root volume of various cuttings that were rooted in an Osmocote amended medium alone. These researchers measured the extent of rooting after a 10 to 12 week period in the propagation bench. The cuttings of *Acer rubrum* 'Red Sunset' were analyzed after 5 weeks in the propagation bench, which might explain why there were not any significant effects within the natural lighting regime.

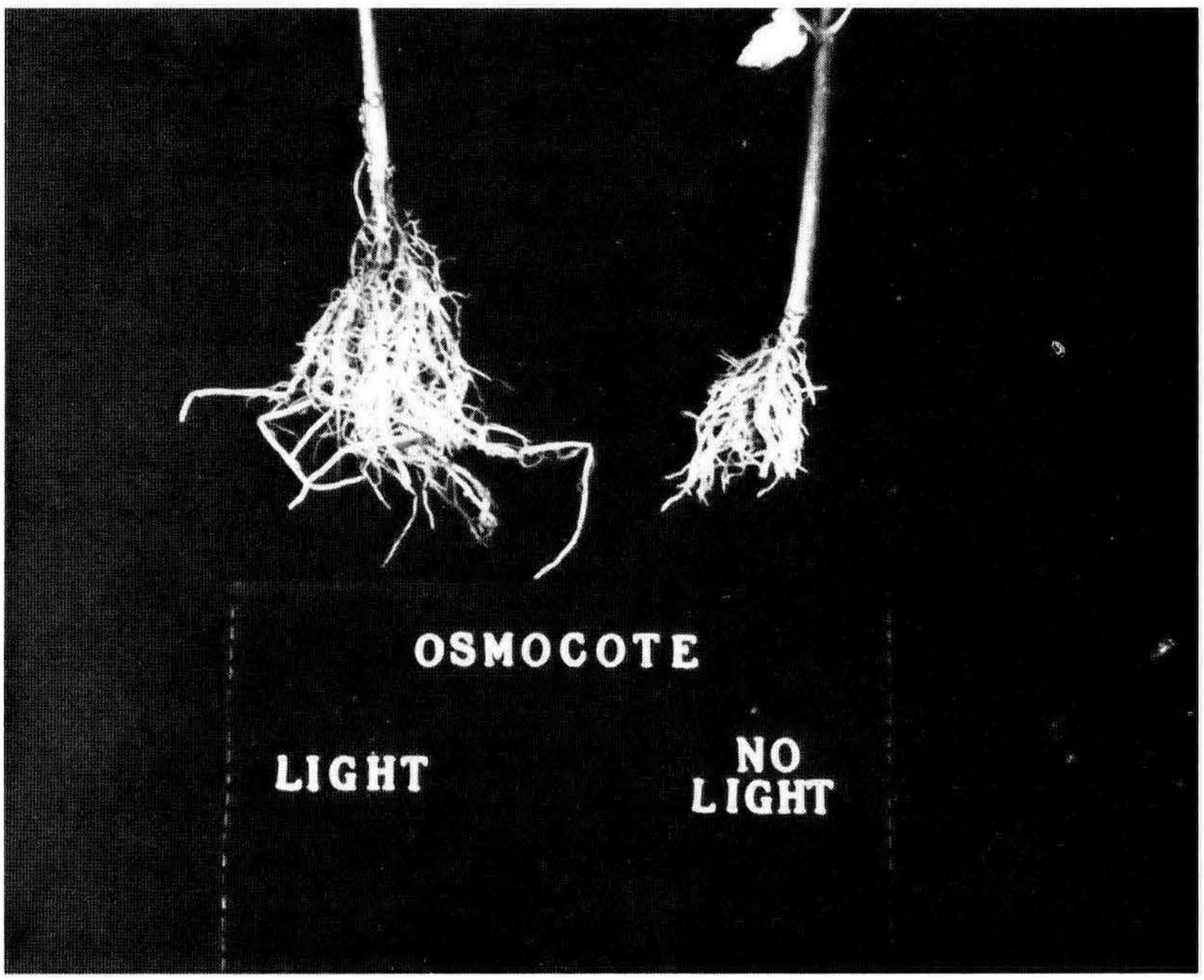

Figure 1. June-rooted *Acer rubrum* 'Red Sunset' cuttings in an Osmocote amended medium, under (*left*) an extended photoperiod (light), or under (*right*) a natural photoperiod (no artificial light).

Many of the cuttings taken on June 16 had broken bud before they were removed from the propagation area The cuttings that were rooted in an Osmocote amended medium and under the extended photoperiod treatments had a significantly greater mean percent bud break than any of the other fertility-photoperiod treatments (Table 1) These cuttings had more than a two fold increase in bud break than cuttings propagated in the same fertility treatment under natural light. Within the natural light regime, fertility had no effect on percent bud break. The combination of Osmocote and supplemental light appears to be important in order to achieve optimal bud break for June cuttings.

Average shoot length of broken buds in the cutting bench followed the same trends as percent bud break. Cuttings receiving a treatment combination of Osmocote and supplemental lighting had the longest average shoot growth. There is an interaction between Osmocote and photoperiod that yields increased bud break and shoot growth Osmocote used without lighting caused no significant differences and vice versa.

Cuttings taken on July 23 had similar rooting percentages when rooted in the same photoperiod treatment (Table 1) For this date, the cuttings rooted in Osmocote and under the extended photoperiod treatment had a significantly greater rooting percentage than cuttings rooted in the same fertility but under natural light. Unlike the first experiment, photoperiod didn't affect rooting. Root dry weights were significantly higher in the first experiment for the following treatments. (1) Osmocote and supplemental light; (2) Control and supplemental light (Table 2). The remaining 4 treatments had similar weights for both cutting dates. In general, rooting percentage was not affected by either cutting date, but root weight was higher for cuttings taken in June when they were treated with an extended photoperiod or an extended photoperiod plus Osmocote incorporation. An extended photoperiod apparently has a more marked affect on rooting when natural day lengths are long also.

Bud breaks did not occur in cuttings during the July 23 cutting date Bud break and shoot growth in the propagation bench was only stimulated by the early cutting date. The cuttings taken in mid-July might have been in a different physiological state than cuttings taken in June These cuttings might not have been as sensitive to the specific treatments that stimulated bud break.

On the August 28 cutting date, within a photoperiod treatment, there were no significant differences in percent rooting (Table 2). As with the other cutting dates, there was no fertilizer effect. However, the cuttings that received an extended

photoperiod had significantly greater mean rooting percentages than cuttings rooted under natural light at corresponding fertility levels (Table 1). These results are similar to the other cutting dates. The use of an extended photoperiod treatment in late August significantly increased rooting percent but the use of fertility in the rooting medium at this time was not beneficial In general, the rooting percentages recorded for all 6 treatments were significantly less than percentages observed for the first two cutting dates (Table 2). The low rooting percentages observed can be explained by the late cutting date. The shoots of the stock plants in the nursery were growing very slowly or had stopped growing when the cuttings were taken The shoots had hardened substantially and terminal buds were forming. These conditions will often lower the rooting percentage.

Table 2. Effect of cutting date on mean rooting percentage, and root dry weight for fertility-photoperiod treatments on cuttings of *Acer rubrum* 'Red Sunset'

	Extended photoperiod			Natural photoperiod		
Cutting Date	*Osmocote*	*Liq Fert*	*Control*	*Osmocote*	*Liq Fert*	*Control*
June 16						
Rooting percentage	'91 4a	82 8a	94 2a	60 0a	74 0a	57 0a
Root Dry Wt (g)	2 92a	1 84a	1 90a	1 49a	1 13a	0 93a
July 23						
Rooting percentage	91 4a	88 6a	82 8a	57 0a	74 0a	65 6a
Root Dry Wt	1 82b	1 24a	0 89b	1 32a	0 80a	0 62ab
August 28						
Rooting percentage	54 0b	60 0b	48 6b	25 8b	20 0a	25 6a
Root Dry Wt (g)	0 46c	0 38b	0 31b	0 27b	0 13b	0 11b

* Mean Separation in columns by Duncan's multiple range test, 5% level

There were no significant differences in mean root dry weight among any of the fertility treatments within each photoperiod regime for the August cutting date. However, cuttings treated with liquid fertilizer under an extended photoperiod had a significantly higher mean root dry weight than cuttings treated with the same fertility level and rooted under natural light. Extending the photoperiod only increased root dry weight when fertility was added to the rooting medium. The root weights taken from the third cutting date were significantly less than the first two experiments for the following treatments. (1) Osmocote and supplemental light; (2) liquid fertilizer and supplemental light; (3) Osmocote and natural light, (4) liquid fertilizer and natural light (Table 2) There were no bud breaks recorded for cuttings taken on August 28.

In general, cuttings of *Acer rubrum* 'Red Sunset' had the

highest rooting percentages and root dry weights when they were propagated in June and July. Only those cuttings propagated in June broke bud and began to grow while still under mist. The use of an extended photoperiod in the propagation area significantly increased rooting percentages for all cutting dates. However, the actual percentages were significantly less on the third date. Cuttings that were rooted in an Osmocote amended medium and under an extended photoperiod had a significantly greater root dry weight than cuttings of all other treatments for the first two experiments. In the first experiment, percent bud break and shoot length were highest when cuttings were treated with Osmocote and an extended photoperiod. This study indicates that to maximize rooting percentage and stimulate the most root and shoot growth while plants are still under mist it is important to propagate *Acer rubrum* 'Red Sunset' cuttings in June under an extended photoperiod and in a rooting medium amended with Osmocote.

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MICHAEL DIRR Why select 6,000 ppm IBA for your auxin treatment?

BRYCE LANE. My advisor recommended that concentration on the basis of his experience.

ELWIN ORTON: Is there any interest from Ohio growers in using the single node cutting for propagation? When I first reported this in 1977 all treatments rooted 98% in 21 days. Commercial growers appear to be using tip cuttings.

BRYCE LANE· After having followed up on this research with ideas on production, I would recommend single node cuttings because we had to pinch out one of the two nodes that broke. This caused the production of a "dog leg" in the stem at the 6 to 8 in level

ELWIN ORTON: Yes, we established that fact in 1977

Friday Morning, December 11, 1981

NEW PLANT FORUM

JACK ALEXANDER and PETER DEL TREDICI

MODERATOR DEL TREDICI. Our first speaker today is Jack Alexander.

JACK ALEXANDER· *Syringa pekinensis*, a native of China, is a small tree seldom reaching 25 feet The most attractive specimens have exfoliating, cinnamon brown bark that peels off in strips. This characteristic varies greatly between specimens and the plant may display a cherry like bark similar to the Japanese tree lilac, S. *reticulata*.

To be assured of exfoliating bark we should propagate only from specimens exhibiting this characteristic. Cuttings are difficult-to-root and grafting or budding may be necessary for asexual propagation. Seed from attractive plants may yield satisfactory results and have the added benefit of variation, from which we might select superior clones.

The flowers of the Chinese tree lilac appear at about the same time as the Japanese tree lilac and are also creamy white The leaves of S. *pekinensis* are smoother, less oval shaped than S. *reticulata* and more closely resemble the leaves of the common lilac. They are only slightly effected by mildew.

S. *pekinensis* is very cold hardy. What is probably the oldest specimen on this continent has been growing at the Ottawa Research Station in Canada since 1902.

MODERATOR DEL TREDICI: Wayne Mezitt has three plants to show.

WAYNE MEZITT· *Pinus rigida* 'Sherman Eddy', discovered in the Pocono mountains in the 1930's by Sherman Eddy. It is very slow growing, 4 to 6 inches a year, and late breaking. Large whorls of bright green needles surround the bud and produce a dense, tufted appearance. The plant is grown exclusively from grafts.

Pinus strobus 'White Mountain', has brilliant silver-blue needles but is similar in all other respects to the species. It may be slightly less winter hardy or less tolerant to air pollution. We have experienced winter needle discoloration twice in the ten years. Discovered in a lot of understock purchased from Western Maine Forest Nurseries in the early 1970's.

Tsuga canadensis 'Westonigra' has exceptionally dark green foliage which is especially noticeable in winter. It grows as fast or faster than Canadian hemlock but not as fast or rank as the parent plant The original 'Westonigra' was discovered

in a field at Gillette Nurseries in Southwick, MA in the early 1940's and grown by cuttings and grafts for many years. It is too loose-growing to be of great value as a landscape plant, but seedlings from isolated plants are 75 to 95% dark-foliaged and more uniformly "normal" growing.

MODERATOR DEL TREDICI. The next speaker is Don Shadow

DON SHADOW: *Cotinus obovatus*, American smoketree, is a small tree or large, few-stemmed shrub, growing 20 to 25 feet and forming an upright-oval to rounded outline. The rich blue-green leaves turn to brilliant yellow-orange-red in fall. Intensity of fall color varies among individuals and superior clones should be selected. Flowers and fruits are not quite as showy as *C. coggygria*. Bark on older trunks develops a unique fish-scale appearance. Seeds will germinate if fall planted and softwood cuttings can be rooted.

Pseudocydonia sinensis, Chinese quince, is a lovely small tree or large shrub with a distinct upright oval habit 15-25 feet. The leathery dark green leaves change to yellow-red-orange and purple in the fall The whitish pink flowers are followed by very large oblong yellowish fruit. These fruits are highly aromatic. The most beautiful characteristic is the bark which is fluted and mottled much like *Ulmus parviflora*. The bark forms a patchwork of gray, green, brown and orange.

Seeds will germinate quite well when planted immediately upon extraction from the fruit. They must not be allowed to dry before planting. Grafting and budding of select forms may be used.

MODERATOR DEL TREDICI. Sidney Waxman from the University of Connecticut has some plants to show.

SIDNEY WAXMAN: *Tsuga canadensis* 'Florence' is low, mound-shaped with a fine texture. It was selected from a population of several hundred seedlings taken from a witches' broom. The plant grows at the rate of 2 to 3 inches per year and can be propagated by cuttings.

Pinus strobus 'Blue Shag' was selected from a population of 700 seedlings taken from a witches' broom. It has very dense branching and long blue-green needles. Its dimensions after 8 years growth, are 3 feet high and 5½ feet wide. Its current growth rate is approximately 5 inches per year.

Pinus strobus 'Green Shadow' was found in a Torrington, Connecticut woodland. It's a rounded, dense shrub with long dark-green needles. With time this selection develops into a rounded tree with ten or more trunks arising from its base. This tree is unusual not only because of its color and growth

habit, but because its grafts appear to be incompatible. Its cuttings root relatively easily.

Pinus resinosa 'Sand Castle' is a dwarf and dense upright shrub with tufts of short deep-green needles. It originated as a graft from a red pine witches' broom. Its growth rate is very slow for a red pine (3½ to 4 inches per year), and its dimensions after 10 years are 4 feet in height and 4½ feet across.

Pinus resinosa 'Thunderhead' is a broad vigorous shrub with long dark-green needles arranged in tufts. It was selected from a population of 70 seedlings collected from a witches' broom seedling in Wolfboro, New Hampshire. After 10 years of growth, it is 3½ feet tall and 5 feet wide.

Pinus strobus 'UConn' was introduced at the meeting 2 years ago. Unfortunately the printer misspelled the name which should have read, *UConn*, an abbreviation of The University of Connecticut. Also, the unnamed weeping larch I previously introduced is now named, 'Varied Directions', and the umbrella pine also unnamed at that time has been given the name, 'Wintergreen'.

MODERATOR ALEXANDER. The next speaker is Peter Del Tredici.

PETER DEL TREDICI: *Chionanthus retusus* is a relative of our native fringetree, *C. virginicus*. This is not a new plant insofar as it has been cultivated since the late 1800's, but it is a good plant, and should be much more widely grown than it is.

The plant is reliably hardy to Zone 6 and grows well in Boston, Massachusetts. It is an excellent small tree, although it starts out more like a shrub than a tree. The plant is relatively pest free, with unblemished foliage that it keeps well into October The species is usually considered dioecious, with separate male and female plants. This dioeciousness may not be absolute, however, since some individuals, such as Arnold Arboretum #13051, bear bisexual flowers and are capable to setting viable seeds without cross pollination. In winter, the tree is striking for its neat, compact form and its beautifully fissured bark. Culturally speaking, the plant is slow growing and does best in full sun in a moist, sandy loam.

Now you might ask, if a tree is as good as this and has been around for a long time, why isn't it more common? The reason is that there are propagation difficulties with the tree. Cuttings can be rooted, but not without some difficulty and inconsistency from year to year, and the seeds supposedly take 2 years to complete germination. In addition the plants are difficult to transplant But today at least one of these problems should be eliminated since the seed we have for distribution

(from A A #13051) have already put their radicles down and only require an additional chilling period of 3 months in order to complete germination. The problem of transplant difficulty can be solved by growing the plants in containers. It is interesting to note that the seeds we have for distribution put their radicles down less than a month after being collected. This is remarkable given that the standard recommendation calls for 5 months of warm stratification. To further complicate matters, ripe seeds that were collected two weeks earlier (on September 17) and treated in exactly the same way have failed to put down their radicles after 2 months Clearly, the timing of the seed collection plays an important role in obtaining successful germination

In conclusion, I should note that when grown from seed, *C. retusus* is rather variable in its shape and growth rate. Be that as it may, you nursery people no longer have any good reason for not growing this plant

MODERATOR ALEXANDER Ruth Kvaalen has a plant she would like to present.

RUTH KVAALEN. *Microbiota decussata* was discovered in southeast Siberia in 1921 and described in botanical literature in 1923. Nevertheless, it is seldom mentioned in plant manuals even today. *Hortus Third* does not list it, nor does Bean's *Trees and Shrubs Hardy in The British Isles.* It is not mentioned in Harrison's *Ornamental Conifers*, but Welch does include it in his *Manual of Dwarf Conifers* published in 1979

This plant has confused taxonomists The second edition of Rehder's *Manual of Cultivated Trees and Shrubs* (1940) said that it is probably only a variant of *Thuja orientalis* which retains its juvenile foliage up to the fruiting stage. Den Ouden and Boom's *Manual of Cultivated Conifers* stated that it is closely related to junipers, and that one taxonomist considered it an abnormal juniper. Today, however, it is considered a separate genus with this single known species.

M. decussata was discovered in the Olga River valley east of Vladivostock and on mountains near Vladivostock at high elevations above the timber line In 1949, two seedlings collected from the wild were obtained by the Botanical Garden in Taschkent, USSR. From there it was distributed to Czechoslovakia, and from there to Germany. Cuttings from these plants were received at the Trompenburg Arboretum in Rotterdam, Holland, in 1968. Two plants are growing there. Since then, cuttings from these plants have been fairly widely distributed.

J.R.P. Van Hoey-Smith of the Trompenburg Arboretum described this species as an ideal ground cover. The growth habit is low and spreading In 1978, the 10-year old plant in

the Trompenburg Arboretum was 12 feet across but only 8 inches high The species is said to grow well in both full sun and half shade, a fact that gives it an advantage over juniper species. In winter, *Microbiota* changes from green to a color described variously as dull brown, copper brown, or like that of *Juniperus horizontalis* 'Plumosa' in winter.

As might be expected from its origin, it is very hardy, probably at least to USDA hardiness Zone 3 and maybe to Zone 2.

In the wild, propagation is from seeds or layering. Cuttings root readily. The species was initially described as dioecious, but one of the two plants in Rotterdam apparently bore viable seeds in 1978 Since both plants growing there were ramets of the same clone, it appears that there must be some exception to the dioecious condition, unless the species can be pollinated by other conifers such as *Juniperus* or *Thuja*, which the observer thought unlikely on the basis of cone morphology. I have not found information on seed germination requirements. Russian cypress has been suggested as a common name.

Plants are available from Isely Nursery, Boring, Oregon, and perhaps elsewhere The Arnold Arboretum has it, as does the Minnesota Landscape Arboretum.

MODERATOR ALEXANDER· Rob DeFeo from the U.S. National Arboretum, Washington, D.C., has four plants to discuss

ROB DeFEO. *Hibiscus syriacus* 'Helene', NA 41786, PI 445779. is a selection from (*H. syriacus* 'Sokobien-yae' × *H. syriacus* 'William R Smith') × *H. syriacus* tetraploid seedling. The multiple-stemmed, erect-growing, densely branched shrub in 9 years has grown 2 5 m high and 2 m wide The glabrous, firm-textured, dark green (Green 137A above and Green 137C beneath) leaves are 7-10 cm long, 4-7 cm wide, triangular or rhombic-ovate, mostly 3-lobed, and variously toothed and notched on the margins The waxy, companulate, 10-15 cm diameter flowers are undulate to heavily ruffled, with 3-20 twisted lanceolate petaloids. The white flowers have a trace of pink (Red Purple 70C) on the reverse and a prominent dark red (Red Purple 60A) eye spot that radiates along the veins to mid-petal The seed capsules. when formed, contain mostly aborted ovules Being a triploid plant, seed production is none or very sparse with the result that the plant continues to initiate flower buds from early summer to autumn.

This new cultivar was selected by Dr. Donald R. Egolf and

Color designations are according to the Royal Horticulture Society Colour Chart, 1966

results from a breeding program with the objective to combine polyploid sterility with superior ornamental characteristics. 'Helene' can be readily propagated by softwood cuttings that frequently will flower the first season, but it is not until the second or third year that plants produce heavy flowering. It will grow on a wide range of soils but will do best in a sandy loam with a pH of 5.5-7.0. The flowering will be heavier and the plant much more compact if grown in full sun. It is reliably hardy to USDA Zone 5b.**

Lagerstroemia 'Muskogee' and *L.* 'Natchez'. 'Muskogee', NA 38448, PI 427114, is a hybrid selection from the cross *L. indica* 'Pink Lace' × *L. fauriei*. The multiple-stemmed, large shrub or small tree in 12 years has grown to a height of 7 m and a breadth of 3.5 m. The exfoliating bark of the vigorous, upright trunks is medium brown (Greyed-Orange 164B-165D). The heavy, glossy, dark green leaves, which are 5-9 cm long and 2.5-4.5 cm wide, turn good reds and yellows in the fall. The abundant inflorescences of light lavendar (Violet 84C) flowers are 10-18 cm long and 10-12 cm wide. 'Muskogee' produces a landscape-sized plant in 3 years suitable for specimen or avenue plantings.

'Natchez', NA 38449, PI 427115, is a hybrid selection from the cross *L. indica* × *L. fauriei*. The multiple-stemmed, large shrub or small tree in 12 years has grown to a height of 7 m and a breadth of 3.5 m. The most outstanding characteristic of the plant is the dark cinnamon brown (Greyed-Orange 166B-174D) exfoliating trunk bark that remains spectacular throughout the year. The glossy, dark green leaves, which are 3.4-8 cm long and 2-4 cm wide, assume good autumn oranges and reds. The pure white flowers are borne in inflorescences 14-30 cm long and 10-15 cm wide throughout the summer. 'Natchez' produces a select flowering specimen within several years, but the distinctive trunk bark coloration is not spectacular until about the fifth year.

These hybrids were selected by Dr. Donald R. Egolf and result from a breeding program with the objective of combining mildew resistance with superior ornamental characteristics. These are the first hybrids to be produced by controlled interspecific hybridization with *L. fauriei* and *L. indica* and are unique with resistance to mildew incited by *Erysiphe lagerstroemia*. They can be readily propagated from softwood cuttings. They will grow well in many soils but will do best in a sandy loam with a pH of 6.0-7.0. These plants are reliably hardy to USDA Zone 7b.

** Hardiness ratings are based on the USDA Plant Hardiness Zone Map, USDA Misc Publication 814

Magnolia 'Galaxy', NA 28352-14, PI 433306 was selected from an F_1 hybrid population from the cross *M. liliflora* × *M. sprengeri* 'Diva'. It is a single trunked tree with an excellent branching habit. In 14 years the original tree has grown to a height of 8 m with a trunk diameter of nearly 18 cm. There are 11-12 tepals pigmented on the outer surface at the base ruby-red (Red Purple 64A) shading to magneta-rose (Red Purple 64C) toward the tip. The inner surface of the tepal is a paler red (Red Purple 65C). The flowering period is about two weeks later than the early parent 'Diva', thus allowing flowers to escape most early frosts.

This new cultivar was selected by Dr. Frank S. Santamour Jr. and results from a breeding program with the objective of developing cultivars with superior characteristics. The adaptability, tree form, late flowering, and flower color of this cultivar are significant improvements of existing cultivars of *Magnolia*. 'Galaxy' is adaptable to a wide range of soil conditions, including sod culture, and can be readily propagated from softwood cuttings. It is reliably hardy to USDA Zone 5.

Viburnum 'Chesapeake', NA 43149, PI 445781, is a hybrid selection from the cross *V carlcephalum* 'Cayuga' × *V. utile*. The deciduous compact shrub in 16 years has grown 2 m high and 3.3 m wide. The densely stellate, light green (Yellow Green 147B) young branches become glabrate, wide spreading and grey-brown. The glossy, dark green (Yellow Green 147A above and Yellow Green 148C beneath), obovate elliptic leaves are 5-7 cm long and 3-4 cm wide. In autumn the leaves assume red to orange (Greyed Red 179A to Greyed Orange 173D) coloration During early May the profusion of 5-8 cm diameter cymes have pink buds that open to white flowers. The fruit ripens in August to a dull red before becoming black.

This new cultivar was selected by Dr. Donald R. Egolf and results from a breeding program with the objective of developing cultivars with superior ornamental characteristics. 'Chesapeake' is suitable for use in the landscape as a specimen, a hedge, or a mass planting. This cultivar will grow well in many soils but will do best in heavy loam with a pH of 6.0-6.5 and can be readily propagated from softwood cuttings. It is reliably hardy to USDA Zone 5b.

The planting stock increased by cooperating wholesale propagation nurseries will be the source of plants for introduction. A distribution from the U.S. National Arboretum to arboreta and botanic gardens will follow. The U.S. National Arboretum does not have stock of this cultivar available for general distribution.

MODERATOR DEL TREDICI: Jack Alexander will next present a plant with description by Gary Koller.

GARY KOLLER. *Kalopanax pictus*, castor aralia, is most significant because of a cold hardiness tolerance to −30°F (Burlington, Vermont), and perhaps lower if more widely tested. This cold tolerance is a primary attribute for it would make *Kalopanax* a useful addition to northern landscape markets where the selection of trees is drastically restricted due to winter temperatures. Another important consideration is that this tree tolerates lower, flood plain type soils and situations. Many of the best trees for street tree and urban landscapes possess this attribute. It also adapts to higher drier soils and a wide pH range

Ornamental features are limited to large terminal clusters of small greenish-white to creamy-white flowers in August. Followed by tiny blue-black fruits in late September and October. The ripened fruits attract several types of birds which quickly devour them At the Arnold Arboretum autumn foliage is yellow-brown to amber-yellow but at best is relatively non descript.

One characteristic which can be viewed as an asset or a disadvantage are short, pointy spines along the trunk, stems and branches As a disadvantage they make transplanting and pruning care more difficult. However, when used as a street or park tree these spines may discourage vandalism to the stem as well as tree breakage On mature bark the spines are reduced or absent and the bark is dark brown and deeply furrowed and could be compared to the bark of *Robinia pseudoacacia*, the black locust Winter form of *Kalopanax* is a bit irregular and coarse with an open branching pattern

If you live in or market your plants in the northern portion of the United States or southern Canada this is a tree you should evaluate.

WEED CONTROL IN LINERS AND FIELD TRANSPLANTS

LLOYD MODEN

Mid-Western Nurseries, Inc.
Tahlequah, Oklahoma 74464

The weed control methods that will be covered here are ones that have been used by Mid-Western Nurseries at our Tahlequah, Oklahoma growing facility. Tahlequah is in the northeastern part of the state and most of our soils are loam to silt loam and clay loam. The field soils average about 2% organic matter. Our annual precipitation is 46 inches.

WEED CONTROL IN SOFTWOOD CUTTING BEDS

All of our softwood cuttings are stuck in plastic-covered bowhouses 12 ft wide and 96 ft long. There is a narrow walkway down the center of each house. The growing medium in the beds is a mixture of sand and bark. The beds are reused from year to year After a bed is used, it is cleaned up and renovated if needed. The soil is loosened with a Troy-bilt rototiller. This tiller works well because the handle can pivot away from the outside bows.

The beds are then fumigated with methyl bromide (MeBr) containing 2% chloropicrin at the rate of 1½ lb/100 sq ft. We used to use 1 lb- or 1½ lb-cans of MeBr but now use 200-lb cylinders because of the cost savings. The 200-lb cylinder and the accompanying bottle of nitrogen used to pressurize the MeBr are mounted on a small trailer that can be pulled from house to house by hand. The bottle cradle is hinged so the bottles may be layed down when the trailer is being moved. The trailer remains outside the bowhouse with three hoses from a manifold on the MeBr bottle leading into evaporating pans in the cutting house.

We use one sheet of plastic to cover the whole cutting bed including the middle walkway. The plastic is covered from the inside with soil so that all the soil is exposed to the fumigation treatment. We find it helps to shake the plastic to trap air underneath. The soil temperature must be at least 55° at the 3-inch depth when fumigation is initiated. With our manifold pressure and orifice size, leaving the manifold valves open for 60 seconds gives us the correct rate in this size house. After fumigation the plastic is left on the bed for at least 24 hours if the soil temperature is above 70°F and 48 hours if the soil temperature is below 70°F degrees Then the soil is allowed to air out undisturbed for another 48 hours before sticking begins. On beds containing evergreen cuttings stuck and rooted

early, we apply Ronstar or Scotts Ornamental Herbicide I (oxadiazon) (1) 4 lb AI/A in July for spurge control. It is important to keep the area around the houses clean to prevent weed seeds from blowing into the cutting beds.

WEED CONTROL IN SEED BEDS

Our field seed beds are slightly raised beds 4 ft wide and 300 to 350 ft long. We have the equivalent of over 10 miles of seed beds. The soil is mostly a silt loam with some areas silty clay loam. We fumigate these seed beds prior to planting with MeBr at 350 lb/A. The seed beds are thrown up with a bed former then worked down slightly with a section of a rotary hoe to break up clods. The MeBr is injected into the soil with a fumigation implement that covers the bed with plastic at the same time. The fumigation rig has 5 tines through which the MeBr is injected 6 inches deep into the soil. The plastic is 66 inches wide 1¼ mil (0.00125 inches) thick, embossed for additional strength. I prefer black plastic to clear plastic for additional warming of the soil on cool sunny days

After fumigation the plastic is left on the bed at least 48 hours. After the plastic is removed, we let the soil air 3 to 4 days before planting. The unplanted, non-fumigated edges of the beds may still be infested with weed seed. We spray these edges with Surflan (oryzalin) (2) 2 lb AI/A.

It is very important that the soil not be too dry nor too wet when fumigated. If the soil is too wet, the fumigant will not move through the soil; if too dry, the fumigant will not penetrate the clods.

MeBr fumigation does a good job of controlling grasses, but seeds of some broad-leaved plants have hard seed coats or germinate from deep in the soil and may not be totally controlled. These include velvet-leaf, morning glory and pigweeds. Only partial control can be expected of nutsedge.

Methyl bromide will cost us $9.00/bed ($322/A), plastic $8.50 ($200/A), and labor about $5.00 ($120/A). Two people can generally cultivate between the beds and do all the necessary weeding and hoeing during the summer.

WEED CONTROL IN FIELD TRANSPLANTS

All soils which are to be planted to field liners are sprayed with Treflan (3) EC 1 qt/A preplant incorporated if johnson-

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[1] Oxadiazon — Ronstar, Rhone-Poulenc, Scotts Ornamental Herbicide I, O M Scott & Sons, Maryville, OH 43040

[2] Surflan — oryzalin, Elanco

[3] Treflan — trifluralin, Elanco

grass is not a problem. If the field has a history of johnsongrass, the field is sprayed with Treflan EC 2 qt/A.

After the plants have been settled in with ½ to 1 inch of rain or irrigation, we band simazine (4) 80W 1 lb/A (0.8 lb AI/A) over the top in an 18-inch band. Simazine is used on all narrow-leaved evergreen liners, most shade tree and shrub liners. Shrubs as a group are more sensitive to simazine than evergreens or deciduous trees. We do not apply simazine on linden, althea, or euonymus spp. Surflan 2 lb AI/A is banded on these species.

During the first year of growth of a new liner it is most important to maintain as near a weed-free environment as possible. This includes control of perennial weeds as well as annuals. The herbicides we use for annual weed control do not do a good job of controlling perennial weeds, so special attention must be given to those perennials. Two of the perennials we contend with in Oklahoma are bermuda grass and johnsongrass. During the summer preceeding planting, if the vacant block has a perennial weed infestation, we spray with Roundup[5] 3 qt/A for johnsongrass or 5 qt/A for bermuda grass.

During the summer after planting and successive summers as long as a weed problem remains, we walk the blocks, spot spraying with Roundup herbicide using Solo-brand backpack sprayers. We modify all our Solo sprayers to make them more comfortable for the person spraying by attaching Kelty backpack shoulder straps and hip belts. If we are attacking a bermudagrass problem, we mix Roundup 2⅔ oz/gal of water. For johnsongrass, we mix Roundup 1⅓ oz/gal. We must exercise great care to avoid getting spray drift on desirable plants.

CONCLUSION

Weed control in liners and field transplants is important to give the young plants a vigorous start. The methods just outlined have worked for us under our growing conditions. Other soils and growing conditions may be different from ours; so if you feel any of the ideas presented have merit in your liner production, they should be used with caution until tested in your own nursery.

QUESTIONS FOR LLOYD MODEN

JAKE TINGA: Why do you not also cover your aisles with plastic and treat with MeBr to avoid the continuing cost of control throughout the summer?

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[4] Simzaine — Princep, Ciba-Geigy.
[5] Roundup — glyphosate, Monsanto

LLOYD MODEN: We do cover the aisles in the plastic houses, but it would double our cost to do so in the field.

BRUCE BRIGGS: Have you tried Goal (6)? Reported results look good for broad-leaved weed control.

LLOYD MODEN: We have not used it.

PHIL BEAUMONT: Why do you use such a high rate of Roundup? We have found we can add liquid dishwashing detergent and cut the rate one-half to one third.

LLOYD MODEN. 2⅔ oz/gal is the recommended rate. We feel the cost of additional chemical, which gives us better control, outweighs the cost of more labor to hand weed or repeat applications.

HUGH STRAIN· Do you use a spreader?

LLOYD MODEN. No. It is not suggested on the label.

EARL ROBINSON: Does MeBr help with disease control?

LLOYD MODEN: We have fumigated for so many years that we have few disease problems.

GERALD SMITH: Where do you buy the Kelty shoulder straps and hip belts?

LLOYD MODEN. We buy these at the outdoor backpack sports supply houses.

A VERTICAL AIR-ROOT-PRUNING CONTAINER[1]

CARL E. WHITCOMB

Department of Horticulture
Oklahoma State University
Stillwater, Oklahoma 74078

Abstract. A container was designed to prevent root circling and stimulate root branching A test with the air-root-pruning container using Pyracantha × 'Mojave' showed an increase in top and root weight, number of branches per plant and number of 2 in long roots 10 days after transplanting of 63, 38, 158, and 187%, respectively, compared to plants grown in conventional containers This container nests for shipping, can be filled by existing potting machines and can be handled and stacked for plant shipping like conventional containers

INTRODUCTION

Plants have long been grown in pots in greenhouses and homes. However, the practice of producing large numbers of

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plants out-of-doors in containers has developed primarily since the early 50's. The container nursery industry began in Southern California and spread rapidly across the southern states. The #10 food can with a few holes punched in the bottom was widely used and soon became known as the "one gallon container." During the 60's and 70's, the container nursery industry increased rapidly for several reasons: 1) landscape plants grew at a faster rate in containers than in the field, 2) turnover time decreased, 3) the root system of the plant remained undisturbed allowing planting to be done anytime, not just during early spring as with bare root or balled and burlapped nursery stock and 4) ease of display and handling made container grown plants attractive to the consumer.

However, development of the container nursery industry was not without problems. The complex nutritional requirements of plants in containers took years to refine so that plant growth and quality was comparable to plants grown in the field. The medium for the container evolved from field soil, to mixes of field soil and compost, to soilless mixes. The far greater pore space of the soilless mixes aids in providing oxygen to the root system.

Root development, especially that of woody plants in containers, has been the subject of numerous articles (1,4,5,6,7,8) and is a common topic at gatherings of nurserymen. As a root grows from a cutting or seedling in a container, its path is out toward the side of the container and downward. When a root reaches the side of a round container, it follows the contour; and generally after ½ to 1 full circle, reaches the bottom Here it may continue to elongate and circle sometimes for 5 or more revolutions.

Whitcomb (9) tried placing holes in the sides of container to improve root growth, but without success. Subsequent studies with tree seedlings grown in square, bottomless container on a raised wire bench showed that "air-root-pruning" was effective in stopping root elongation and wrapping at the bottom of the container. Air-root-pruning also stimulated lateral branch root development because it caused the death of the root tip (2). Later studies by Hathaway and Whitcomb (7) showed bur oak trees *(Quercus macrocarpa)* grew larger and developed a more fibrous root system in a square bottomless container than in a conventional round container of the same volume

Unfortunately, growing plants in bottomless containers on raised wire benches is not practical or economical Therefore, additional container designs were studied. Birchell and Whitcomb (1) compared the growth of river birch *(Betula nigra)*

trees in containers with vertical ribs on the sides, with or without bottoms. The vertical ribs stopped the circling or wrapping of the roots of a fine, fibrous-rooted species such as birch. In addition, when the vertical ribs were present with birch, there was no advantage to removing the bottom from the container for air-root-pruning. Dickinson and Whitcomb (3) tried placing ribs across the bottom and vertical ribs in round containers only ¼ to ½ the height of the sidewall of the container so that the containers could be "nested" for stacking and shipping. Japanese black pine (*Pinus thunbergi*) and bald cypress (*Taxodium distichum*) trees were grown in the containers for one growing season. The vertical ribs in the lower ¼ or ½ of the container were effective in stopping circling of the pine roots However, the more coarsely-rooted cypress either bent the rib and continued to circle or was stopped by the rib from circling but continued to elongate, creating a "tangled ball of string" effect.

These studies showed that the root system of a plant grown in a container could be improved: 1) as in the case of the bottomless container on a wire bench, and 2) that vertical ribs inside the container could improve the root structure of fine, fibrous rooted plants but only made the problem worse on strong, coarsely rooted plants. Both techniques were impractical for the production of nursery stock on a commercial scale.

EXPERIMENTAL PROCEDURES AND RESULTS

Methods: During February, 1981, the idea of air-root-pruning the roots system on the sides of the container instead of the bottom was born and studies begun. In order to study this container modification, vertical slits were cut in the sides of conventional polyethylene containers (Figure 1) In addition, horizontal cuts about ¾ inch long were made at the top and bottom of the vertical slit so that section of the pot could be forced out and a wire inserted to prevent closure. The vertical slits created were about ⅛ inch wide. Some slits opened clockwise and others counterclockwise. It is important that slits go clear to the bottom of the container and that they are offset. If they are not, roots do not grow out and are not air-pruned. *Pyracantha coccinea* 'Mojave' cuttings were planted in the new containers as well as in conventional containers of the same size and color. The growing medium for both containers was a 3.1:1 mix of ground pine bark, peat, and sand amended with 14 pounds of 17-7-12 Osmocote, 8 pounds of dolomite and 1 5 pounds of Micromax/cubic yard. Containers were located in full sun and were watered from overhead sprinklers as needed

RESULTS AND DISCUSSION

By air-root-pruning the roots on the sides of the container (Figure 2) the objections of the previous techniques were overcome: 1) Containers have a conventional bottom for ease of filling, handling and shipping. 2) Roots are more evenly distributed throughout the container medium, not mostly in the bottom (Figures 4 and 5). 3) The vertical air-root-pruning causes stimulation in branch-root development. The increase in root surface area results in increased absorption of water and nutrients, which in turn results in increased plant growth (Table 1).

Figure 1. The container design with vertical slits to air-root-prune root tips as they circle the container. By alternating the opening of the slit, the root tips will be pruned whether they circle left or right.

Figure 2. Close-up of root development at the vertical slit in container. Note that the roots have been air-root-pruned at the slit and have stopped elongating. When the plant is placed in the landscape, however, the newly formed branch roots will elongate rapidly into the surrounding soil.

Figure 3. Root development of a pyracantha shrub (left) in a container with vertical slits and (right) in a conventional round container of the same size and composition. Note that some roots in the conventional container circle half way or more around the container even though these plants are only 3 months old.

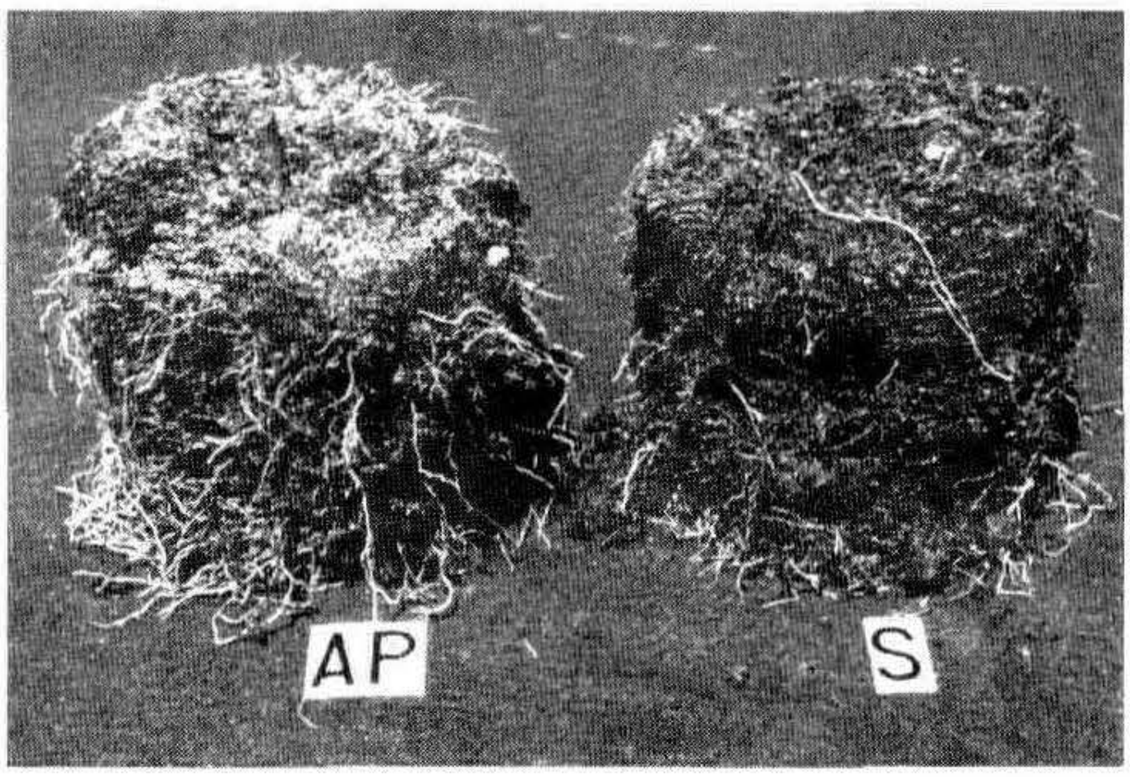

Figure 4. Root development of pyracantha grown in 2-gallon container then transplanted into 5-gallon containers and allowed to grow for 10 days. Note the greater number of white roots on the vertical air-root-pruned container (AP) as opposed to the standard pot(s).

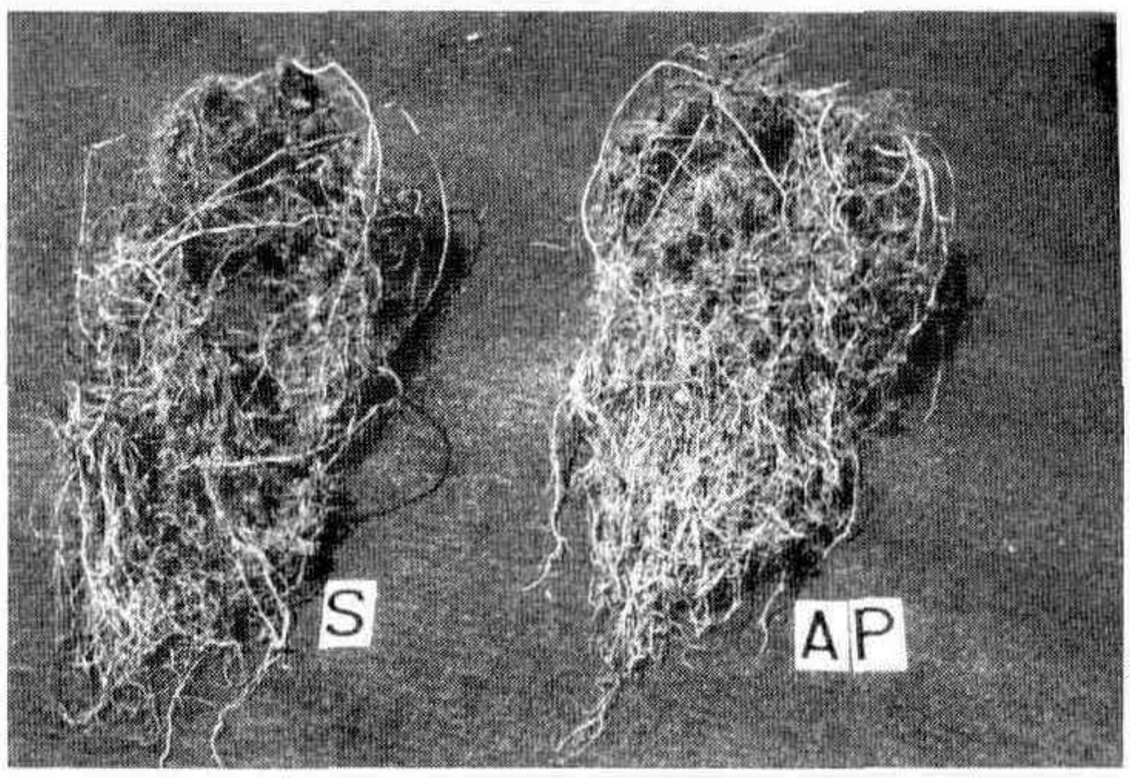

Figure 5. Root development of pyracantha in a standard pot(s) vs the vertical air-root-pruned container (AP). Note the numerous circling roots of the standard pot as opposed to the more fibrous root system and no circling of the air pruned pot.

With nursery stock grown in conventional containers only a few root tips exist at the bottom of the container (Figure 3). At time of planting in the landscape, the root tips extend into the surrounding soil (3). With the vertical air-root-pruning container, a great increase in number of root tips exists at planting time (Figure 4 and Table 1); thus, establishment of the plant in the landscape is accelerated. Other advantages of the container are: 1) It can be filled by existing commercial pot fillers without modification. 2) This container will "nest" or stack so that freight costs for shipping containers from manufacturers to nurserymen will not be increased.

Table 1. Effects of vertical air-root-pruning on growth of Pyracantha × 'Mojave'

	Standard pot	Air-pruned pot	Percent increase
Branches/plant	12 5	32 2	158
Number of roots 2" long 10 days after transplant	44	126	187
Top weight (g)	93 3	152	63
Root weight (g)	109	192	38

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QUESTIONS FOR CARL WHITCOMB

TED GOREAU: Must the slits be offset in opposite directions?

CARL WHITCOMB: Yes. Otherwise only the roots circling in one direction will be pruned.

BRYSON JAMES. Did just ribbing help?

CARL WHITCOMB: We found that roots still wrapped around the inside of the container

BRAD MAY: With our 85% relative humidity, we don't get air-pruning even if the roots come out.

CARL WHITCOMB. When we started our experiment, we had 85% relative humidity We still got root pruning. However, this is a legitimate concern.

TERRY GRACE· How hard is it to remove the plant from the container?

CARL WHITCOMB· We've had no problem

JIM BERRY: Do you get the same effect with strongly taproots?

CARL WHITCOMB: Yes, although it is not quite as dramatic Pecan will produce an extensive fibrous system but these roots do not remain functional following transplanting. However, that is not typical of other species.

JUDSON GERMANY: Will these containers require a separate watering system?

CARL WHITCOMB. I can't see that they will. The slits are not truly openings and seem not to affect water requirements.

BILL PINKHAM: What about a pot with a mesh screen at the bottom?

CARL WHITCOMB. We have tried that. A pot with a false bottom of any sort is hard to manufacture. Also, anytime the soil ball is elevated, the soil column is shortened and drainage is not as good

STEVE HAMMOND· We have found baskets effective in producing fibrous roots

CARL WHITCOMB. Yes. We have obtained similar results with wooden-slat type containers.

JUDSON GERMANY. What about a square container?

CARL WHITCOMB· Changing shape is no help unless slits are put at the corners.

STEVE HAMMOND. Have you tried a wider pot or using field soil?

CARL WHITCOMB· Oxygen content in the medium is a function of both surface area and depth. However, pulling in the oxygen at the surface ıs a function of depth sınce gravitational pull ıncreases as the heıght of the soil column becomes greater.

I do not feel field soil has a place in container production Maintaining good water relations is very difficult, and sooner or later *Phythophthora* becomes a serious problem.

JOSE GARCIA: Are these pots available?

CARL WHITCOMB. We have contacted two manufacturers, but they are not producıng them so far.

GROUND COVERS FOR HIGHWAY USE

RICHARD J. STADTHERR

Horticulture Department
Louisiana State University
Baton Rouge, Louisiana 70803

Abstract. Over 200 different kınds of plants were ınvestigated over eight years for their adaptabılity, hardıness, propagation. maıntenance, and general suıtabılity for use as ground covers on slopes, medıans, and flat areas along highways ın Louısiana Ratıng for overall appearance, weed presence and crop establishment over a 13 month perıod ındicated that lırıope rated highest sıgnificantly *Lonicera japonica* 'Purpurea', *Trachelospermum asiaticum* and *Wedelia trilobata* rated highly also *Wedelia* kılls back to the ground after exposure to 28°F The others are evergreen

Research was ınitiated in July, 1973, with the Louisiana State Highway Department to learn which low-growing ground cover, preferably under 2 ft, could be used to enhance safety and beauty, prevent erosıon and reduce maintenance costs primarily on slopes, on entrıes and exits along the interstate highways (4).

There was very lıttle information available on low-growing herbaceous and woody materials for the South (1,2,3). This study was undertaken with the following objectives: to obtain, select, and propagate plants for trial; to learn the best method of propagating and producing them; and to set up replicated field trials to learn how they would establish under local conditions. Ultimately the goal was to make recommendations for future plantıngs based on ınformation obtaıned.

MATERIALS AND METHODS

A review of the lıterature was started in 1973 and collectıon made of varıous plant materıals that had possibilities of fulfilling the objectives. Over the 8 year perıod 8 different

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plantings were made

Plants were usually started by cuttings or divisions, depending on species. They were placed in 2¼ to 3 in pots using, basically, 85% shredded pine bark, 5% washed builders sand, and 10% gravelite (a baked montmorillonite clay) Osmocote (18-6-12) at 5 lbs, dolomitic limestone at 10 lbs, hydrated lime at 2 lbs, and fritted trace elements at ¼ lbs per cu yd were applied. If phosphate was low, it was added at 2 lb/yd^3 A 20-20-20 soluble fertilizer at 100 ppm was applied every 2 weeks while the liners were in the lathhouse. After plants were large enough to put in trade gallons, they were moved to full sunlight and fertilized every 4 weeks with Osmocote at 42 grams (about 1.4 oz) per container.

For the last planting 8 different plants were selected to be replicated at 3 different locations By that time a great deal had been learned. Plants in general that would tolerate full sunlight were needed. Cultivation and use of a mulch on these steep slopes gave excessive erosion Erosion was minimal if original cover was killed and holes made staggered from row to row on the slope Holes were made by a power digger. Plantings should be completed ideally in February From results of the preliminary tests the following 8 plant materials were selected for replicated trials at 3 different sites in the Baton Rouge area:

Trachelospermum asiaticum, dwarf Confederate jasmine; *Lonicera japonica* 'Purpurea', purple honeysuckle; *Euonymus fortunei* 'Colorata', bronze wintercreeper: *Coreopsis auriculata* 'Nana', dwarf coreopsis; *Asparagus densiflorus* 'Sprengers Compacta', dwarf compact asparagus fern, *Verbena peruviana* 'St. Paul', St. Paul verbena, and *Wedelia trilobata*, wedelia.

Over the years these plants had shown fast establishment, good coverage and relative freedom from diseases and insects.

A randomized planting was made at each location with individual plantings running from top to bottom of the slope or across the plot. Individual plantings varied depending on species and were 12 inches from center to center of the balls for the fern, coreopsis, and liriope, 15 inches for verbena, 20 inches for the dwarf Confederate jasmine and 24 inches for the wintercreeper, honeysuckle and wedelia Plantings were completed on April 20, 1980

Monthly ratings were made by 6 judges starting in June for overall crop appearance, weeds present and establishment of each crop plant in each of the 3 replications An extended period of drought from May 20 to June 19, 1980 and August, 1980 took out most of the dwarf coreopsis and verbenas, thus

eliminating these two plants from the statistical analyses.

Herbicides applied in the fall before cool temperatures set in did not kill all existing vegetation; therefore, weed control was started as soon as the plantings were completed. Paraquat was applied between the rows. While plants were small, they were covered with plastic containers, and spraying was done within the rows, too. Johnson grass and Bermuda grass were the 2 worst weeds encountered. Glyphosate (Roundup) was applied over the dwarf Confederate jasmine after it was well established at the rate of 10 ml/l, and at 5 ml/l over the honeysuckle and wintercreeper. There was no visual damage. The jasmine had terminal buds killed and more breaks induced from the herbicide. Four sprayings were made of glyphosate during the growing season. Hand weeding was done on the other species, which were susceptible to injury.

In 1981 glyphosate was used twice over crops having tolerance. Quickdraw, a bar applicator containing a solution of glyphosate, was used primarily to control the tall weeds like Johnson grass. This bar had a solution of 2 parts glyphosate to 1 part water on a volume basis. The bar was used 3 times during the growing season.

RESULTS

Overall establishment ratings were made for the three replications by 6 judges. A rating of 1 to 9 was used, with 9 indicating the highest number of plants per plot. Analyses of variance were made for each month from June, 1980 through June, 1981 and for the entire 13 month period for the 6 species.

For the first date in June, liriope received the best rating followed by wedelia and honeysuckle. Liriope plants were spaced closer, resulting in fewer weeds and less weed competition. The overall rating in June 1981 was, in order: liriope, jasmine, and honeysuckle, indicating that liriope tended to establish the most rapidly.

For weed ratings the same general pattern was shown among species. Significantly more weeds were found in the wintercreeper plots. The honeysuckle and wedelia plots had significantly more weeds than jasmine and liriope plots. No herbicides were applied to the wedelia, which is very susceptible to glyphosate. The honeysuckle had a more open nature, thus greater weed penetration. In general the liriope had the fewest weeds; however, weed populations were not significantly less than in the jasmine, which had had periodic herbicide applications. Whether these sprays will have a long term effect on the jasmine will have to be determined.

In conclusion the liriope performed best over this 13 month period followed closely by the honeysuckle, jasmine, and wedelia, which could be placed in a second group. The wintercreeper and fern appeared to require a longer time to establish. Ratings are being continued for another year to observe which species will develop a solid cover and be resistant to weed penetration Thus far the wedelia and honeysuckle appear to become more dense with less weeds than in the liriope.

DISCUSSION

All vegetation should be killed before a planting is started. Fumigants that can be watered-in should be tried. If glyphosate and 2,4-D are used, at least 3 sprayings spaced a minimum of 2 weeks apart should be made to kill all grasses and weeds. Weeds should be in active growth and temperatures 70°F or above, when herbicides are applied. If the area is rototilled, some method to prevent erosion is necessary Shredded bark did not prove successful between plants for heavy rains carried it down the slopes Possibly straw or erosion netting might be used Digging holes staggered from row to row and not cultivating the soil resulted in less erosion.

Akebia quinata, five-leaf akebia; *Arundinaria pygmaea*, dwarf bamboo; *Lantana montevidensis*, trailing lantana; *Miscanthus sinensis* 'Variegatus', variegated eulalia, *Rubus parviflorus*, thimbleberry; and *Shibatea kumasaca*, kumasaca are others which showed much promise in small trials.

Table 1 gives the ground-cover plants, their characteristics and evaluation.

Table 1 Ground covers showing promise in Louisiana trials

Scientific/ common names	Height (cm)	Spacing (cm)	Propagation*	Remarks
Achilea Millefolium L Common yarrow	55	30 5	d	Slow to increase. Cut seed heads in July Drought tolerant, attractive flowers.
Ajuga reptans L Carpet bugleweed	8	30 5	r	Full sun not tolerated Root rots and nematodes problem
Akebia quinata (Houtt) Decne Five leaf akebia	15	50 8	c	2 to 3 per container Quick spread Competes well with weeds Dense cover One of the best
Arundinaria pygmaea (Miq) Asch & Graebn Dwarf Bamboo	30	30 5	d	Propagation & establishment slow Drought tolerant Pest free Dense cover in time, poor growth in containers

* Propagation by c - cuttings, d - division, l - layering, r - runners; s - seeds, x - rhizomes

Scientific/ common names	Height (cm)	Spacing (cm)	Propa- gation*	Remarks
Asparagus densiflorus (Kunth) Jessop 'Sprengeri Compacta' Dwarf compact asparagus fern	48	30 5	d	Propagation & establishment slow Weed competition poor Better fertility & moisture needed
Aspidistra elatior Blume Cast-iron plant	60	30 5	d	Slow Little lateral spread Deep shade tolerant, not full sun
Chrysanthemum X *superbum* Bergmans ex J Ingram Shasta daisy	15	30 5	d	Slow Rosette growth flowers up to 55cm High maintenance Attractive flowers & foliage
Coreopsis auriculata L 'Nana' Dwarf coreopsis	10	30 5	d	Fast Succumbed to extending drought in test Shallow but dense root Considered one of best Species more vigorous but taller growth
Duchesnea indica (Andr) Focke Mock Strawberry	8	30 5	r	Fast Hard to get dense cover in full sun Shallow roots Spreading
Euonymus Fortunei (Tarcz) Hand-Mazz 'Colorata' Bronze winter-creeper	15	61	c,1	Fast Dense cover in seasons Purple leaves in winter One of best
Glechoma hederacea L Ground ivy or Creeping Charlie	6	38 1	c,1	Fast in moist soil & cool temperatures Intolerant of hot, dry conditions
Hedera canariensis Willd Algerian ivy	12	61	c	Fast but slow to establish Prefers some shade Fair tolerance to drought
Hemerocallis fulva (L) L Tawny daylily	38	30 5	d	Slow Lateral spread very slow Drought tolerant Persistent Attractive flowers Evergreen Flower stalks taller
Juniperus conferta Parl Shore juniper	15	50 8	c	Slow Mites a problem Loss by pilferage great
Lantana montevidensis (K Spreng) Briq Trailing lantana	60	61	c	Fast Species evergreen but hybrids killed by frosts to ground line Beautiful, long-season flowering More trails One of best
Liriope muscari (Decne) L H Bailey Big-blue liriope				Quite rapid Attractive flowers Evergreen Drought tolerant Pest free Some lateral spreading One of best

Scientific/ common names	Height (cm)	Spacing (cm)	Propa- gation[1]	Remarks
Liriope spicata Lour Creeping liriope				Similar but more lateral spreading Faster establishment Narrower leaf & flowers not as nice One of best
Lonicera japonica Thunb 'Purpurea' Purple-leaved honeysuckle				Fast Dense cover usually in 2 growing seasons. Leaves very purple in winter Attractive flowers Hasn't reseeded like species One of very best
Lysimachia Nummularia L Moneywort or turkey ivy				Fast Roots along stems Prefers some shade Dense cover Shallow roots and not drought tolerant
Miscanthus sinensis 'Variegatus' Variegated eulalia or cemetery grass	75	50 8	d	Fast Flower heads to 1 meter Lateral spread good Drought tolerant One of very best
Ophiopogon japonicus (Thunb) Ker-Gawl Mondo grass or lily turf	25	30 5	d	Rapid Few pests Drought tolerant Grows & spreads under taller weeds & grasses One of best
Rosa Wichuriana Crep Memorial rose	60	161	c	Quite rapid Prune to spread & get denser Leaf disease, drought and low temperature cause leaf drop Flowers in May Good
Rosmarinus officinalis L 'Lockwoodii' Lockwood rosemary	38	30 5	c	Slow Drought tolerant but not to wet conditions Attractive foliage & flowers Rather open
Rubus parviflorus Nutt Thimbleberry or creeping raspberry	60	61	c	Rapid Prune to get dense Competes well Persistent No leaf diseases One of best No flowering yet
Rudbeckia hirta L Black-eyed susan	60	38 1	s,d	Rapid Not all perenials some died out Reseeds Drought tolerant Attractive flowers Rosette with flower stalk to 60cm and more
Santolina Chamaecyparissus Lavender cotton	50	30 5	c,d	Slow Clumpy rosette growth Disease problem in wet weather Species S virens was similar
Shibatea kumasaca (Zoll ex Steud) Makai Kumasaca	50	30 5	d,x	Fairly rapid Drought tolerant No pests Lateral spreading Poor growth in containers Needs more testing

Scientific/ common names	Height (cm)	Spacing (cm)	Propa- gation*	Remarks
Teucrium chamaedrys 'Prostratum' L Dwarf germander	25	30 5	c	Fairly rapid. Drought tolerant but not of wet conditions Attractive dark green foliage and flowers
Trachelospermum asiaticum (Siebold & Succ) Nakai Dwarf confederate (Jasmine)	46	50 8	c,1	Rapid 2 to 3 cutting per container
			c	Slow to establish but dense cover in second season usually Pest free Evergreen One of very best.
Verbena peruviana (L) Britt 'St Paul' St Paul verbena	15	38 1	c	Fast and quick spread White fly and mite susceptible Intolerant of extended drought until well-established Rather shallow roots but dense & root along decumbent branches Very attractive & long flowering Good
Vinca major L Big or Greater periwinkle	48	38 1	c,1	Fairly rapid Prefers some shade Hard to get dense stand Spreads fast Competes well with other plants
Wedelia trilobata (L) A S Hitchc Wedelia	38	61	c	Very rapid Spreads fast Dense cover Attractive foliage & yellow flowers Kills to ground annually at about 28°F. Slow next spring to emerge Competes well One of best

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PREPARATION OF CONTAINER GROWING BEDS

GRADY L. WADSWORTH

Greenleaf Nursery Company, Inc.
El Campo, Texas 77437

Greenleaf Nursery Company has two growing areas. Our original location, near Tahlequah, Oklahoma, consists of 310 acres and is located on the rolling, rocky hills adjacent to Lake Tenkiller. The second growing area was located in El Campo in 1971. Gil Nickel and Austin Kenyon selected the area for its mild climate and closeness to large and developing metropolitan areas of Texas.

They liked the level land and the deep black clay which would make it easy to prepare growing beds Due to the levelness of the land they decided to reverse the block design; instead of the block's being crowned it would slope to the center This would allow the roads to be built on the crown and assure good drainage of the roadway and block.

We contacted the Texas Highway Department and road building firms to see what preparation should be made to the base. They recommended lime stabilization. We put in 8 test areas where we incorporated lime at the rate of 10 lb/sq yd and compared them to areas with no stabilization. We covered these areas with 4 materials: 4-mil black plastic; oyster shells; washed 1-inch bunker gravel; and bay prairie aggregate (a baked clay approximately ¼ to ½ in in size)

Lime stabilization worked very well for all of the materials. We first selected the bay prairie aggregate to top the blocks. However, after one year of use we discovered the aggregates broke and crumbled. Therefore, we selected washed 1-in bunker gravel.

Our first ditches were V-ditches. They also required modification. After the first year we discovered they should be dug and boarded. We first used 1×12 in penta-treated boards; we have since changed to two 1×6 inch penta-treated boards and leave a small crack to allow water to seep into the ditch.

PREPARATION OF CONTAINER GROWING BEDS
(Block area 100 × 615 ft with 20-ft road on side)

Land preparation. The land is disked 6 to 8 in deep to provide a sufficient amount of loosened dirt to work with. Then a maintainer is used to shape two 120- × 615- ft container blocks at a time. This is accomplished by windrowing dirt and moving it away from the desired "V"ed area to the roadway (Figure 1). A sheep foot packer is employed to pack the

dirt in the crowned area of the adjacent blocks. A disk is then employed to loosen approximately 6 in of earth.

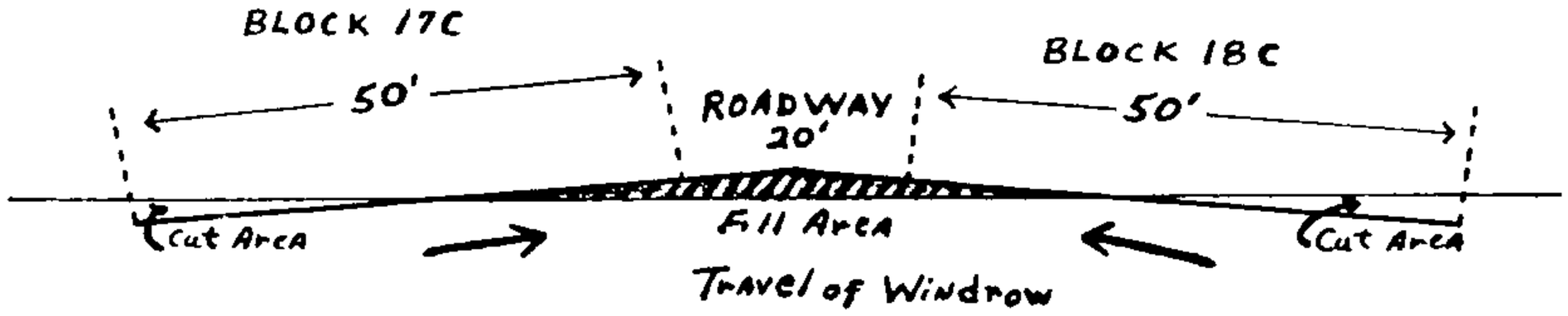

Figure 1. Arrows denote travel of windrowed dirt from cut area to fill area This is accomplished with a maintainer by working with two adjacent blocks

Lime stabilization. Lime is then applied at a rate of 10 lb/sq yd, disked in, watered and packed until a firm base is achieved. We apply lime at a rate of 20 lb/sq yd on our roadways. The 100- × 615-ft block area requires 48 tons of lime. The side road requires 12 tons and the end road requires 4½ tons.

Ditch preparation. A back hoe is employed to dig a "V"ed ditch down in the center of the block This is accomplished by bolting two halves of a plow sweep to the sides of the back hoe bucket. The ditch is 12 in deep with an 18-in bottom width and a 32-in top width. After the ditch is dug, 2- × 1- × 24- in penta-treated pegs are driven into the outside edges. 1- × 6- in penta-treated boards are then secured to these pegs with nails. Two in of concrete are placed in the bottom of the ditch. Four 2- × 4- × 34- in penta-treated boards are then secured to the top of the board ditch for each 40 ft length. These 2- × 4- inch boards support the 4-in aluminum irrigation lines (Figure 2).

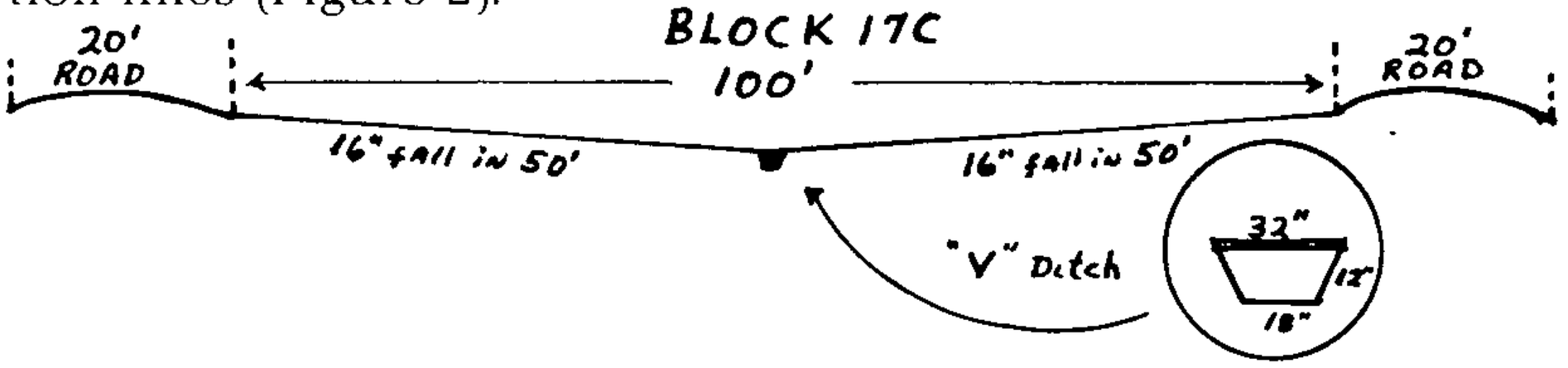

Figure 2. Block is 100 ft in width by 615 ft in length with a 20 ft roadway on each side of the block There are 16 in of fall from edge of roadway to the block ditch

Gravel application. Trucks are employed to haul 1-in washed bunker gravel to the stabilized block area. This requires 280 tons of gravel. The maintainer is then used to windrow and spread the gravel. A land plane assists in the latter stages, and some hand work is required for the final touches. Road gravel is applied 4- to 6- inches deep on the 20-ft roadways. They are lime stabilized with 10 lbs/sq yd and then packed A standard side road, 20- × 615- ft in length, and a 25- × 100- ft end road require 140 yards and 60 yards,

respectively. Road gravel is a pit-dug product, which contains approximately 50% red clay and 50% gravel, and is unwashed.

Irrigation installation. Sixteen 40-ft joints of 4-in aluminum irrigation pipe, equipped with steelheads, are installed down the center of the ditch and supported by the 2- × 4- in boards on top of the ditch, two 21-ft × 1-in galvanized pipes run out from each side of the steelhead and terminate with 4-ft × ¾-in galvanized pipe and Weather Tec sprinkler.[1] A ¾-in bell reducer, ½-in threaded nipple and ½-in gas cock allow the sprinklers to be turned on and off individually. A ¾-in hose bib is located at the bottom of every other riser for the purpose of hand watering during planting and other times. The centers of the steelheads are equipped to accommodate a ¾-in riser and sprinkler head; therefore, the sprinklers are on a 40- × 42-ft spacing. A 4-in gate valve at the end of each block allows the block to be watered with 48 sprinklers at one time.

Can filling. There is room for 5 beds between each of the lateral lines The beds are 6½ ft wide by 50 ft long with an 18-in aisle between beds. The beds will accommodate 1.206 one-gallon, 516 two-gallon, or 250 five-gallon cans per bed. When the plants are large enough in size, the plants are spaced on both sides of the ditch; thus, the beds become 6½ × 100 ft.

QUESTIONS FOR GRADY WADSWORTH

LIN TABER. What type of lime are you using?

GRADY WADSWORTH: We buy it in Austin, Texas It is a pit-mixed rock in hydrated form.

JAKE TINGA Could you give us some approximate per-acre costs?

GRADY WADSWORTH. A growing block occupies 1¾ A. Costs per block are as follows.

Lime stabilization	$5,500
Gravel, 1 inch layer	
Bed	2,800
Roadway	1,500
Hardware and lumber (ditches)	1,445
Use of backhoe	300
Plumbing	2,800
	$14,345

or approximately $14,500. Cost per acre would, therefore, be between $8,200 or $8,300. The blocks last at least 7 years. We

[1] Mfg by Weather Tec Corporation, 510 E Clinton Way, Suite 214, Fresno, CA 93727 Full-circle sprinkler — No 10-20AJ, half- or full-circle sprinkler — No 10-25 KAFP

have 130 A in production and spend less than $10,000/year for gravel.

BILL BEATY: From your discussion of can spacing it seems you are using only half of the prepared area.

GRADY WADSWORTH: No, we use all of it since the previous year's plants occupy the area where this year's crop will be spaced out By that time, the others will have been sold

JOHN HOPKINS: What herbicides, if any, do you use?

GRADY WADSWORTH: We use 80% wettable powder simazine at the rate of 20 lb ai/A.

PROPAGATION METHODS USED AT HINES WHOLESALE NURSERIES

STEVEN A. HOTTOVY

Hines Wholesale Nurseries, Inc.
Houston, Texas 77042

Hines Wholesale Nurseries operates a 200-acre container nursery approximately 20 miles west of Houston, Texas. Construction of this facility has been completed over the past 3 years. Hines Nursery grows 227 cultivars of ornamental landscape plants in several size containers. The nursery averages 170 employees during the year with seasonal fluctuations.

At the hub of the nursery is the propagation department. This branch of the nursery has been developed over the last two years and now occupies 9.6 acres Propagation is divided into three departments. cutting, potting and liner maintenance. Propagation produced 3 million potted liners for canning and liner sales in 1981. These liners were started as rooted cuttings, seedlings or divisions. In 1982 a grafting and a spore program will be initiated.

PROPAGATION

Water source. The heart of all propagation is the water source and the mist system. Hines nursery draws its water from deep-water wells. The mist water is pH adjusted to 6.5 by acid injection and chlorinated before used. The mist system operates at 90 psi. The mist nozzles are a parasol type made by Spraying Systems Co.[1] These nozzles give excellent coverage on a 7- × 7-ft spacing with minimum maintenance. The mist

[1] Spraying Systems Co , North Ave at Schamle Rd , Wheaton, Illinois 60187

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system is automated by centrally located time stations. Each station has a series of time clocks, which allow for flexible operation of the mist beds. The time clocks can be set to operate in frequencies from one minute to one hour.

Mist area. The mist area is divided into 3 sections. A saw-toothed greenhouse is equipped with hot water bottom-heated beds. It is primarily used in the late fall, winter and spring for cuttings of *Ilex, Juniperus, Nandina, Ternstroemia* and *Thuja* The shade mist is under 73% Saran. The flats are placed on gravel beds. It is used in the spring, summer and fall for cuttings of *Cotoneaster, Ilex, Elaeagnus, Lagerstroemia, Ligustrum, Raphiolepis* and *Viburnum*. The full-sun mist also has gravel beds and is used in the spring, summer and fall for cuttings of *Leucophyllum, Ilex, Nerium, Photinia* and *Trachelospermum*, listed as *Rhynchospermum* in our catalog.

Propagation by cuttings. Propagation by rooted cuttings accounts for 85% of liner production The plant types produced by this method include most vines, ground covers, conifers, broad-leaved and deciduous shrubs.

All cuttings are produced in the propagation building. The cutting wood is collected from container stock in the fields by the cutting crew or the field pruners. Most of the wood collected is soft or semi hardwood. This wood can be stored several days in the walk-in cooler until needed.

The cutters in propagation process this wood by making a tip cutting of 3 to 5 in, according to the cultivar. The cuttings are put into bundles with a rubber band. Each person on the cutting crew is paid $4/hour and is required to cut and stick an average of 300 cuttings/hour (2400/day). Each person's daily production is recorded and each cutter exceeding their quota is paid incentive on a piece-rate basis of ½ cent/cutting. The cutters usually average over 3500/day.

The bundles of cuttings are washed in a captan/Benlate/Agri-strep* solution as a disease preventative treatment. After draining, the cut end of each bundle is quick-dipped in a shallow pan of rooting hormone. IBA solutions are the most commonly used. On certain kinds of plants NAA, the potassium salt of IBA, or talc preparations are used The different concentrations of IBA are color-coded to prevent mix-ups. The prepared cuttings are rooted either in a standard flat or are stuck directly into individual containers. When the standard flat is used, the cuttings are stuck in a grid pattern, varying the number per flat with the cutting size, 15 × 15 is the most

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* Agri-strep — streptomycin, Merck
Benlate — benomyl, duPont
Captan — Orthocide, Chevron, many others

commonly used. The rooting medium is 90% coarse perlite and 10% peat. Each flat is tagged with the propagation information including cultivar, date, stock number, hormone, number per flat and the cutter's identification number The cuttings are carted to the appropriate mist area to root. Later as the cutting flats have rooted, they will be moved to a hardening-off area to await potting Two-thirds of our rooted cuttings are produced in this way.

In the direct-stick method, the cuttings are stuck directly into a 2¼-inch rose pot of potting soil to root. The empty rose pots are placed in standard flats, which are placed on a flatbed trailer and the potting soil shoveled on and leveled off. It is not packed. The trailer is built up on one layer at a time until it holds 10,000 pots. The trailer is hauled to the appropriate mist bed, where the cutters work directly off the trailer, sticking their cuttings, and setting the flat into the mist bed. The flats are labelled as before. The cuttings are not immediately watered-in as we want to avoid waterlogging in every way possible

Directly sticking a cutting into a liner pot of soil to root is labor saving since it eliminates the potting process. This method also saves on plant loss and growing time since the plant's growth is not interrupted. Plants that grow quite well by this method include cultivars of *Berberis*, *Euonymus*, *Ilex*, *Lagerstroemia*, *Ligustrum*, *Leucophyllum*, *Nerium*, *Photinia*, and *Rhynchospermum*. In many cases, the new liners can go directly to the liner beds with no need for time in the hardening-off area One-third of our rooted cuttings are produced by this method.

Propagation by seed. Propagation by seed accounts for 8% of liner production Plants produced by this method include *Quercus*, *Nandina*, *Magnolia*, *Prunus*, *Ternstroemia*, *Pinus*, *Podocarpus* and *Pittosporum* The seed is ordered from a variety of sources to ensure a source of supply, or it is collected locally. When the seed arrives, it is given the necessary preplant treatment such as stratification or scarification and is stored in the cooler for future planting.

The seed is planted by two methods. Large seeds that are easily handled, *Quercus* and *Sophora*, are planted directly into liner pots of the standard potting soil The majority of the seeds planted are planted in seed flats. The seed flat is built up in a layer cake fashion At the bottom of a standard flat is an inch of potting soil. Next, an inch of the perlite-peat cutting mix is added and firmed in. The seed is treated with a fungicide and rodenticide, scattered on top of the perlite mix and firmed in. A thin layer of silica sand is sprinkled on top to

cover the seed and prevent algae growth and crusting. Each flat is labeled with the name of the seed, date, source and amount of seed per flat. The seed flats are placed in a quonset or the greenhouse to germinate. The seedlings are potted into liners as needed

Propagation by division. Propagation by division accounts for 7% of liner production Plants produced in this manner include *Acorus, Liriope, Ophiopogon, Hermocallis* and *Yucca.* Stock plants are selected from the field, divided, and potted directly into liners. Dividing of plants is done by the potting crew and requires no time in the mist area.

Three million liners were produced from these rooted cuttings, seedlings, and divisions in 1981. All these liners were finished in 2¼-inch rose pots placed in Cal-flats, using one potting soil for standardization. The potting soil used is a 60% peat:40% sand, with 7 lb/cu yd of 8 to 9 month Osmocote. This is the soil used in the direct-stick propagation method also.

POTTING

The cuttings are put into the rose pots in the potting shed. Each potter exceeding their quota is paid incentive on a piece-rate basis of ½-cent/liner. Most potters average 4000 liners/day. Each potter is required to pot an average of 300 liners per hour (2400 per day) Their daily production is recorded

The new potting is loaded directly onto the liner-rack trailer as potted. The potting is watered-in and hauled to the shadehouse or a shaded quonset. After the new liners are established, they can be moved to the full-sun growing areas or the quonset shade can be removed. Shade-grown items remain in the shade house.

LINER MAINTENANCE

Liner maintenance is the department responsible for growing the liner to a finished size. There are three growing areas, which are the full-sun liner beds, the shade-house liner beds, and the quonsets. The liner beds are staked out so they all hold approximately 8,000 liners. The quonsets hold approximately 55,000 liners.

Watering is done by 40-ft Rain Bird[1] or K-5P Whirly bird[2] sprinklers. The liners are constantly fed 100 ppm nitrogen and 60 ppm potassium in the irrigation water. The liners are pruned by hand using hedge shears or by machine using a

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[1] Rain Bird Sprinkler Mfg Corp , 7045 N Grand Ave , Glendora, CA 91740

[2] Whirlybird sprinklers — AMS, Inc , 1246 Vernon Way, El Cajon, CA 92020

modified lawnmower. The finished liners are held in these areas until needed for canning or for shipping to customers

QUESTIONS FOR STEVEN HOTTOVY

BILL DOUCHER. What pesticides do you use in your seed culture?

STEVE HOTTOVY: We use thiram* for fungus control and red lead powder for rodents.

GREG AMMON: Could you give us more information on the mist nozzles?

STEVE HOTTOVY: This company manufactures various types of nozzles. It is important to find the one best suited to your needs and order that specific one by exact catalog number. The exact choice and spacing is dependent on your water pressure. We use a parasol nozzle designated as ¼ E 5.8.

VIVIAN MUNDAY. Do you have any problem with quality control when you pay incentive on a piece-rate basis?

STEVE HOTTOVY. We monitor carefully, and our employees know that if quality fails, they will not receive the additional pay

* Thiram-Arasan, duPont

THE SPEEDLING SYSTEM

GEORGE TODD, JR

Speedling, Incorporated
P O. Box 220
Sun City, Florida 33586

Speedling means different things to different people. To some, Speedling is the grower of quality transplants, to others a pioneer in the automation of transplant production. To still others, Speedling is the manufacturer of greenhouses, water systems, and flats that enable them to grow their own transplants. Most of our plants are presently marketed in the eastern part of the country.

The containerized transplant has obvious advantages over a bare-root plant. Primarily, these are uniformity in plant height as well as root system and the absence of transplant shock because the roots are not torn apart when the plant is pulled.

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The Speedling system can be used on virtually every transplant crop. In the early days, our production was limited to vegetables. It has now expanded to include ornamentals as well as tree seedlings.

The first Speedling plants were produced in 1967 in the patented Todd Planter Flat. Other growing containers were available. However, a cylinderical container directed the roots in a circle rather than in the more natural orientation they receive from the inverted pyramid and air pruning.

Speedling uses a systems approach from seed to field. This incorporates the use of many different styles of Todd Planter Flats, Speedling seeding equipment, water system, greenhouse and transplanter.

The filling of the container is important. Of course, the right soil formulation must be used, and just as important, the soil must be loosely placed into the cell to avoid compaction. Basically, the mix is a Cornell-type formulation. If it is compacted, transplanting becomes much more difficult. The seed should be placed as near the center of the cell as possible at a uniform depth. We accomplish this with an array of seeders ranging from a small hand seeder to a semi-automatic seeder, and ultimately, to our very high-speed seeding equipment, which has a vacuum-equipped planting drum to hold the seed during the planting process (Figure 1).

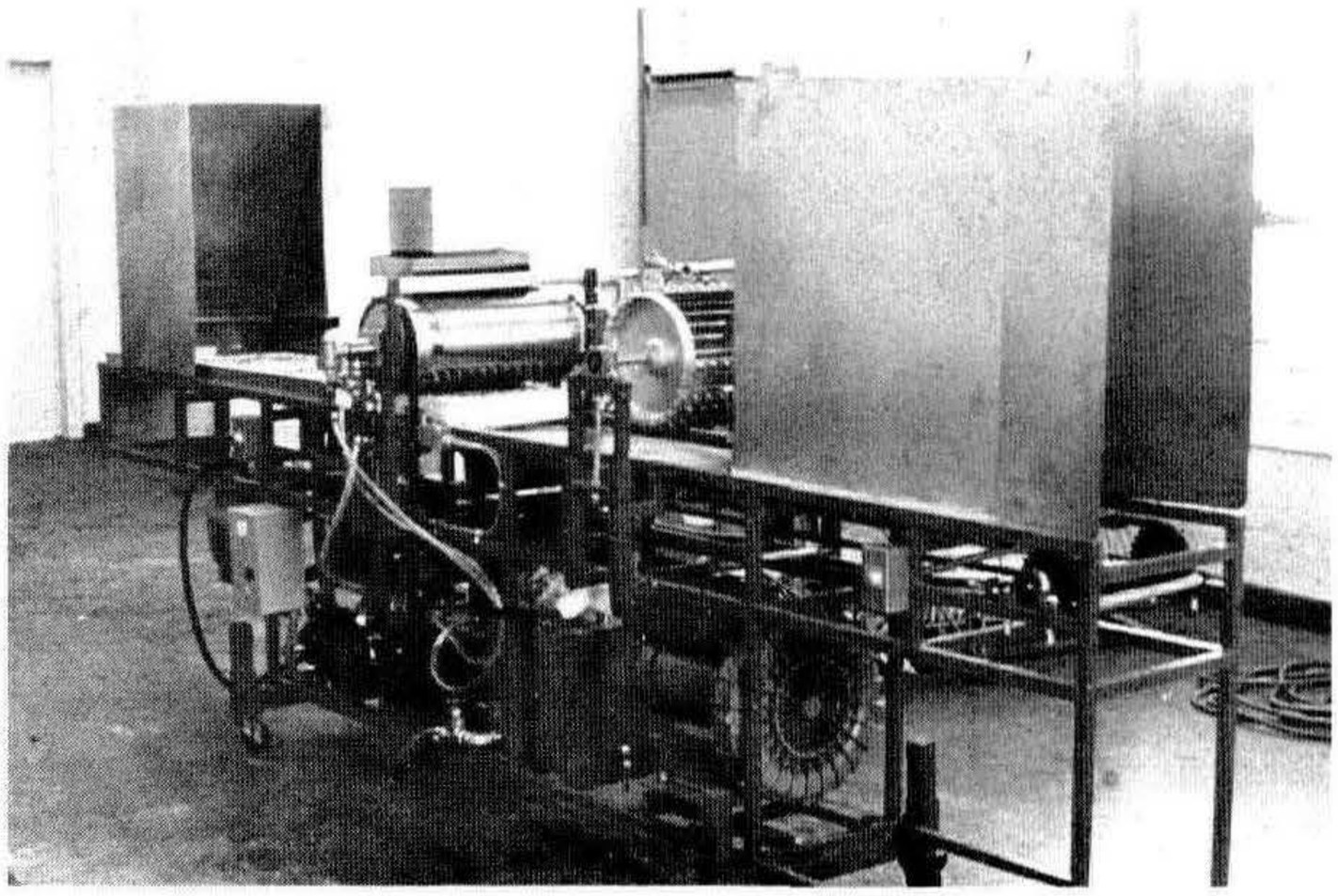

Figure 1. The Speedling seeder.

After a stay in the germinating room the seeded flats are placed on aluminum rails in the greenhouse. The T-rail supports only the edge of the flat so that the drain holes in the bottom of the flat are exposed to air circulating under the bench. This allows air pruning to take place when the root reaches the bottom of the soil.

The Speedling greenhouse has several good features (Figure 2). The side-curtain design allows ventilation on warmer days without using costly electric fans. This design gives us a ventilating area to bench area ratio of 1 to 4, or about 25%. If we take into consideration the ventilation area from the bench to the ground, it increases our number to 46%. The greenhouse has radiant heat, which is a very efficient heating system. The heat is then directed to the crop and the air is heated only by the heat given off from the crop. This results in a drier foliage and fewer disease problems. The system itself is expensive, however.

Figure 2. The Speedling greenhouse. Note the watering mechanism and side ventilation.

The greenhouse has either a ground-drive or aerial watering system. This system waters one side of the house, gets to the end of the house, reverses, and then waters the other side. This means that the starting point for the watering system is always at a particular end of the house. Typically, one grower controls approximately 10 greenhouses.

Transplanting is an important part of the Speedling system. The Speedling transplanter has provided a uniform planting method for Speedling transplants. When I refer to transplanting, I am talking about moving a plant from a smaller flat size into a larger flat size. This allows us to save a considerable amount of greenhouse space during the early weeks of a crop's growth. Then when the plant fills the smaller cell, it is moved into a larger flat size (Figure 3). Transplanting also gives us the opportunity to grade the plants and use only the stronger plants in the group. This additional step of grading out the weaker plants adds to the uniformity of the crop.

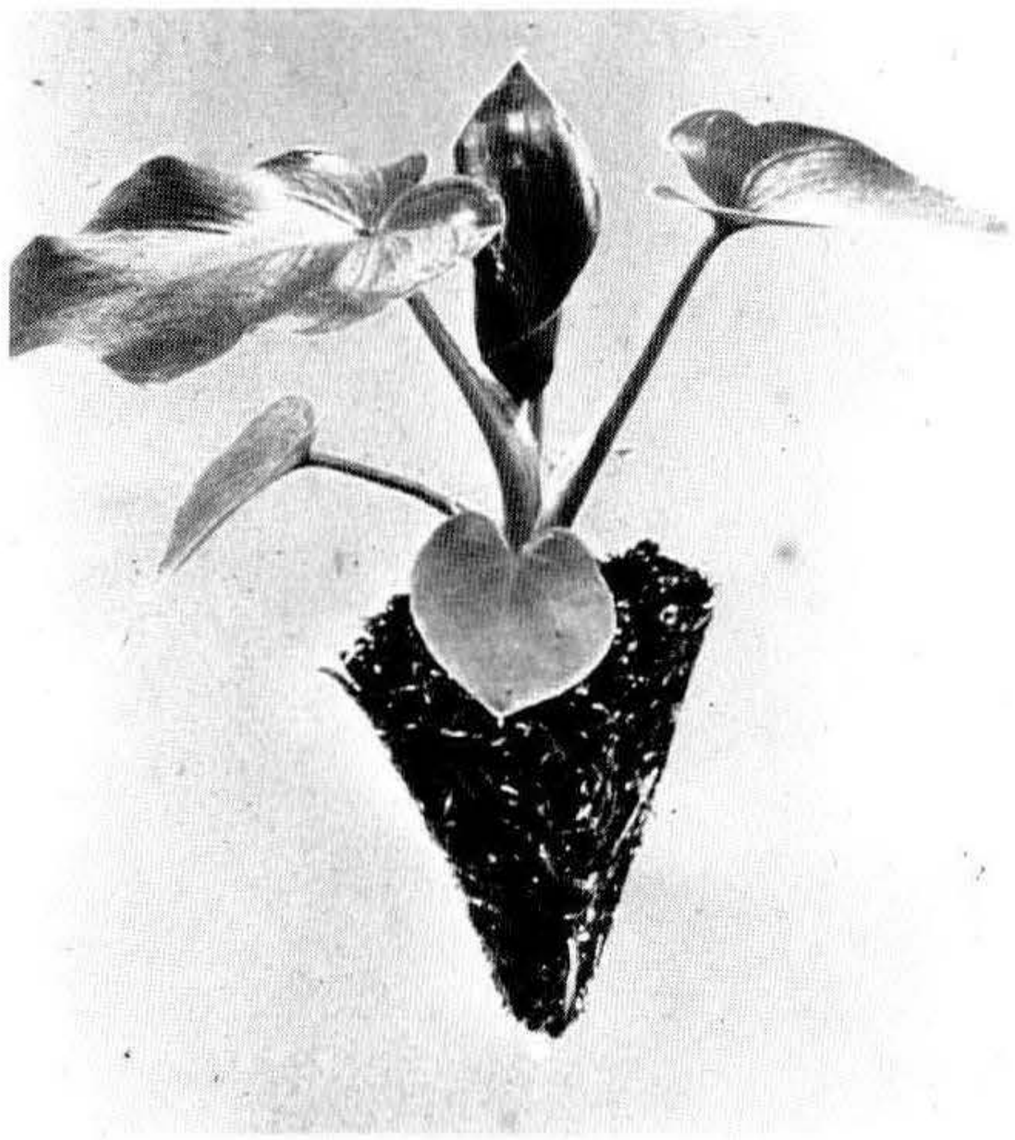

Figure 3. A Speedling transplant. Note shape of root ball.

When the crop is ready to go to the field, we bring it from the greenhouse to our central packing facility on racked trailers. There they are packed in corrugated boxes and shipped to the customer. Some customers pick up their plants in their own racked containers. These containers can be taken to the field for the field transplant operation (Figure 4). Of course, this is economical only for growers who are relatively close.

Figure 4. Mechanized transplanting of lettuce from Speedling flats.

Speedling transplants are especially helpful in applications where the crop must not wilt. They are used in very hot climates and when a crop is planted through plastic. In these applications, if the plant wilts and lies down, it will surely die.

The Speedling system works best when high quality seeds are used. After seeding and throughout their life, we try to protect the plants from any stresses that would hinder their uniformity. Uniform transplants are essential for a profitable growing operation.

QUESTIONS FOR GEORGE TODD

CHARLIE PARKERSON: Do you reuse your trays?

GEORGE TODD: Yes. We shake out the soil and rinse with 5% Clorox solution. We expect about 30 rotations as they are very durable

CHARLIE PARKERSON: What if the grower takes them with him?

GEORGE TODD. We charge a deposit

PRODUCING BUDDED *MAGNOLIA GRANDIFLORA* CULTIVARS

GEORGE ITAYA

Saratoga Horticultural Foundation

Saratoga, California 95070

The procedure of budding magnolias at Saratoga Horticultural Foundation evolved for several reasons. For our purposes propagation by budding was superior to propagation by cuttings or grafting since the necessary controlled greenhouse environments and structures were unavailable. Budding also allowed us to conserve our propagation material at the time our magnolia cultivars were introduced and the stock of these new cultivars was limited. Now our small acreage does not allow the extravagant use of space necessary for the stock plants that would be required to produce the same quantity of magnolia cultivars we produce by budding

Saratoga Horticultural Foundation propagates four selected cultivars of *Magnolia grandiflora*, namely 'Russet', 'Samuel Sommer', 'San Marino' and 'St. Mary'. The production schedule and budding techniques are the same for all of them.

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The production schedule starts with the collection or purchase of fresh seed of *Magnolia grandiflora* in the fall of the year. It is immediately stratified at 38° to 48°F for 90 days and,

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PRODUCTION OF UNDERSTOCK

The production schedule starts with the collection or purchase of fresh seed of *Magnolia grandiflora* in the fall of the year. It is immediately stratified at 38° to 48°F for 90 days and,

in January, the seed is sown in screen-bottomed flats using a medium of equal parts of coarse perlite, coarse vermiculite and fine vermiculite and then placed in a greenhouse. When seedlings have their first set of leaves, they have already root pruned themselves and are transplanted into peat pots. They are placed in a lathhouse and watered carefully to keep the plants growing vigorously and keep stress at a minimum.

The seedlings are transplanted to gallon cans in June when the roots break through the sides of the peat pots. These plants in gallon cans are placed under lath to promote even and continuous growth. Continued vigorous growth of the seedling with particular emphasis on avoidance of water stress is necessary from transplanting in June until budding the following April so that the plants have sufficient caliper (6 mm or more) to accommodate the rather large bud. If growth of the seedling is stopped, it is very difficult to cause growth to resume and be of sufficient size to bud on schedule.

THE BUDDING PROCESS

Shield or T-budding is used, and the bud shield is prepared with the wood out. The caliper of magnolia budwood is frequently larger than that of the seedling rootstock, and magnolias have a rather thick bark, which makes it necessary to cut deeply to be certain to get the cambium with the bud. The result is a bud which does not fit well unless the wood chip is removed to expose the entire cambium layer and allow the bud to fit snugly into the incision on the rootstock. The T-cut on the rootstock should be made before the shield is cut so that the bud can be inserted immediately upon being dewooded to avoid drying. After the bud shield is inserted in the rootstock, it is wrapped with a budding rubber. No paint or wax is used to cover the cut.

One-third to one-half of the top of the rootstock is removed at the time of budding to allow the new bud to compete more favorably for nutrients and to provide it with adequate light.

The budding rubber is cut off after 3 or 4 weeks to prevent constriction of the stem and interference with the flow of sap. With spring budding the final cut on the rootstock above the implanted bud is made about 2 weeks after the budding rubber is removed. At this time the implanted bud should have complete contact with the rootstock and be ready for active growth. In fall budding it may be necessary to refrain from making the final cut until growth starts in the spring.

The budded plant must be given adequate water until it is cut back and the implemented bud begins to grow. However,

after the final cut when only a single bud remains, too much moisture may weaken and finally kill the plant.

The budded plants grow rapidly so that those budded in April are ready for sale in one-gallon containers in August and September. Sucker removal during the growing season is the only special care needed.

With experience and care budding success can be as high as 95%, and plants can be sold at the end of the same season they are budded.

QUESTIONS FOR GEORGE ITAYA

RICHARD SANGER: Is the bark slipping on magnolia in April?

GEORGE ITAYA: Yes. In California the first surge of growth begins in April.

VOICE. Do you need to stake the new shoot when the bud breaks?

GEORGE ITAYA: No We plant the magnolias on an angle so that the shoot grows straight up.

TED GOREAU: You say it is possible to rebud. Do you make a fresh cut?

GEORGE ITAYA: Yes. As soon as we see that the first bud has failed, we make a new cut on the smooth surface of the opposite side of the stock.

VIVIAN MUNDAY: You emphasized the importance of the age of the buds. As I understand it, you use buds of the previous season's growth up until the time the ones on the current new growth appear and become firm.

GEORGE ITAYA· Yes, that is true. It is difficult to tell when the new buds are ready. The 3 or 4 at the base of the new shoot may be the only ones that are mature enough during the grafting period. If a bud is too soft, it will not survive. When the new shoot develops, the previous year's buds are inhibited and will not break as easily.

BRUCE BRIGGS: I believe at one time both chip budding and inverted-T budding were used at Saratoga Why did you change?

GEORGE ITAYA: At one time we grafted all of our magnolias, as information at that time indicated budding was not successful. However, we found we could no longer use the space to provide enough plant material for grafting. We, therefore, tried budding each month of the year and found that

using the mature buds was most successful. The regular T-bud works best with the physical arrangement of our benches. The plants are in solid blocks and with this technique we do not have to pick them up to bud them. We are still trying to improve; 90% take may not be good enough if that means 1,000 out of 10,000 fail for a nurseryman.

Chip budding and inverted-T budding have never been used on magnolia at the Foundation. Chip budding was used on *Ginkgo biloba* at first because of the extreme thickness of the bark at the point where the buds were inserted. Later it was changed to T-budding because of the extra work involved in painting and waxing the budded portion of the plant. The thickness of the bark was reduced by using younger rootstock.

MAGNOLIA PROPAGATION

BILL CURTIS

Wil-Chris Acres
Sherwood, Oregon 97140

For many years I have propagated magnolias, both evergreen and deciduous, from cuttings, using coarse sand and perlite, or sand and pumice, half and half, for the rooting medium, treating with Hormodin #3 (0.8% IBA in talc), and using bottom heat, 75° to 78° F. The technique that seems to work best is to wound one side before applying the hormone. With such high bottom heat, watering is critical.

The deciduous cultivars are propagated using summer cuttings under intermittent mist, on 3 to 5 sec/6 min. If wood is available, we use a 4- to 6- inch heel cutting. Mid-July or early August seem to give the best results. You cannot set a definite date by the calendar. The wood is ready when the terminal snaps easily We take the tip out of the cutting, which will generally leave a 2- to 3- inch cutting of the magnolias such as *M. soulangiana*, *M. stellata*, and most of the Kosar hybrids. *M. soulangiana* 'Rustica Rubra' cuttings will be much longer. I like to take the cuttings off field stock in vigorous growth. We do have some stock plants for cutting wood.

The deciduous magnolia cuttings are stuck in flats when rooted, and are wintered in a cool house with heat, if necessary Just as the new foliage breaks in the spring, they are potted and set out in a heated house. We never prune any of the roots when potting. Sometimes a few of the *M.s.* 'Rustica Rubra' are potted into 1- gallon short cans.

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In most years they are planted in the field in early August, but if the weather is too hot, we line the potted magnolias out early next spring.

We grow evergreen *M. grandiflora* 'Victoria'. It is hardier than most and easy to root. (I think Joe McDaniel has one alive at Urbana, Illinois.) *M. grandiflora* cuttings are stuck in early November. The most economical size cutting is from 4 to 8 in long. We have rooted cuttings 18 in long, but the losses are greater.

Two-year field-grown *M. grandiflora* plants send out many shoots along the stem below the heavy branches. We use a sharp knife to cut these shoots off, leaving a heel. The cuttings are taken to the propagating house where some of the leaves are removed, the heel is trimmed and a 1- to 1¼- in wound is made on one side, depending upon the size of the cutting. We then dip in Hormodin #3 and stick the cuttings in a deep flat using sand and perlite or sand and pumice, 50% of each.

We hand water to keep the medium moist. There is a lot of foliage as we do not trim the top leaves. Again, we use high bottom heat. In 90 to 120 days the cuttings are heavily rooted. When we pot, we do not trim off any of the roots. If the roots are too heavy for a 1- gallon container, we put the cuttings in a 2- gallon container. These potted magnolias grow one year before lining out in the nursery. In the spring they are planted in the nursery with 2- ft spacing in rows of 4 ft apart.

Ordinarily, we get 90% rooting with the cuttings having a good root system. However, two years ago we did not get this percentage because our timing was off.

Last year the *M. stellatas* let us down. We only had a 50% stand. A visiting nurseryman from Europe who was touring the Northwest, saw our problem and made this suggestion: "In Europe we use a 2-bud cutting for the smaller-leaved cultivars of deciduous magnolias" By the time he was out of the driveway, I was in the nursery taking *M. stellata* cuttings. The crew filled flats with coarse pumice and sand, and before quitting time we filled all the flats with 2-bud cuttings of *M. stellata*, plus several flats of *M.* 'Kosar's Betty' and *M.* 'Susan'. We had over 90% take.

We did not line out any deciduous magnolia this summer. It was too hot. However, the 2-bud cuttings grew vigorously and were hard to distinguish from the normal size cuttings.

BEDDING PLANT PRODUCTION

DEXTER McDONALD
Amfac Garden Perry's
Ventura, California 93006

The bedding plant, by nature, is a quick-turn commodity that moves rapidly through production, through the retailer and into the homeowner's garden in a relatively short period of a few weeks We also find that the marketable life expectancy of most bedding plants is only 3 to 4 weeks on the average.

As with most any crop, it must be emphasized in the beginning that cultivar selection, scheduling, and production operations vary with the change of geographical location of the growing grounds Temperature highs and lows, light intensity, as well as coastal conditions, air pollution, and other environmental factors all influence one's approach to bedding plant production. Our bedding product is not only grown year-round in California and Arizona, but a large portion of that product's production time is spent outside under mother nature's influence, over which we have little control.

GROWING MEDIA

The growing media we use is typical of most other bedding plant growers. The basic objectives are the same:

1) Optimum characteristics for the particular crop.
2) Uniform and consistent in quality and performance.
3) Available and economical.
4) As clean as possible.

We basically use the same medium for our total product line which, other than bedding plants, includes a large production of ground covers and a sprinkling of specialty crops, such as poinsettia, garden mums, and cyclamen. This medium doubles as a rooting and growing medium for our ground covers and poinsettias.

Our current growing medium consists of.
40% peat moss
30% vermiculite (#4 fine grade)
30% perlite (#2 Horticulture grade)

These components come to us clean and bagged and, consequently, we do not fumigate. However, we are quick to apply preventive fungicide treatments soon after planting to insure protection for our crop.

Our growing medium is analyzed regularly to assist us in regulating our fertilization program Currently, our medium is being supplemented during mixing with the following base fertilizer mix.

Per ton. 120 lbs calcium nitrate
560 lbs single superphosphate
120 lbs ferric sulphate
560 lbs calcium carbonate
640 lbs dolomite lime

This fertilization supplement varies slightly from location to location due to change in water quality. Calcium nitrate is injected through a proportioning system into daily waterings to complete the fertilization program for our bedding plant production.

SEED PLANTING

Our seed operation is handled by a precision planter that was designed for efficiency in labor and precision in seed planting. This planting unit is calibrated and adjusted by changing the conveyor belt speed, cup orifice size, and/or speed of the rotating seed-distribution head. As the seed size and weight change, the planter is readjusted for ideal seed-planting density in the seed flat.

Typically, the planter is calibrated so that seed flats, when mature, will produce up to 25 to 30 finished flats. Finished flats are based on 6 plants per pack and 12 packs per flat or a total of 72 plants per flat. Our current Amfac Garden Perry's product line has over 300 bedding cultivars and practically all are started by seed.

However, not all these kinds of seed are planted with this precision planter; several cultivars are still planted by hand broadcasting and some are hand-planted direclty into the salable unit. Amfac Garden Perry's other primary finished bedding units are the pot pak with 6 plants per pak and 6 paks per flat/unit, and the 4-inch pot with 1 plant per pot and 16 per flat/unit.

After the seed flats have been planted, the conveyor takes them through a light watering application. They are then top dressed accurately with silica sand at the end of the conveyor. This silica sand is ideal for seed cover due to its uniformity, cleanliness, ease in application and ideal air/water holding capacity.

Seed flats are then placed in greenhouses where air temperatures are maintained at approximately 70 to 80°F. Depending on the cultivar, germination usually takes place anywhere from 5 to 21 days.

Ideally, we prefer our seedlings to be in the first true leaf stage before they are spotted off. If they have a tendency to get too tall before the true leaf stage is reached, then the height becomes the determining factor for spotting off. The length of

time to this stage varies considerably by cultivar. The average range of time is 3 to 5 weeks.

As seed flats near the spotting-off stage, they are occasionally treated with B-Nine, a growth regulator (using 6 to 11 oz/25 gal) to hold them for later use. These flats can be held in prime condition for up to 7 to 12 days with B-Nine* treatment. This not only enables us to hold our seed flats until we can get to them but also allows us to plant more seed flats than projected in order to respond quickly to increased market activity

Once finished flats are planted, they are immediatley irrigated and treated with a Benlate/Lesan** fungicide application for their protection against any soil disease problems. These newly planted flats are placed in greenhouses for approximately 2 to 4 weeks for their initial development.

The average time from seed to market for our primary product types are:

Pot paks: 6 to 8 weeks (6 wk ave)
Pot paks: 10 to 14 weeks (12 wk ave)
4-inch: 12 to 16 weeks (14 wk ave)

After spotting-off, the primary plant maintenance operations, other than irrigation, consists of:

1) Fertilization: calcium nitrate (7% nitrogen solution) is injected into daily waterings.
2) Pest control: various insect larvae are primary problem pests and various rots are primary diseases.
3) Fixing: replacing any damaged plants in flat
4) B-Nine treatment. Help maintain salable life.
5) Rotation and moving: necessary for proper development and finishing.

California's unique climate allows us to grow bedding plants year-round, and also makes it possible to finish out many of our crops outside, under mother nature. Depending on the crop, cultivars are moved outside 2 to 4 weeks after spotting off. Sun-requiring bedding plants like petunias, marigolds and zinnias are moved out into direct sunlight, whereas shade plants, such as impatiens and begonias, are moved out under shade cloth for the finishing of the crops.

In summary, we are supplying a product to satisfy demand projected a year in advance. This product is grown from seed that can run several thousand dollars per pound, purchased 6 to 8 months prior to planting. It goes from seed to the homeowner's garden in an average of 10 weeks, with a market-

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* B-Nine — daminoazide, Uniroyal
** Benlate — benomyl, duPont
Lesan — fenaminosulf, Mobay

able period of 3 or 4 weeks Those plants that do not move to market make the compost pile shortly thereafter. After considering the implications of these production and marketing conditions, now think of the challenge of outguessing the season to determine when spring will break and sales will soar. If we are conservative and plan for a late spring, the market can leave us in the dust; and we lose that early market surge. If we throw caution to the wind, gamble on that early spring market, and spring breaks 3 weeks later than planned, only our compost pile reaps the benefit. Bedding plant production is a real challenge.

QUESTIONS FOR DEXTER McDONALD

CHARLIE PARKERSON: Do your 4-inch and pak materials compete with each other in the market? Is the season longer for the 4-inch?

DEXTER McDONALD: Yes, they do compete. The season is not longer for the 4-inch, but the holding time is. They remain salable for a longer period of time.

CHARLIE PARKERSON: Can all types of containers go through the same filling and planting equipment?

DEXTER McDONALD. Yes, with minor adjustments.

CHARLIE PARKERSON: How do you water?

DEXTER McDONALD: We use sprinklers. We have no specific nozzles. Often we hand water as well.

IRIS SOFT ROT CAUSED BY *ERWINIA CHRYSANTHEMI*, ASSOCIATED WITH OVERHEAD IRRIGATION AND ITS CONTROL BY CHLORINATION

GEORGE H. LACY[1], ROBERT C. LAMBE[2] and CYNTHIA M. BERG[3]

Department of Plant Pathology and Physiology
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Abstract. Iris soft rot, previously reported to be caused by *Erwinia carotovora* subsp *carotovora*, was correlated positively with the intensity of sprinkler irrigation rather than iris borer damage in a commercial rhizome production operation in Virginia *Erwinia chrysanthemi* was consistently isolated from the rotted plants and reproduced the symptoms observed in

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the field in artificially inoculated healthy plants. *Erwinia carotovora* subsp. *carotovora* and garden slug damage were associated with a minor outbreak of soft rot in a greenhouse. Both bacterial pathogens were reduced in viability by exposure to sodium hypochlorite and the incidence of soft rot was reduced on sprouting rhizomes in greenhouse tests, especially when treated with 20mg Cl/liter (20ppm Cl). However, the effectiveness of chlorination was reduced in some water sources or when the number of bacteria suspended in the water was increased.

INTRODUCTION

In the summer of 1980, extensive bacterial soft rot of iris (*Iris germanica* L.) was observed in a commercial rhizome production operation near Fishersville, Virginia. The initial symptoms included water-soaked streaks on the leafblades progressing upward from the base of the leaf fans (Figure 1). Some of these rotted leaves lodged or could be pulled very easily from the fans. Later, leaves that died became dry and brownish-grey in color. The rhizomes, at the base of the fans, were rotted at or near the soil line. The interior of the rhizomes was reduced to a viscous cream-colored mass that was often foul smelling (Figure 2). These symptoms were consistent with those described first by van Hall in 1902 (in ref. 11) and later by Massey in Virginia (11). Thanos (15) confirmed that the pathogen was *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey et al. and Howard and with Leach (9) established a vector relationship for the pathogen with the iris borer (*Macronoctus onusta* Grote).

Figure 1. Leaf symptoms of iris soft rot caused by *Erwinia carotovora* subsp. *carotovora* and *Erwinia chrysanthemi* in *I. germanica* cv. 'Jesse Viette'.

In this epidemic, however, iris borer damage to the rhizomes was not obvious and an increasing incidence of soft rot was correlated positively with the intensity of overhead irrigation from "Rain-bird" sprinklers. The incidence in non-irrigated areas was <1%, in irrigated areas 5-25%, and 20-40% in areas that received overlapping irrigations. Irrigation water was pumped directly from a small visibly turbid creek that drained a cow pasture and an alfalfa (*Medicago sativa* L.) hay field located adjacent to the iris production area.

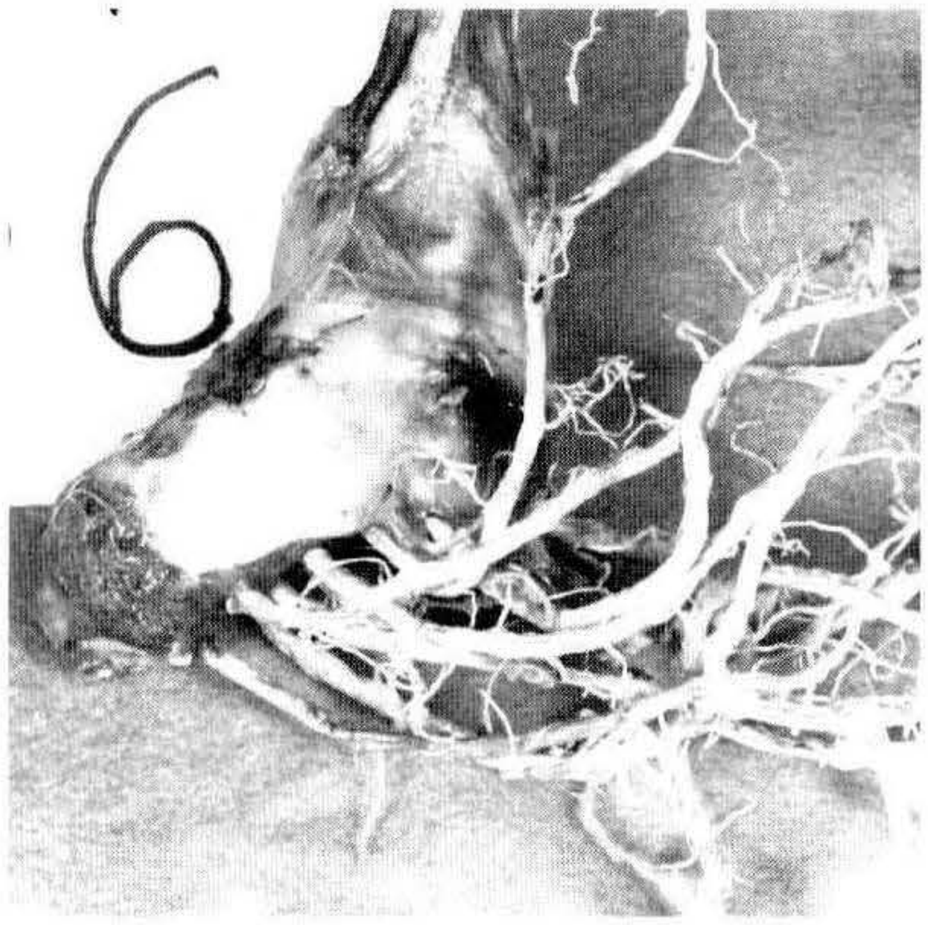

Figure 2. Rhizome rot symptoms of iris soft rot caused by *Erwinia chrysanthemi* strain L-436 on *I. germanica* cv. 'Jesse Viette.'

Erwinia chrysanthemi Burkholder et al. strains capable of rotting wild *Iris* spp. growing on the banks of paddies were isolated from rice (*Oryza sativa* L.) plants with foot rot in Japan (5,6). Therefore, *E. chrysanthemi* may also be a pathogen of domestic iris.

In the past, control of iris soft rot has been accomplished chiefly by control of the iris borer and sanitation (13,17). However, some bacterial diseases such as stalk rot of maize (*Zea mays* L.) (16), soft rot of tomatoes (*Lycopersicon esculentum* Mill.) and potatoes (*Solanum tuberosum* L.) (1), diseases caused by *E. chrysanthemi* and *E. carotovora* subsp. *carotovora*, have been controlled by chlorination of irrigation water, wash water and flume water. Therefore, chlorination should be considered for control of iris soft rot if disease spread is related to irrigation.

This report confirms that *E. chrysanthemi*, as well as *E. carotovora* subsp. *carotovora* (Jones) Bergey, can be a pathogen of cultivated iris, that soft-rotting *Erwinia* spp. may be isolated from irrigation water, and that chlorination reduces the numbers of pathogenic bacteria in water and the incidence of iris soft rot in greenhouse tests.

MATERIALS AND METHODS

Bacterial strains. The bacterial strains used in this study are listed in Table 1

Table 1. Origins of bacterial strains

Strain designation	Origin	Authority	Host
Erwinia carotovora subsp *carovotora* (Jones) Bergey et al			
E32 & E34[x]	New York	W H Burkholder	*Iris* sp
SR-53[y]	Vermont	L R Jones	*Daucus carota* L
L-441 to L-443[z]	Virginia	C M Berg	*I germanica* L
Erwinia chrysanthemi Burkholder, et al			
EI1[x]	Japan	M Goto	*Iris ensata* Thunb
SP-26[y]	Wisconsin	J I Victoria	*Zea mays* L
L-434 to L-436[z]	Virginia	G H Lacy	*I germanica*

[x] Provided by Dr R S Dickey, Dept Plant Pathol , Cornell Univ , Ithaca, NY 14853

[y] Provided by Dr A Kelman, Dept Plant Pathol , Univ Wisconsin, Madison, WI 53706

[z] Isolated during this study from field-grown iris (L-434 to L-436) and greenhouse-grown iris (L-441 to L-443)

Media. Unless otherwise specified, plate count agar (PCA; Difco, Detroit, MI 48232), crystal violet pectate medium (CVP; 14) and King's medium B (KB, 14) were used at 25°C to maintain and culture the bacteria.

Isolation from plant tissues. Diseased leaf sections were surface sterilized in 0.5% sodium hypochlorite for 30-60 sec and rinsed with sterile distilled water (SDW). A smaller section was cut aseptically from the leading margin of the lesion and placed in a tube containing 2ml SDW. After 10-30 min, the resulting bacterial suspension was streaked onto CVP medium. Colonies of pectolytic bacteria that caused pitting on CVP were restreaked twice on PCA and then again on CVP.

Physiological and biochemical characterization of bacteria. Production of acid from lactose, trehalose, mannitol, inositol, esculin, maltose and raffinose and nitrate reduction was detected using the Minitek® method (BBL,. Cockeysville, MD 21030) according to the manufacturer's directions except that incubations were carried out at 25°C rather than 37°C

Phosphatase production was detected using phenolphthalein diphosphate-containing medium (14) and erythromycin sensitivity tests were performed on PCA plates swabbed with bacterial cells and exposed to a paper disk impregnated with 15 μg of erythromycin (SensiDiscs®, BBL). The diameter of the zone of inhibition was measured at 48h. Cytochrome oxidase was detected with Taxo® N disks (BBL). Growth in 5% NaCl-nutrient broth (Difco) was determined by an increase in turbidity seven days after inoculation. Positive and negative controls were used for all tests.

Greenhouse culture of iris. During the winter, iris rhizomes, *I. germanica* cv. 'Jesse Viette', were dipped in captan WP-50 (479 g a.i./liter) for 15 mın. to control fungal rotting and potted in 25 cm plastic containers with a mixture of one part composted pıne bark and one part Weblite® (50 mesh particle size. heat-expanded shale; Weblite Corp, Blue Ridge, VA 24064). The plants were fertilized with about 5g of slow release Osmocote® (Sierra Chem. Co., Milpitas, CA 95035; elemental nitrogen, phosphorus, and potassium in a 14:14:14 ratio by weight). The irises were watered when necessary with tap water and sprayed periodically with diazinon EC-25 (2.5 ml/liter) to control insect pests The greenhouse temperature range was maintained at 18-28°C during the 16 week growth perıod

Inoculations. Colonies of bacteria on PCA (48h) were suspended ın SDW and diluted to about 10^7 colony forming units (cfu)/ml Plants were inoculated by two techniques. For the first, iris leaves or rhizomes were swabbed with 1% sodium hypochlorite and injected with a total of 1.0 ml of the bacterial suspension through five syringe punctures. Six ırıs plants were inoculated with each strain of bacteria or SDW as a control.

For the second inoculation method, sprouting rhizomes were wounded by removing a tangential slice with a knife through the leaf fan base and into the rhizome. Plants were sprayed immediately with bacteria suspended in SDW or ın sodium hypochlorite solutions of 0.2, 2.0 or 20mg elemental chlorine (Cl)/liter/ using a hand sprayer.

Inoculated plants were placed in clear plastic boxes (open at the bottom) on a wire greenhouse bench and misted with water for 15 sec every 15 min. After 24-26 h, the mist frequency was reduced to 8 h/day. Observations for disease development were made daily

Detection of soft-rotting bacteria in irrigation water. Water collected in sterile 3 8 liter polyethylene containers from a creek, a pond and a well at the iris rhizome production facility was stored at 5°C until assayed The well water was collected from a flowing tap. Creek and pond water was sampled well away from the sides and bottoms of these water sources.

Seventy ml of water were centrifuged at 5,000 × g for 15 min. The supernatant was discarded and the pellet was resuspended in Meneley and Stanghellini's enrichment broth (12). After anaerobic incubation (GasPac®, BBL) for 48-72 h, the enrichment broth was centrıfuged, the supernatant discarded and the pellet streaked on CVP and incubated aerobically. All Gram-negative, pectolytic, facultative anaerobic bacteria capa-

ble of rotting carrot root (*Daucus carota* L.) and/or potato tissue were considered to be *Erwinia* spp.

Effect of chlorination on the survival of bacteria in water. Soft-rotting pathogens or iris were suspended in filter-sterilized (to pass 0.22 μ filter), pond water, creek water, well water, or SDW and exposed to various concentrations of sodium hypochlorite for 1 min. The titer of viable cfu remaining was determined by trapping cells on 0.45 μ pore-size nitrocellulose membranes (Millipore Corp., Bedford, MA 01730) and rinsing them with SDW. The membranes were placed on PCA and the colonies that developed were counted after incubation at 30°C for 24-48 h.

RESULTS

Pectolytic bacteria were isolated on CVP medium from rotting field-grown (FG) iris from near Fishersville and from rotting greenhouse-grown (GHG) garden slug-infested iris cultured at Virginia Polytechnic Institute and State University. The rotting of the GHG rhizomes was centered on the slug wounds but rotting also progressed in streaks upward into the leaves as occurred with rotted FG iris. The bacteria isolated

Table 2. Comparison of physiological and biochemical properties of authentic *Erwinia carotovora* subsp *carotovora* (Ecc) and *E. chrysanthemi* (Ech) strains with those strains isolated from rotting field-grown (FG), greenhouse-grown (GHG) iris, and strains reisolated (RI) from iris inoculated with FG strains of Ech

Test	Authentic Strains		Strains from rotted iris		
	Ecc (3 strains)	Ech (2 strains)	FG (3 strains)	GHG (3 strains)	RI (6 strains)
Production of acid from					
Trehalose	2[x]	0	0	2	0
Mannitol	3	2	3	3	6
Inositol	3	2	3	3	6
Esculin	3	2	3	3	6
Maltose	0	0	0	2	0
Raffinose	3	2[y]	3	2	6[y]
Sensitivity to 15μg erythromycin	0	2	3[z]	0	6[z]
Phosphatase production	0	2	3	0	6
Nitrate reduction	3	2	3	3	6
Growth in 5% NaCl	3	0	0	3	0
Pectate hydrolysis	3	2	3	3	6
Cytochrome oxidase production	0	0	0	0	0
Fluorescence	0	0	0	0	0
Growth at 37°C	3	2	3	3	6

[x] Figures refer to the number of strains with positive reaction to specific tests

[y] One strain was weakly positive

[z] One strain was intermediate in sensitivity

from both FG and GHG iris were Gram-negative and peritrichously flagellated.

The bacteria were characterized biochemically and physiologically as described in Table 2. The strains isolated from rotting iris segregated into two groups similar to the two groups formed by authentic strains of *E. carotovora* subsp. *carotovora* and *E. chrysanthemi*. The three isolates from FG iris are identified here as *E. chrysanthemi* and the three from the slug-infested GHG plants as *E. carotovora* subsp. *carotovora*.

Inoculations of iris plants (cv. 'Jesse Viette') with purified and characterized strains of bacteria indicated that symptom development by *E. carotovora* subsp. *carotovora* and *E. chrysanthemi* were very similar; however, symptoms developed more slowly in *E. carotovora* subsp. *carotovora*-inoculated plants (3). Symptoms developed on plants inoculated with either pathogen within 96 h.

Strains of *E. chrysanthemi* were re-isolated and recharacterized (Table 2) from rotted artificially-inoculated GHG iris. These strains showed the same biochemical and physiological profiles as the parental strains indicating that Koch's postulates for pathogenicity had been fulfilled.

Isolation of pectolytic *Erwinia* spp. from the water of a creek and a spring-fed pond, but not a well, used for irrigation indicated that the numbers of pectolytic erwiniae were extremely low (< 1cfu/ml) at the time of observation several weeks after the epidemic of iris soft rot.

Table 3. Percentage of *Erwinia chrysanthemi* strain L-435 and *Erwinia carotovora* subsp *carotovora* strain L-442 colony forming units (cfu) surviving exposure for one minute to sodium hypochlorite in water

Ppm of elemental chlorine	% of cfu surviving[z]	
	L-435	L-442
0 5	>99 9	>99 9
1 0	1 8	3 6
2 0	1 5	0 9
5 0	1 3	<0 002
10 0	<0 002	<0 002

[z] cfu/ml = L-435, $1\ 2\times10^9$, L-442 $1\ 4\times10^9$

In the laboratory, pectolytic bacteria, suspended in SDW, were reduced in viability by chlorination with sodium hypochlorite (Table 3) This reduction varied with the number of cfu suspended in the water. For instance, when 1.2×10^9 cfu/ml of *E chrysanthemi* strain L-435 were suspended for one minute in water containing 0.5 mg Cl (in sodium hypochlorite)/liter (or 0 5 ppm Cl), no reduction of viability was ob-

served However, at 1 0 mg Cl/liter (1 ppm), viability was reduced 98%, and it was reduced more than 99% at 10 mg Cl/liter (10 ppm). In contrast, when only 1.8×10^6 cfu were suspended in water, 0 2 mg Cl/liter (0.2 ppm) reduced viability 98%.

The source of irrigation water also affected the efficiency of chlorination for reducing the survival of bacteria (Table 4). Well water and SDW were no different in their effect on the survival of bacteria after chlorination (data not shown). However, pond and creek water increased the survival of pathogenic bacteria compared to well water. At collection, creek water was visibly turbid (0.05-0.15 O D at 550 nm), the pond water was clear and light tan in color, and well water was clear and colorless

Table 4. Percentage of *Erwinia chrysanthemi* strain L-436 and *Erwinia carotovora* subsp *carotovora* strain L-442 colony forming units (cfu) surviving exposure for one minute to sodium hypochlorite in filter sterilized water from various irrigation water sources

	% cfu/ppm of elemental chlorine			
Water Source	1	2	5	10
	Erwinia chrysanthemi strain L-436			
Well	0 01	<0 002	<0 002	<0 002
Pond	90 0	38 5	1 2	0 04
Creek	99 6	45 0	5 8	0 58
	Erwinia carotovora subsp *carotovora* strain L-442			
Well	0 03	<0 002	<0 002	<0 002
Pond	12 8	27 8	24 0	0 19
Creek	96 4	30 0	34 3	0 01

In two greenhouse trials, chlorination with up to 20mg Cl/liter (20ppm Cl) was effective for reducing the incidence of iris rot on sprouting iris rhizomes (Table 5). In this test, bacteria were suspended in SDW to simulate contaminated irrigation water and then exposed for one minute to various concentrations of sodium hypochlorite The freshly wounded plants, to

Table 5. Incidence of iris rhizome wounds rotted by *Erwinia chrysanthemi* strain L-436 or *Erwinia carotovora* subsp *carotovora* strain L-442 treated for one minute with sodium hypochlorite in water

Ppm of elemental chlorine (Cl)	% Wounds rotted[y]			
	L-436[z]		L-442	
	1	2	1	2
Not inoculated	0	0	0	6 2
Inoculated				
Cl treated 0 2	20 0	68 8	40 0	6 2
2 0	0	25 0	30 0	6 2
20 0	0	0	0	6 2
Not treated	30 0	81 2	40 0	43 8

[y] % of 10 wounds (1) and 16 wounds (2)
[z] cfu/ml = L-436, $3\ 5\times10^7$, L-442, $2\ 4\times10^7$

simulate pest or cultural wounding, were sprayed immediately with the chlorinated suspensions.

No phytotoxicity was observed on the treated irises. However, more extensive tests with long-term repeated irrigation will be necessary before any firm conclusion about chlorine toxicity for iris can be reached.

DISCUSSION

Although *E. carotovora* subsp. *carotovora* has been reported as the pathogen causing iris soft-rot, this study indicated that *E. chrysanthemi* also causes an iris soft rot with similar or identical symptoms. *Erwinia chrysanthemi* strains isolated from diseased field-grown irises were characterized biochemically and physiologically, inoculated into healthy plants, found to reproduce the symptoms of iris soft rot, and were re-isolated and re-characterized as being similar or identical to the parental inoculant strains. This confirms, by Koch's postulates, for the first time that *E. chrysanthemi* is also a pathogen of *I. germanica*. Although other workers, including W.H. Burkholder (Table 1) and M. Goto (5,6) have isolated *E. chrysanthemi* from rotting iris tissues, none have reported fulfilling Koch's postulates.

Another interesting feature of this iris soft rot epidemic was that the highest symptom incidence was correlated with overhead irrigation rather than iris borer damage. Since Bald suggested irrigation may help spread iris soft rot (2) and Kamerman found that unwounded iris leaf fans could become infected and diseased after exposure to aqueous suspensions of bacteria (10), the irrigation water sources at the site of this epidemic were assayed for the presence of soft-rotting bacteria. Significantly, pectolytic *Erwinia* spp were recovered from the spring-fed pond and creek, but not the well. The populations of bacteria detected were too low to establish these irrigation reservoirs as sources of the pathogenic inoculum. However, both the pond, lined with succulent weeds, and the stream, passing through a cow pasture and an alfalfa field, could be contaminated occasionally with high populations of pectolytic *Erwinia* from decomposing submerged plant tissue Similar conditions have been reported for *E. chrysanthemi* dissemination by water (8). The iris grower has discontinued use of the creek water and reports that iris soft rot was not a problem during the 1981 growing season.

Garden slugs apparently may act as vectors or provide wounds for bacterial penetration and colonization of iris rhizomes The only bacterium isolated from the slug-damaged

and rotted plants was E. *cartovora* subsp *cartovora*. This reconfirms that this bacterium is also a soft-rotting pathogen of iris.

Perhaps, under optimal conditions for disease development, both of these pathogens are able to penetrate unwounded plants. This hypothesis is supported by Kamerman's observation of *E. carotovora* subsp. *cartovora* penetration into unwounded iris (10), and Hartman's evidence for penetration by *E. chrysanthemi* into unwounded maize plants (7) Although iris borers were not associated with disease development during field observations of this epidemic of iris soft rot, damage by other unrecognized organisms (insects, nematodes or slugs) or cultural practices may have provided wounds for the pathogen (3).

Chlorination of water was effective for reducing the populations of pathogenic bacteria surviving in water. However, increased numbers of suspended bacteria and water source may reduce the effectiveness of chlorination (Reviewed in ref. 4). Although both the pond and creek water were filtered to remove indigenous bacteria prior to these chlorination studies, dissolved and suspended inorganic and organic materials may have bound chlorine, thus reducing the actual concentration of chlorine available for chlorination In greenhouse tests, chlorination was effective for reducing the incidence of iris soft rot caused by both *E. casrotovora* subsp. *cartovora* and E. *chrysanthemi*.

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INFLUENCE OF SOIL FUNGICIDES ON PRODUCTION EFFICIENCY OF *PEPEROMIA GRISEO ARGENTEA* 'BLACKIE'

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Soil-borne diseases are important constraints to efficient production of many types of greenhouse crops. Direct plant losses and delayed growth of crops affected with various types of root and stem rotting diseases contribute to higher production costs, unpredictable growth, and reductions in plant quality at the time of sale. Familiarity and use of sanitary growing practices advocated by Baker, et al. (1) are necessary for control of soil-borne diseases. The growing medium and container, the plant used for production and cultural operations are potential avenues of entry for soil-borne pathogens into the crop production cycle. Sanitary production practices can be effectively used to eliminate soil-borne pathogens from greenhouse production programs provided the procedures are uniformly adopted for all facets of the growing operation.

SANITATION AND THE GROWING MEDIUM

The growing medium is an important and common source of soil-borne pathogens for greenhouse crops. Use of a wide

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SANITATION AND THE GROWING MEDIUM

The growing medium is an important and common source of soil-borne pathogens for greenhouse crops. Use of a wide

range of growing media for commercial production of ornamental plants has generally restricted efforts to adopt uniform sanitation measures for specific types of plant production. Production strategies for commercial greenhouse crops should insure initially low populations of soil-borne pathogens in growing media at the time the growing cycle is initiated. High populations of soil-borne pathogens cannot be controlled by applications of chemical sanitation measures following introduction of plants into the growing medium. When populations of soil-borne pathogens are high, greater amounts of active ingredients in chemical drenches are required for effective disease control. With few exceptions, applications of harsh chemical treatments necessary to overcome the problem result in delayed crop growth and are not effective for complete eradication of soil-borne pathogens.

Production of plants in growing media containing soil or other media constituents with initially high populations of soil-borne pathogens requires a supplemental program of sanitation before the growing cycle can be initiated Applications of steam heat or fumigants, such as methyl bromide or chloropicrin, are often employed as a pathogen knockdown procedure to eliminate or reduce populations of soil-borne pathogens from growing media prior to the planting operation A microbiological vacuum created by the biologically destructive action of steam or fumigants is partially overcome by the use of aerated steam for treatment of growing media (1) Media pasteurization with aerated steam (160°F, 30 minutes) leaves many of the beneficial microorganisms capable of suppressing root disease activity by soil-borne pathogens (1). Re-use of growing media for propagation beds or for container growing is always a dangerous production practice because of the presence of high populations of soil-borne pathogens. All re-used growing media and containers should be exposed to heat or chemical fumigants before the planting operation in order to avoid severe root disease problems.

Soil-borne diseases can be reduced by careful selection and handling of growing media prior to the planting operation. In recent years, commercial greenhouse producers have relied heavily on soilless potting mixtures as a method of reducing soil-borne disease problems. Several commercial potting mixtures are formulated with media constituents containing low levels of soil-borne pathogens. Mixtures of commercial peat moss, perlite, vermiculite, styrofoam, calcined clay, volcanic rock or washed sand can also be prepared for use as soilless potting mixtures that contain initially low populations of soil-borne pathogens. Grower experience has shown that the use of soilless potting mixtures cannot completely overcome the

problem of soil-borne diseases without the use of additional sanitary precautions during the cropping cycle. Applications of soil fungicides at the time of planting have been effectively used to maintain sanitary growing conditions where soil-borne pathogen populations are initially low.

LIMITED AVAILABILITY OF DISEASE-FREE PLANTING MATERIALS

Limited availability of disease-free planting materials for production of ornamental crops is a major problem in the plant growing industry and is a particularly important problem in the production of greenhouse crops. Large-scale production of greenhouse crops generally cannot insure the use of disease-free planting materials for production of healthy plants. Lengthy periods required to produce rooted cuttings or seedlings for the finishing stage of growth increase the opportunity for root infection to occur prior to the planting operation. The importation of pre-finished planting materials from distant sources has also resulted in variable degrees of root disease from shipment to shipment. In overall perspective, most growers should assume all disease-sensitive planting materials are infected to one degree or another with soil-borne pathogens at the time of planting. Sanitation tools can be employed to overcome this pitfall in growing greenhouse crops. The use of hot water soaking for elimination of pathogens can be used for a few types of planting materials. The method is not commonly used for treatment of most types of greenhouse planting materials because of the dangers of injury to plants by high temperatures required to kill plant pathogens. A variety of chemical sanitation tools are widely used for direct treatment of planting materials or as drenching agents for sanitation during the cropping cycle.

EFFECTIVE USE OF SOIL FUNGICIDES

Over sixty soil fungicides, bactericides, and combination drenches or soaks are available to commercial growers for use in soil-borne disease control programs. The selection of chemicals and strategy for their effective use has been a problem to commercial growers for many years. Chemical products differ in the types of pathogens they control, formulations, rates to apply, and frequency of application necessary to perform satisfactorily. When used properly, chemical control measures can be thought of as short-term crop insurance with predictable expiration dates. When used improperly chemical disease control measures have limited effectiveness as problem-solving tools.

Strategies of disease control involving the use of soil fungicides should be based on an understanding of the limitations of their use. Applications of soil fungicides are most effectively used as sanitation tools in overcoming low populations of soil-borne pathogens. Soil fungicides can be effectively employed for disease control in many types of soilless potting mixtures or as supplemental sanitation tools following preplanting media treatment with various types of steam or fumigants. Proper use of soil fungicides for control of soil-borne disease problems requires the presence of the chemical in the growing medium or on the plant surface at the beginning of the growing cycle. Periodic drenching may be required as a supplemental sanitation tool to maintain vigorous and healthy roots during the growth of the crop. The rationale for use of chemical disease control measures in this manner is based on the fact that root and stem rotting diseases cannot be controlled readily once they appear. Chemical applications are effective for preventing infection by soil-borne pathogens, not as curative measures for disease control.

GREENHOUSE PRODUCTION TRIALS

Dependable and expedient growing programs are the criteria of success for commercial producers of greenhouse crops. Efficient growing programs are particularly important for greenhouse crop production where operational costs are very high. Unit production costs for tropical and floral crops can account for 75 to 90% of the wholesale value of the plant under optimal growing conditions. Requirements for long production cycles can severely reduce the margin or profit of greenhouse crops because of excessive demands for labor and energy needed to produce salable crops. Production efficiency studies were initiated to determine the influence of commercially available soil fungicides on efficient growing of typical greenhouse crops. The cropping efficiency of *Peperomia griseo argentea* 'Blackie' is an example of production trials with vegetatively propagated plants.

Propagation efficiency. Leaves of *Peperomia* 'Blackie' were planted in peat-perlite growing medium infested with millet seed inoculum of *Pythium aphanidermatum* to determine efficient propagation in the presence of a common soil-borne pathogen. Sanitation methods used for propagation included application of soil fungicides at the time of planting and treatment of the growing medium with aerated steam or methyl bromide-chloropicrin prior to the planting operation. Soil fungicides* were applied at recommended rates (excepting Terra-

* Benlate — benomyl, duPont
Captan — Orthocide
Lesan — Dexon, fenaminosulf
Subdue — metalaxyl, Ciba-Geigy
Terrachlor — PCNB, quintozene, Olin Corp
Truban — Ethazol, Malinckrodt

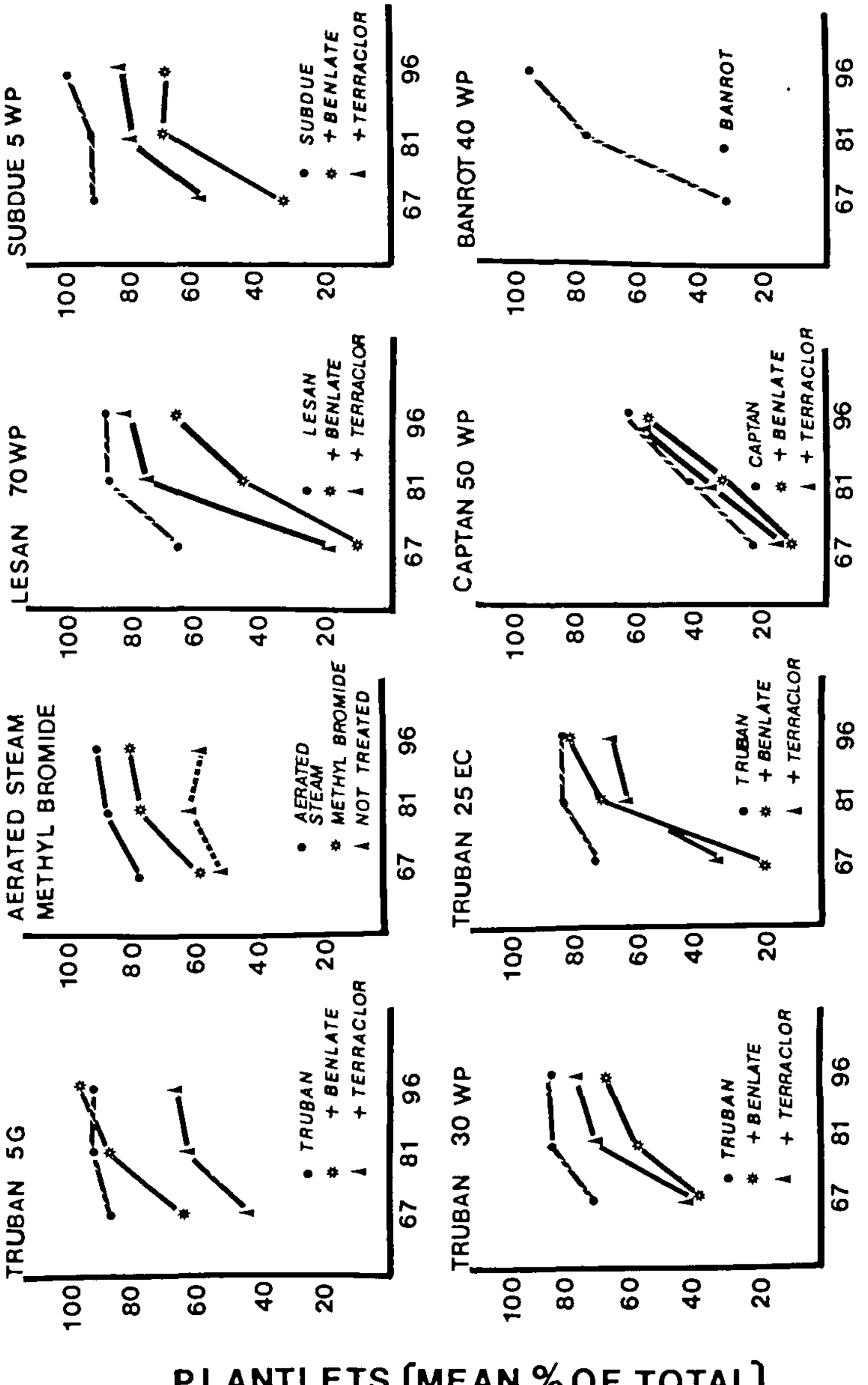

Figure 1. Influence of chemical drenches and preplanting medium treatment on plantlet production by vegetative leaf cuttings of *Peperomia griseo argentea* 'Blackie' in peat-perlite growing medium infested wth *Pythium aphanidermatum* inoculum Topical drenches were applied 1 and 45 days following planting Granular Truban 5G fungicide, aerated steam, and methyl bromide were used as preplanting medium treatments

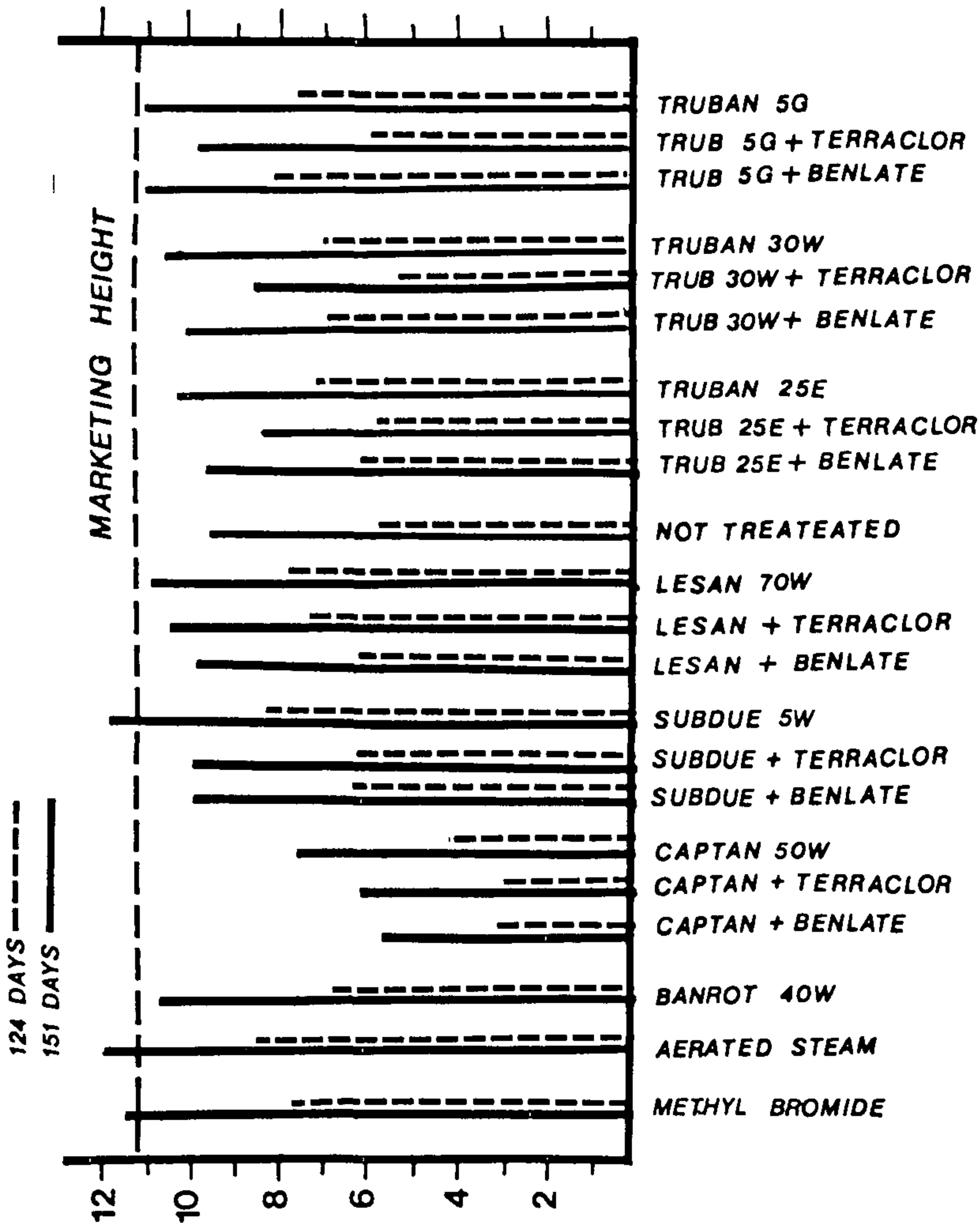

Figure 2 Production efficiency of *Peperomia griseo-argentea* 'Blackie' raised from vegetative leaf cuttings on production programs indicated Tropical drench applications in the finishing phase were applied at 1 and 45 days after transplanting into 4-inch pots Truban 5G fungicide, aerated steam and methyl bromide were used as preplanting medium treatments

clor used at a 4 oz rate) and applied singly or in combinations for broad spectrum disease control activity. Truban 5G fungicide was incorporated into the growing medium prior to planting as a single application. Other chemical controls were applied as a topical drench immediately after planting and after 45 days. (See Figure 1 for treatment used.) Leaf cuttings were maintained under cultural programs used by commercial greenhouse producers for a 96-day period of study.

Use of Truban 5G, Lesan, and Subdue at recommended rates resulted in production of plantlets comparable to or exceeding plantlet production in growing media treated with aerated steam or fumigation. Plants were produced more efficiently using recommended rates of Truban 5G or Subdue than other chemical control measures or preplanting medium treatments. The use of fungicide combinations resulted in delayed plantlet production when compared to use of chemicals applied singly as a soil drench. Combination soil drenches were generally the least desirable of chemical teratments used for plantlet production studies.

Finishing-stage growth. The same sanitation methods were used for transplanting plantlets into 4-in pots for the finishing stage of growth. Soil fungicide drenches were applied 1 and 45 days following transplanting. Truban 5G, aerated steam, and methyl bromide-chloropicrin were used as preplanting medium treatments.

The height of test plants 124 and 151 days following the initial planting of vegetative leaf cuttings was markedly different (Figure 2). Peperomias planted in growing medium treated with aerated steam, methyl bromide, Subdue, Lesan, and Truban 5G reached a marketing height faster than other treatments used. Application of fungicide mixtures resulted in reduced growth of treatment plants when compared to single chemical treatments.

CONCLUSIONS

Use of an aerated steam-treated or a fumigated growing medium was an effective sanitation measure for eliminating *P. aphanidermatum* from the growing medium prior to initiating the growing cycle. Alternative sanitation treatments of applying the soil fungicides Subdue or Lesan, the broad spectrum drench Banrot, or incorporation of Truban 5G into the growing medium were also effective for efficient production of *Peperomia* 'Blackie' plantlets and market-quality plants. Poor results obtained with captan drenches could be attributed to the long interval of fungicide application used; however, reduced plantlet production compared to untreated control plants suggests

phytotoxicity as a probable cause of the delayed growth observed (Figure 1).

The development of a healthy and vigorous root system is a fundamental requirement for efficient plant growth. Chemical sanitation tools can promote the development of vigorous root systems when used as preventative disease control measures. Greater attention should be given to effects of chemical treatment on plant growth. The elimination of soil-borne disease problems must be accompanied by minimal effects on plant growth to be useful in efficient greenhouse growing programs. Inability of growers to predict requirements to control specific soil-borne pathogens will continue to emphasize the use of broad-spectrum control measures during the cropping cycle. The use of fungicide with control activity will require the use of fungicide combinations. Long-term effectiveness, cost of application, and production efficiency of chemical control programs are important considerations for future research.

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SOME ASPECTS OF INTERIOR LANDSCAPING

LEN SPENCER

The Spencer Company
Houston, Texas 77042

The Spencer Company entered the horticultural services field in 1959 in commercial landscape management. During the early 1970's we noted the environmental trend and began an indoor plant leasing service, which is now producing about 55% of our gross revenues. In 1977, the landscape division rounded out our services with landscape design-and-build capabilities.

For this presentation, I requested a brief statement from three department managers in our indoor division with regard to the needs you might address in your propagation, growing and shipping operations. These are their memos to me.

PURCHASING

"In reference to your memo, the problems I have are rather isolated due to our excellent sources in Florida. However, there are certain plants that are almost always difficult to obtain. At certain times of the year, around January, *Dracaena fragrans massangeana* and other *Dracaena fragrans* cultivars

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grown as a cane are almost impossible to locate in quantity. I would urge all growers to gear up for that time of the year. Other materials that are difficult almost always are 17-inch *D. fragrans massangeana* grown in bush form, *D. deremensis warneckii*, and *D. deremensis* 'Janet Craig.' Fourteen-inch *D. warneckii* with good height (5 ft) are also hard to get."

SHIPPING AND GREENHOUSING

"*Condition of plants received.* Some plants are over-fertilized with Osmocote, which is a slow-release fertilizer. Generally, most plants have been thoroughly watered prior to shipping and are pest-free We do run into occasional problems of leaf spot caused by bacteria or fungus on leaves of *D. f. massangeana* canes. Growers need to be aware of the need for application of fungicides prior to shipping since the cool, dark, humid conditions in the truck are ideal for the spread of bacteria and fungus.

Other. We run into a supply problem with 14- and 17-inch *D.f. massangeana* canes. The growers never grow enough to cover demand I think our supply situation could be greatly improved if Texas growers were encouraged to produce larger quantities of interior-scaping foliage plants. It seems they are geared only towards the chain-store market. Overall, the industry has vastly improved in supply and quality over the last ten years "

PLANT CARE

"1. We need more kinds of 6- and 8-inch plants that will do well in low light (50 to 75 f c.).
2 We have had problems with virus in sheffleras and 'Janet Craig' dracaenas.
3. Frequently, plants ('Janet Craig' and 'Warneckii' dracaenas) need staking as soon as they come in.
4. Kentia palms need a heavier potting medium to keep them from leaning in the container "

Our sales personnel, who regularly deal with our interior design and architect clientele, constantly remind me that they need a greater variety of adapted plants in order to add a more creative note in the use of plants indoors. Please visit or call us if direct input from users can be helpful in your research and production programs.

ALTERNATIVE PROPAGATION TECHNIQUES FOR PRODUCING TEXAS FIELD ROSE BUSHES[1]

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Abstract. New techniques are needed to produce Texas field rose bushes more efficiently A high percentage of successful bud unions was obtained by bench chip budding dormant roses with either a conventional budding knife or Liliput tool Bench chip budding and utilizing selected forcing techniques to overcome initial dominance of understock axillary buds may help reduce the two year production period for producing field roses

New techniques are needed to produce field rose bushes more efficiently (2). In Texas field roses are conventionally produced over a 2-year production cycle under dry-land farming conditions utilizing the T-bud method (Table 1). T-budding requires active cambial division, which causes the understock bark to "slip" (3). During dry springs and early summers T-budding success is diminished since irrigation is not commonly utilized. Furthermore, only 50 to 85% of the initial field-planted *Rosa multiflora* hardwood cuttings successfully develop into a marketable bush. In addition field roses are individually handled some 20 to 25 times during their 2-year production cycle.

Table 1. Two Year Rose Bush Production Cycle — East Texas

Nov , 1981-Jan , 1982	Multiflora hardwood cuttings placed in field for rooting
March-July, 1982	T-budding of multiflora understock with budwood collected and stored from late fall, 1981
Oct -Dec , 1982	Breaks from multiflora understock used as hardwood cuttings
Jan -Feb , 1983	Scion budwood, which forced during previous season, is cut back before *R. multiflora* is cut back by machine in order to prevent scion damage
Feb -March, 1983	Budded multiflora understock cut back by machine to encourage scion bud break
Oct -Dec , 1983	Rose bushes pruned for budwood and later dug and processed for storage and shipment

It is possible for a grower to have 3 generations of roses at one time
a) 2 yr rose bushes which have yet to be dug in the fall
b) 1 yr rose bushes which were T-budded in the spring
c) *R multiflora* understock cuttings which have just been planted in the fall

Many nurserymen believe that a more hardy rosebush is produced in East Texas than in other parts of the country,

[1] Texas Agricultural Experiment Station Scientific Journal Series No TA. 17397

since *R. multiflora* is used as the principal understock and the cooler climatic conditions of the fall and winter allow for a more natural dormancy and transplanting survival. Clearly, production efficiency must improve if the Texas rose industry is to remain economically viable into the 1980's.

MATERIALS AND METHODS

Experiment 1. To characterize bench chip-budding of roses grown under commercial conditions of East Texas, a 2×2×2 factorial randomized complete block design was initiated in December. Chip budding 'Blaze' and 'Climbing White American Beauty' budwood onto dormant 'Brooks 56' were compared between a Liliput budding tool (J.E. Heitz, Inc., St. Helena, Calif.) and a conventional budding knife. Either parafilm strips or conventional rose budding rubbers were used to wrap grafts. Fifteen grafts in each of the 8 treatment configurations were replicated 5 times. Budded cuttings were stored in a dark growth chamber at 24°C for 1 week in polybags containing moist sphagnum, then planted under field conditions in East Texas.

Experiment 2. Since field rose bush producers leave 2 to 3 distal axillary rootstock buds for future understock propagules, the influence of 0-2 rootstock axillary buds on grafting success was examined. Information obtained could aid commercial growers in determining the feasibility of establishing permanent stock blocks instead of relying on each rose bush generation for new propagules. Hence, with a permanent source of propagules from stock blocks, bench chip budded scions might develop more rapidly since there would be less competition from 0-2 rootstock axillary buds.

One-year-old dormant *Rosa hybrida* 'Mirandy' budwood and shoots of *R. multiflora* 'Brooks 56' were collected from commercial fields of East Texas in December. Rootstock shoots with diameters greater than 4 mm were cut into 20 cm long cuttings. Each dormant 'Mirandy' scion was bench chip-budded to the medial position of unrooted rootstock cuttings with a Liliput budding tool (J.E. Heitz, Inc.) Chip-budded scions were subsequently wrapped with a one layer 1.7×12.5 cm Parafilm (American Can Co.) strip, which left the bud apex partially exposed (1).

Unrooted dormant bench-budded grafts were then inserted into Jiffy trays (Ball Seed Co.) containing steam-sterilized blasting sand (Bryco #2) as a rooting medium and placed underneath a greenhouse bench. Seventeen days later all trays were moved to the top of a greenhouse bench under shade. Shade was removed after one week.

Rooted grafts were transplanted 55 days after planting to sterilized 6.4 × 25.4 cm black plastic Deepots (McConkey and Co., Inc.), which contained 600 ml of 2 peat moss: 1 vermiculite: 1 perlite (v/v). Rootstock tops were pruned off at 1 cm above the chip bud 68 days after budding to enhance scion growth.

The three treatments in this experiment consisted of: a) all rootstock lateral buds removed, b) one rootstock lateral bud left at the distal end, and c) two lateral buds left on the distal rootstock cutting prior to chip budding. There were 20 grafts per treatment, which were replicated 4 times. The length of rootstock lateral shoot(s) and scions was recorded. Root quality of rootstocks was compared with a scale of 1 to 5 sixty-five days after chip budding.

RESULTS AND DISCUSSION

In Experiment 1 successful bud unions occurred with both the Liliput budding tool and hand budding techniques (Table 2). Poorer responses occurred with hand chip budding of 'Blaze' budwood, which may have been due to smaller bud pieces used; it has been our observation that 2 to 3 cm bud pieces are more effective in chip budding of dormant rose understock. Parafilm was more effective than budding rubbers traditionally used by growers, possibly due to reducing desiccation and acting as a protective barrier (Table 2). Some girdling and tissue necrosis occurred with budding rubbers, since grafts were buried under the soil and budding rubbers were not subjected to ultraviolet light breakdown, which normally happens with above ground conventional T-budding system.

Table 2. Effect of bench chip budding by hand and by Liliput budding tool using Parafilm strips or budding rubbers when budding 'Blaze' and 'Climbing White American Beauty' to 'Brooks 56' *R multiflora* understock

Treatment		Bud union (percent)	
		'Blaze' bud	'Climbing White American Beauty' bud
Budding method	Wrapping material	Rootstock 'Brooks 56'	Rootstock 'Brooks 56'
Hand	Parafilm	87a[y]	93a
	Budding rubber	67b	67b
Tool	Parafilm	93a	87a
	Budding rubber	80a	67b

[y] Mean separation within column by Duncan's multiple range test, 5% level

Bench chip budding (2) has potential advantages of eliminating production steps since cutting switches, de-eying cuttings (removing lower buds to prevent suckering), and budding

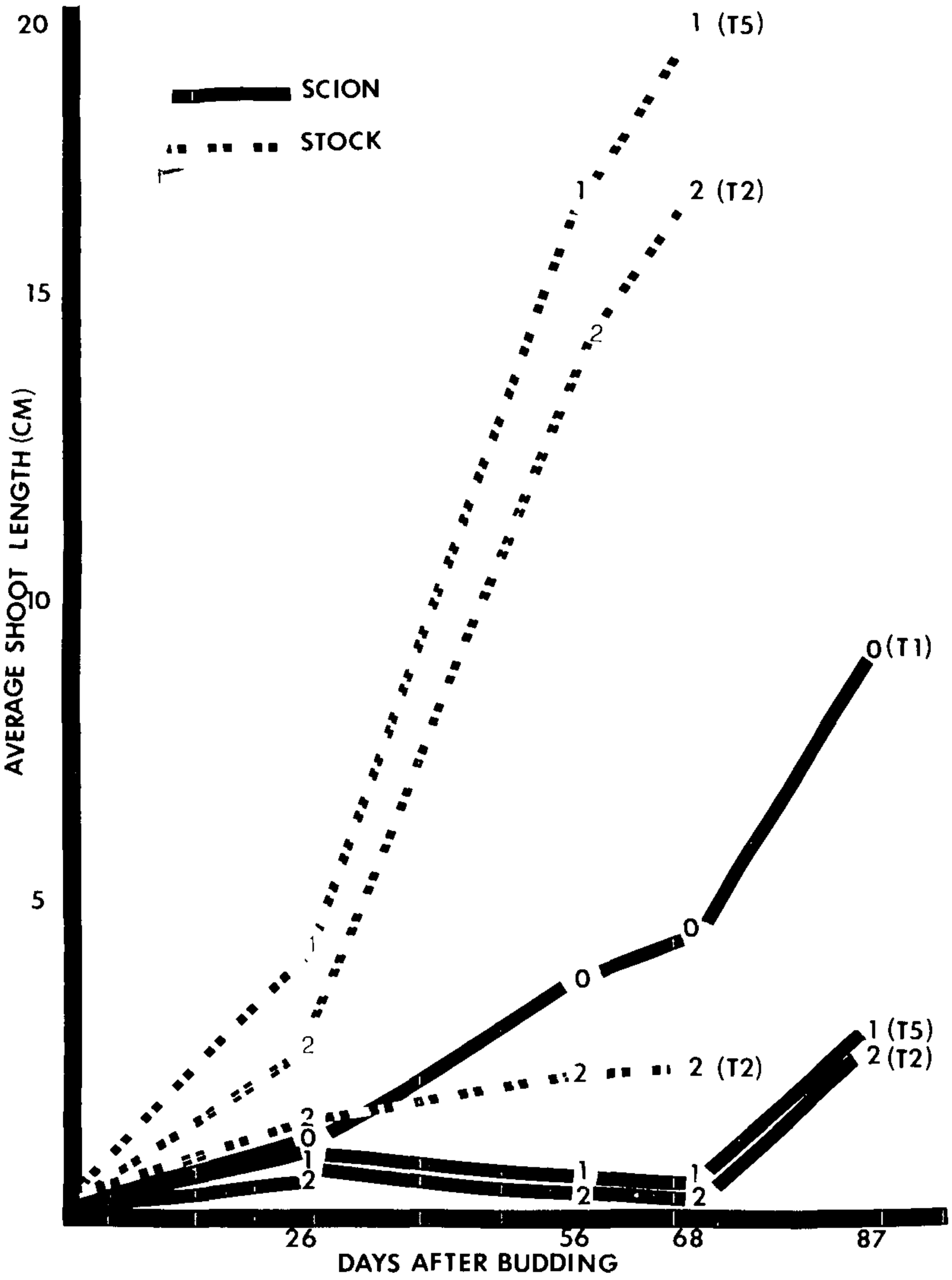

Figure 1. Growth curves of 'Mirandy' scions and 'Brooks 56' rootstock lateral shoots of treatments T1 (no lateral bud left at the top of each rootstock, represented by 0), T2 (one lateral bud left at the top of each rootstock, represented by 1) and T3 (two lateral buds left at the top of each rootstock, represented by 2)

can be done at the same time indoors during the "downtime" of winter. Time and discomfort to the worker could be reduced as he would bud on a bench rather than in the field, as is done with conventional T-budding. Other advantages of bench chip budding are. (1) elimination of T-budding seasonality due to its dependence on active understock cambium, and (2) reduction in the growth cycle since a 3 to 6 month advantage may be gained in the development of the scion.

In Experiment 2, the growth rate of 'Mirandy' scions chip-budded onto rootstocks without any lateral buds (Trt 1) was better than that of chip buds budded onto rootstocks containing one (Trt 2) or two (Trt 5) lateral buds. After pruning the top of all rootstocks at 68 days, a large increase in the growth rate of chip buds occurred (Figure 1). The lateral bud at the top of each rootstock of Trt 2 and one of two lateral buds at the top of each rootstock of Trt 5 became the dominant shoot as indicated by their growth rate. No differences occurred between Trt 2 and Trt 5 in the length of the dominant shoot, and the inhibited lateral shoot of Trt 5 had minimal development. There were no differences in the growth of chip buds budded onto rootstocks with one or two lateral shoots. After pruning rootstocks, scions grow vigorously.

Axillary buds on rootstocks prevent the development of chip-budded scions, which may be caused by the downward transport of inhibitors produced from the dominant shoot (4). Pruning rootstock tops 68 days after chip budding promoted vigorous axillary scion bud growth and consequently broke apical dominance

Root quality of rootstocks with one or two lateral shoots at their tops were superior to rootstocks with no lateral shoots. From experimental observation, it was found that rootstock cuttings of roses usually rooted after partial shoot elongation, suggesting that the shoot system provided growth substances required for root system development. Therefore, for commercial field rose bush production it is best to bench chip bud to rootstocks containing 1 or 2 axillary buds to encourage desirable root system development. Pruning must occur early in the growth cycle to eliminate dominance of rootstock lateral buds and allow for maximum scion development to shorten the production time.

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FIELD ROSE PRODUCTION

JOHN C. WALTER

Kimbrew-Walter Roses

Route 1, Box 172

Grand Saline, Texas 75410

Rose plants have been produced in east Texas for many years where the acid, sandy soil and rainfall are favorable for production of roses as a field crop. It is important that the fields be well-prepared. We begin field preparation in 1981 for the 1983 season.

It takes over 2 years to produce a salable rosebush. The production cycle begins in early November with cutting the budwood from desired cultivars. We use plants that will be dug and marketed this year. The mature wood is deleafed, wrapped in freezer paper, and then in damp newspaper, placed in plastic bags, and stored at 28°F until time to be used next May.

Next, the switches of rootstock are cut from the field that was budded this last year The switches are sawed into 6-inch long cuttings, de-eyed (lower eyes cut out leaving only 3 eyes on the top portion of each cutting), placed in bundles of 100, and put into large plastic bags for storing at least 2 weeks at 34°F before planting. In January, the cuttings are planted along the center of the rows that have been bedded up previously in the prepared field.

As the cuttings put on growth in the spring some of the bed is knocked down and, in May or later, depending on the growth rate and moisture in the soils and plants, the cuttings are T-budded with the desired cultivar buds that have been previously stored. The budsticks are removed from cold storage, slowly defrosted, and completely dethorned before being used in budding.

The field is cultivated and weeded all during the growing season but is not fertilized or sprayed (understock is quite resistant to blackspot and mildew.) That fall switches are cut from the understock plants to start the next crop.

The following February or early March, the understock

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top is cut off just above the bud. We do this by hand with loppers. The tops are ground up and distributed in the field as a bit of organic matter added to the soil.

As the new plant starts to grow, the whole field is "mowed" about 5-inches high to "pinch" the plants back and encourage branching. This procedure is repeated 2 or 3 times early in the growing season.

During the growing season the field is cultivated repeatedly, weeded, fertilized in early April and early June, then sprayed with a fungicide weekly.

When the plants go dormant in the late fall, budwood is cut, and the plants are dug, graded, tied in bundles, labelled, treated with a fungicide, and placed in cold storage at 34°F. The plants must be watered daily in cold storage and are marketed either as bareroot plants or as processed or potted plants.

The growing of field roses is a lengthy and costly process involving a tremendous amount of time-consuming manual labor. Some of the processors have worked out technology for processing the roses for marketing in an economical manner, but there is a real need for economic improvements in producing the plant itself.

WOODY TISSUE CULTURE RESEARCH

JAIME E. LAZARTE
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College Station, Texas 77841

Plant tissue culture is a term used to describe *in vitro* plant propagation in a nutrient medium. Tissue culture uses the totipotency capability of plant cells to differentiate, develop, and grow into a plant (plantlet) from excised plant tissues (explants) (Figure 1). The first requirement for successful tissue culture is obtaining aseptic or sterile condition of the explants, laboratory, and medium to produce clean uncontaminated cultures. This is referred to in the literature as Stage I or "Establishment of Cultures". The type of explants (leaves, roots, shoots, etc.), the conditions of growth of the stock plants (indoors, outdoors, healthy), and the chemical used (sodium or calcium hypochlorite, benzalkonium chloride, ethanol) as sterilizing agent with the interaction of concentration-time of treatment, have a direct effect on the success of the establishing stage.

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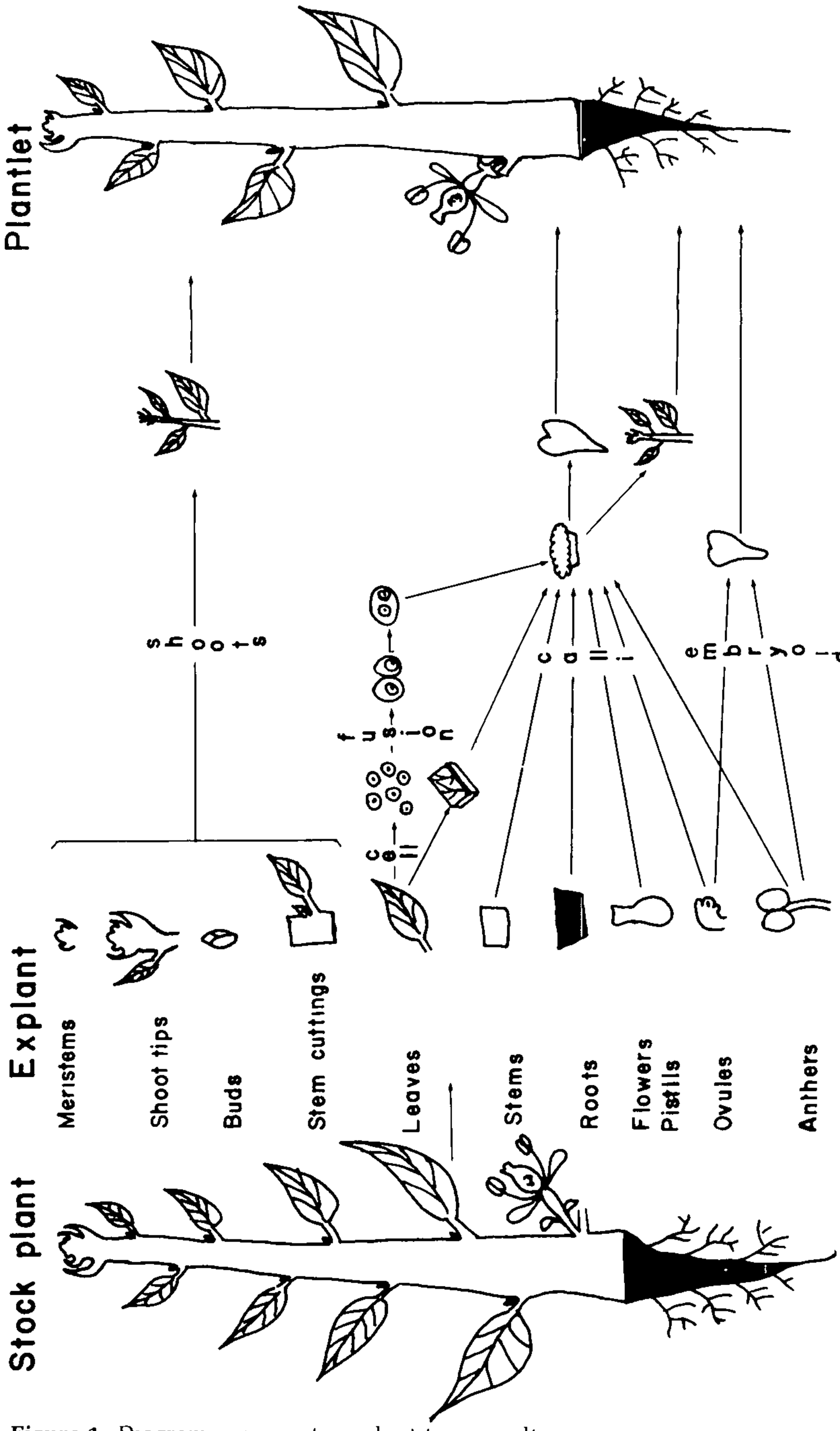


Figure 1. Diagram representing plant tissue culture

The second requirement is the type of medium to be used for culturing explants. Main components of a medium are inorganic and organic substances (Table 1, 2). Shoot, root, callus, embryoid, or plantlet differentiation or development is determined by the absence, presence, or balance of growth regulators. Mainly, auxins (NAA, IBA IAA) are used for rooting and cytokinins (kinetin, 2iP, BA) are used for shoot differentiation and development. However, a balance of these two types of growth regulators is needed for good root and shoot initiation and development. Once plantlets are developed, a last transfer to a medium without growth regulators will permit further growth of roots and shoots. The last step in any tissue culture procedure is the acclimatization of plantlets from the test tube to greenhouse and field conditions. This process requires a smooth transition which generally involves the initial use of polyethylene covers or mist systems to maintain high humidity to avoid desiccation. This humidity should be decreased with time to ambient humidity.

Table 1. Inorganic constituents of Murashige and Skoog (MS) medium and Woody Plant Medium (WPM)

Chemical	**MS** Murashige & Skoog) (mg/ℓ)	**WPM** (McCown & Lloyd) (mg/ℓ)
KNO_3	1900	—
NH_4NO_3	1650	400
$Ca(NO_3)_2$ $4H_2O$	——	556
K_2SO_4	——	990
$MgSO_4$ $7H_2O$	370	370
$MnSO_4$ H_2O	17	22 3
$ZnSO_4$ $7H_2O$	8 6	8 6
$CuSO_4$ $5H_2O$	0 25	0.25
$FeSO_4$ $7H_2O$	27 8	27 8
Na EDTA	37 3	37 3
CaCl $2H_2O$	440	96
KH_2PO_4	170	170
H_3BO_3	6.2	6 2
$NaMoO_4$ $2H_2O$	0 25	0 25

Table 2. Organic constituents of Murashige and Skoog (MS) medium and Woody Plant Medium (WPM)

Chemical	**MS** Murashige & Skoog) (mg/ℓ)	**WPM** (McCown & Lloyd) (mg/ℓ)
Thiamine HCl	1 0	1.0
Nicotinic acid	0 5	0 5
Pyridoxine HCl	0 5	0 5
Glycine	——	2.0
i-inositol	100 0	100 0
Adenine sulfate	10 0	——
Sucrose	30-50 g/ℓ	20 g/ℓ

These basic procedures make tissue culture a tool or aid to study and solve problems in propagation and basic research. Tissue culture is useful in clonal or asexual propagation, since in a relatively small growth area a high number of uniform plantlets can be produced. At present there are several laboratories, located mainly in Florida and California, which clonally propagate plants through tissue culture. Such facilities are provided with growth chambers, hoods, autoclaves, laboratory space and dishwashing areas. The larger laboratory facilities have to be operated 7 days a week and 24 hours a day in 3 shifts to justify the investment and expense. In sexual reproduction starting from the culture of anthers, microspores, or young pollen grains, tissue culture aids in the production of fully homozygous plants and in allowing recessive genes to be expressed. Contrasting, genetic variability can be obtained with protoplast fusion or *in vitro* fertilization Tissue culture of selected genotypes or mutants for genetic engineering has been the factor for the latest proliferation of tissue culture-breeding laboratories. Ideally the engineering, selection, and propagation of plants would start in the laboratory followed by a field test before increasing the "seed" for the grower. Presently the fact that embryoids (embryos developed *in vitro* without fertilization) can develop from diploid callus gives an exciting new vision of clonal propagation by asexual seed.

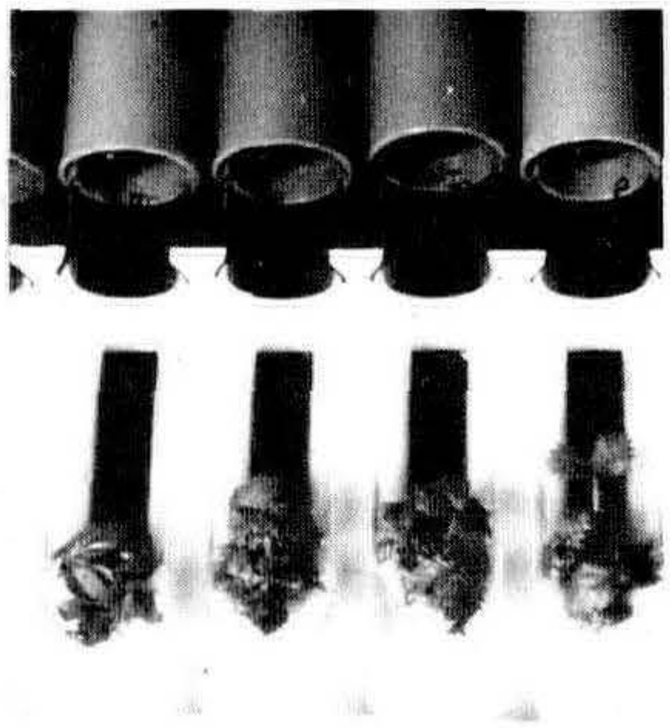
Contrasting with the large amount of information on herbaceous plant and greenhouse plant tissue culture, woody plant tissue culture has been progressing very slowly. The main problems encountered are common on plants of many species, and very often explants are collected from field-grown plants. The endogenous physiological condition of the plant changes according to season, and the juvenility or maturity of the plant will affect the proliferation of shoots and roots. Progress has been obtained by:

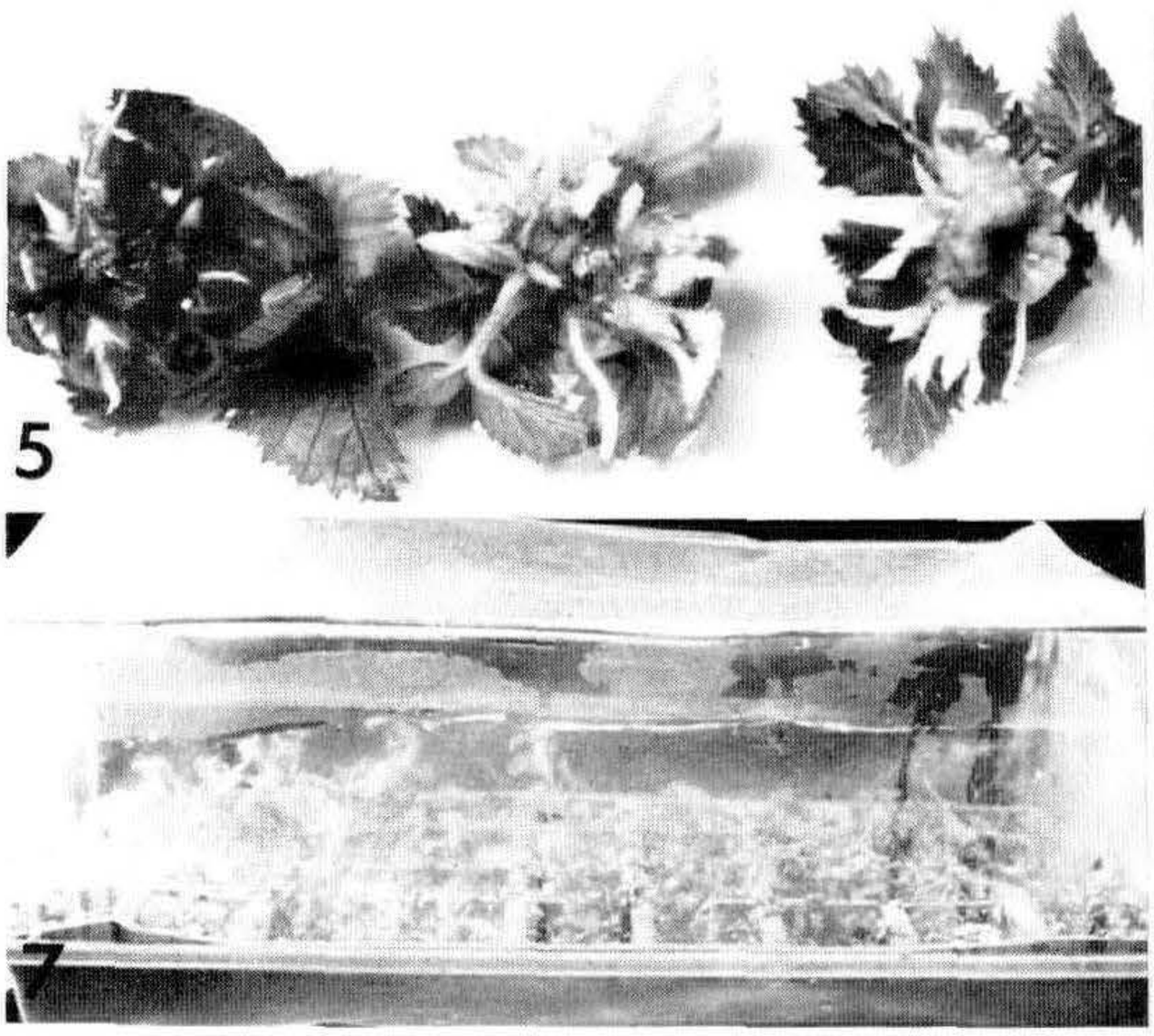
1) Growing stock plants indoors and maintaining healthy plants.
2) Using seedlings as stock plants; they are cleaner and respond more readily to culture.
3) Using hypocotyls or embryonic tissue.
4) Changing medium rapidly to avoid accumulation of any inhibitors leaching into the medium.
5) Reculturing already established plantlets.

The current main use of tissue culture for woody plants is in clonal propagation of new cultivars, selections, or rootstocks, and the production of disease-free plants.

THORNY BLACKBERRY TISSUE CULTURE

Stem cuttings were used for clonally propagating thorny





Figures 2 to 7. Thorny blackberry tissue culture. **Fig. 2,** stem cuttings; **Fig. 3,** *left* lateral bud; *right* lateral shoot development; **Fig. 4,** lateral shoots in rooting medium; **Fig. 5,** IBA rooting treatment: a. *left* 1 mg/l, b. *center* 3 mg/l, c. *right* 6 mg/l; **Fig. 6,** plantlet; **Fig. 7,** acclimatization of plantlets.

blackberries (Figure 2). The medium used was that of Murashige and Skoog at pH 5.7. All cultures were placed on growth shelves at 26±1°C, 16h photoperiod and a light intensity of 15 to 30 lux (provided by Sylvania Grow-Lux bulbs).

Blackberry stem cuttings were disinfected by a 10 to 15 sec dip in 30% EtOH. They were then rinsed in double distilled water, surface sterilized in 0.25% NaOCl, plus Tween-20, and rinsed three times in sterile water. Stem cuttings developed axillary shoots in MS basic salts, supplemented with 0.4 mg/liter myo-inositol, 0.1 mg/liter (GA_3) gibberellic acid, 30 g/liter sucrose, 8 g/liter agar, 0.1 mg/liter benzylaminopurino (BA) and 0 1 mg/liter indolebutyric acid (IBA) (Fig. 3). Once shoots reached 1 cm in length they were excised and transferred to a rooting medium (Fig. 4) where optimum rooting was accomplished using 3 mg/liter IBA (Fig. 5). Immediately after root initiation, plantlets were transferred to a medium without growth regulators (Fig. 6). Plantlets were finally transplanted into 1 peat.1 perlite (v/v). Acclimatization was accomplished by a weekly exchange of a series of polyethylene covers with 0, 14, 40 and 90 1-cm perforations. Plantlet survival was 1C0% (Fig. 7).

Other woody plant species have been tissue cultured, and procedures have been published for the following species.

Acacia koa	koa
Aesculus hippocastanum	horsechestnut
Coryllus avellana	filbert
Eucalyptus spp	eucalyptus
Hevea brasiliensis	rubber plant
Liquidambar styraciflua	sweetgum
Paulownia spp	
Santalum album	sandalwood
Tectonia grandis	teak
Ulmus americana	elm
Betula spp	birch
Populus tremuloides	aspen
Kalmia latifolia	mountain laurel
Coffea arabica	coffee
Vitis vinifera	grapes
Vaccinium spp	blueberries
Rubus	blackberries
Malus domestica	apple
Prunus persica	peach
Prunus amygdalus	almond
Prunus insititia	plum
Prunus avium	cherries
Rubus idaeus	red raspberry
Ribes inebrians	currants
Rosa hybrida	roses
R chinensis	roses
Fuchia hybrida	fuchia
Castanea sativa	chestnut
Theobroma cacao	cacao

Hydrangela macrophylla	hydrangea
Rhododendrons	azaleas
Morus alba	mulberry
Ficus spp	ficus
Simondsia chinensis	jojoba
Citrus	
Panax gingseng	gingseng
Araucaria cunninghamii	hoop pine
Cryptomeria japonica	japanese cedar
Picea excelsa	spruce
Pseudotsuga menziesii	douglas fir
Sequoia sempervirens	redwood
Thuja plicata	western red cedar
Tsuga heterophyla	hemlock
Pinus spp	pine

PECAN TISSUE CULTURE

Stem cuttings from pecan seedlings are presently being cultured in modified WPM liquid media. Shoot development has been very uniform and some cultures with multiple shoots have been obtained.

Acknowledgement: The author wishes to acknowledge information obtained through research studies by Ms Karen Ringhoffer and Mr Keith Hansen

DEVELOPMENTS IN DIRECT ROOTING

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Flowerwood Nurseries
Mobile, Alabama 36600

For generations nurserymen have rooted cuttings in beds. When the cuttings rooted, they were uprooted and planted in soil beds. When these plants were large enough to transplant they were uprooted again. All of this uprooting put growth on hold and took time and effort.

In the last decade direct rooting has become standard procedure with many nurseries throughout the century. No particular nursery or nurseryman could claim the distinction of originating the system because a considerable number of nurserymen embraced the concept at the same time. Evidently the time for this significant development had arrived and many saw fit to give it a try. There is no particular time when one could say direct rooting was born because there have been isolated instances of the practice going on for some time. In a meaningful way the system was basically born during the seventies.

From the beginning there was a considerable saving of

Hydrangela macrophylla	hydrangea
Rhododendrons	azaleas
Morus alba	mulberry
Ficus spp	ficus
Simondsia chinensis	jojoba
Citrus	
Panax gingseng	gingseng
Araucaria cunninghamii	hoop pine
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From the beginning there was a considerable saving of

time and labor. There have been many refinements and developments since 1970 that have contributed greatly to the merit of the system

Essentially direct rooting is the process of taking a cutting and sticking it directly in a pot filled with growing medium. The cutting roots in the growing medium and continues to grow without potting or interruption until the transplant stage.

The area expanse inherent in this system always presented a staggering problem of humidity control. Generally speaking the poly houses provide excellent humidity and temperature control in the cool fall and winter months. During the warmer spring and summer weather intermittent mist gives excellent humidity control and prevents temperature control from being a serious problem.

The first big plus for the system is the rooting percentage. It is usually excellent. Cuttings are not only quick to root but quick to get off to growing. The system is highly versatile because we can stick a large cutting and have a full-size liner as soon as it becomes rooted, or we can stick multiple cuttings in a pot and arrive at the full-blown liner stage in short order.

For years it was felt that top dressing with fertilizer when the rooting process started was sufficient. In recent years mixing 6 pounds Osmocote* 18-6-12 and 1 pound of Micromax* per cu yd of the soil mix has been very rewarding. The cuttings appear to benefit from nutrition even before roots begin to form. This makes the cutting stronger and certainly makes for a quicker take off.

At first cuttings were cut, stripped, dipped in a fungicide, dipped in a rooting powder and then stuck in the pot. Today, cuttings in most cases are cut, dipped in a fungicide and stuck without ever passing through the stripping shed. There is little or no stripping. What little stripping is necessary is performed during the cutting operation.

Cuttings of most cultivars root readily without the application of rooting compounds. If a particular one proves to be difficult, then experimentation with hormone preparations are in order. *Photinia fraseri* is a good example of where a hormone dip has proven beneficial. A soft cutting dipped in an alcoholic solution of 10,000 ppm IBA will usually root very quickly rather than spend a great deal of time developing a large callus before rooting.

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* Osmocote — a slow-release formulation of macronutrients
Micromax — a slow-release formulation of micronutrients
Both products manufactured by Sierra Chemical Co , Milpitas, California 95035

In the beginning round plastic pots were placed in beds between base boards. Today square plastic pots are placed in a square (18″ × 18″) plastic flat. The square pots prevent loss of soil between them during filling. The flat with the pots is run through a flat filler and then placed in the mist area or poly house. A worker will handle the 3-inch pots in multiples of 36. The same flat will hold 64 2¼-inch pots. These flats are a real plus when planting time comes around. Instead of needing 6 or 8 people to get up plants for the planting crew, it takes only 2 workers to pick up flats from the rooting area, deliver them to the planting area, and stay ahead of the planting crew without any trouble.

Peat pots are used for fibrous-rooted species such as azaleas. These come in a 3-inch size in strips of 6, which is a considerable advantage over handling the pots singly. Each flat will hold 36 of the 3-inch peat pots, same as with the plastic pots.

There is great variety in the sprinkler head or mist head being used for direct rooting. Everyone has a favorite head. This depends greatly upon the individual propagator, the drainage of his soil mix and the material being rooted. It would be difficult to recommend one head over all others, but the following arrangement is economical and very effective. A Ross 24H* head has proved very satisfactory when installed at a 15 × 20 ft spacing. The factory recommends 20 × 20 ft spacing but we find the 15 × 20 ft installation works well for us and certainly doesn't pose any problems. The rated output of the Ross 24H is 3 gal/minute at 40 psi. Ordinarily clocks can be set to cycle at 10- to 15-minute intervals until cuttings are rooted.

Ordinarily when a 30-minute clock is set to cycle every 10 minutes, there are 25 to 30 seconds of watering time on each cycle. If this creates excess wetness, a general purpose relay can be inserted in the system to allow an abbreviated watering period.*

The aforementioned system can be set up to function very well in full sun, but for most species 51% shade cloth appears to give better results. If wind becomes a factor, then heavy shade cloth or polyethylene wind barriers around the perimeters works very well.

The system has now been developed to the point where almost all ornamentals are propagated in this manner. Dwarf

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* Available from Transphere Corp , P O Box 1564, Mobile, Al 36633
* A suitable unit is available from Dayton Electric Mfg Co , Chicago, IL 60648

yaupon is a good example of a species that could be difficult. However, heavy cuttings stuck shallow (¼ to ½ inch deep) can give results near the 100% mark.

The ventilation and isolation provided by 2- to 3-inch spacing of the cutting stuck in the pots goes a long ways toward controlling leaf disease problems. If decay at the bottom of the stem becomes a problem, shallow sticking or more porosity in the soil mix will usually correct the situation.

Everyone will have his own pet mix. One such mix that works well is:

3 parts finely ground pine bark
2 parts peat
2 parts gritty sand (very coarse)
6 lbs/cu yd Osmocote (18-6-12)
1 lb/cu yd Micromax
10 lbs/cu yd dolomite limestone

Direct rooting is destined to become standard procedure in the nursery business of the future It lends itself well to year-round planting that can support year-round sales, to say nothing of the considerable savings in the time and labor that are critical factors in anyone's future.

PROPAGATION OF UPRIGHT JUNIPERS

THOMAS J. BANKO
Virginia Truck and Ornamentals Research Station
Virginia Beach, Virginia 23455

Abstract. Cuttings of *Juniperus chinensis* L 'Hetzii' were rooted at monthly intervals over a 2-year period with IBA treatments of 0, 2000, 4000, or 8000 ppm Rooting varied greatly over this period, but was consistently poor in early spring (March) IBA did not significantly improve rooting percentages when rooting capacity was low, but did increase numbers of roots per cutting during favorable rooting periods Trimming the upper half of the leaf from the cuttings also had no effect on rooting In another experiment, rooting medium temperatures of 20° and 25°C improved rooting of cuttings of *J virginiana* L 'Skyrocket' and 'Hillspire', and *J chinensis* L 'Kaizuka' *Cupressocyparis leylandii* rooted equally well at 15°C

REVIEW OF LITERATURE

Rooting juniper cuttings has concerned plant propagators for many years. Although some junipers root readily, others are difficult to root, or root well sometimes and poorly at others. Generally, the upright forms are more difficult and erratic in their rooting than the prostrate forms. For many junipers the time of year for taking the cuttings greatly influences rooting. In 1953 Snyder (4) reviewed several references

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related to juniper rooting prior to that time and found that most investigators indicated November through February was the best time to take juniper cuttings He also found that difficult-to-root cultivars usually were not benefited by root promoting hormones. In the late 1950's Nelson (3) investigated summer rooting of several juniper cultivars in Canada. Most were quite slow to root, with marked differences in rooting success from one year to the next. Cuttings taken in winter rooted consistently for most cultivars (2). Lanphear and Meahl followed seasonal fluctuations of Andorra juniper (*Juniperus horizontalis* 'Plumosa') over a one-year period in 1963 (1). They found high rooting percentages and root numbers from November through April. IBA increased the number of roots initiated during the favorable rooting period, but did not improve rooting during the months rooting was poor

Although these studies indicate juniper cuttings are best taken from late fall to spring, we still hear of poor or erratic rooting of juniper cuttings from nurserymen in Virginia, particularly if cuttings are taken in the spring. It was considered that since the previously discussed studies took place in more northern localities, seasonal response to rooting in southern regions may be somewhat different. Therefore, a two year study was made to follow the seasonal rooting characteristics of cuttings of *Juniperus chinensis* L. 'Hetzii' in Virginia and determine the effects of IBA on rooting.

Some propagators trim a portion of the leaves from their cuttings to reduce crowding or moisture loss. Effects of trimming on juniper rooting has not been reported, therefore, leaf trimming was investigated during part of the study. A preliminary experiment was also conducted to determine optimum bottom heat temperature during juniper rooting.

MATERIALS AND METHODS

Seasonal and IBA effects: At monthly intervals starting in November 1979, and for almost two years thereafter, 20 to 25 cm terminal cuttings of *Juniperus chinensis* L. 'Hetzii' were selected for rooting. The leaves were stripped from the basal 4 to 5 cm prior to dipping for 5 seconds in a 50% ethanol solution of 2000, 4000 or 8000 ppm IBA. Control cuttings were left untreated. During the summer an outdoor mist bench was used covered with 40% shade cloth. In late fall, winter, and early spring the cuttings were placed on a greenhouse mist bench. The minimum greenhouse temperature was 12°C with a rooting medium temperature maintained at 25°C with heat cables. Mist frequency and duration were adjusted according to environmental conditions. After 10 weeks in the rooting

medium the cuttings were evaluated for number of roots initiated per cutting and percent cuttings rooted.

Effects of leaf trimming. From January to June, 1980, the above experiment was duplicated except that the upper half of each cutting was trimmed off with scissors. These trimmed cuttings were compared with the corresponding untrimmed cuttings for number of roots and percent rooting.

Effects of rooting medium temperatures and of IBA: In a separate experiment, cuttings of *Juniperus virginiana* L. 'Skyrocket' and 'Hillspire', and *J. chinensis L.* 'Kaizuka' (Hollywood juniper) and *Cupressocyparis leylandii* (Leyland cypress) were started in flats of 1·1 peat moss:perlite with bottom heat temperatures of 15, 20, or 25°C. Half the cuttings at each temperature had the basal end dipped in a 2000 ppm IBA solution in 50% ethanol for 5 seconds. The other half of the cuttings were untreated. This experiment was started October 29, 1980, and the cuttings were evaluated March 20, 1981.

RESULTS

Seasonal and IBA effects: During the first year (1979-80) (Figure 1) rooting was poor in November, improved slightly in December and January and was very poor again in March (cuttings were not taken February 1980). Rooting improved in April and May, declined again in June, then gradually improved from August through October 1980. During the second year, 1980-81, (Figure 2) rooting was generally better than the first year, with exceptionally good rooting both in December and July Very poor rooting in February and March corresponded with the low point in March of the previous year. Cuttings taken in September and October of 1981 have not yet been evaluated. There was no consistent effect from IBA except during the exceptionally good rooting period of December-January 1980-81, where increasing concentrations of IBA produced greater numbers of roots per cutting but had no significant effect on rooting percentage.

Effects of leaf trimming: There were no significant differences either in rooting percentages or number of roots per cutting between trimmed and untrimmed cuttings during the months this factor was evaluated (Figures 3 and 4).

Effects of rooting medium temperatures and IBA: Table 1 shows the results of bottom heat and IBA treatments on three juniper cultivars and on Leyland cypress. Cuttings were evaluated on a scale of 1 to 4 (1=no roots, 4=heavily rooted). For junipers 20 and 25°C usually produced better root systems than 15°C. The IBA treatment appeared to be of limited bene-

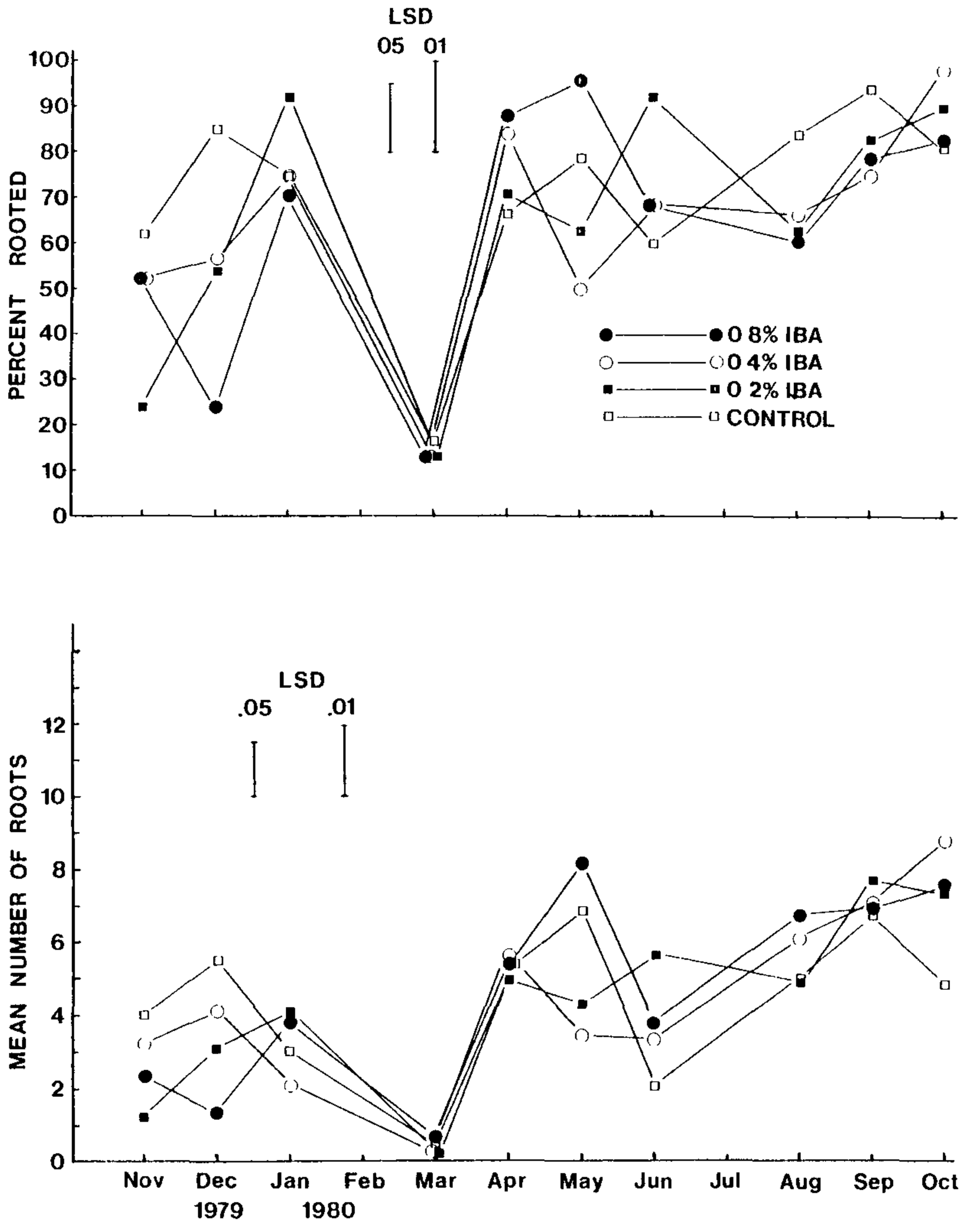

Figure 1. Percentage of cuttings that rooted (upper graph) and mean number of roots per cutting (lower graph) for cuttings of 'Hetzii' juniper taken from November 1979 to October 1980

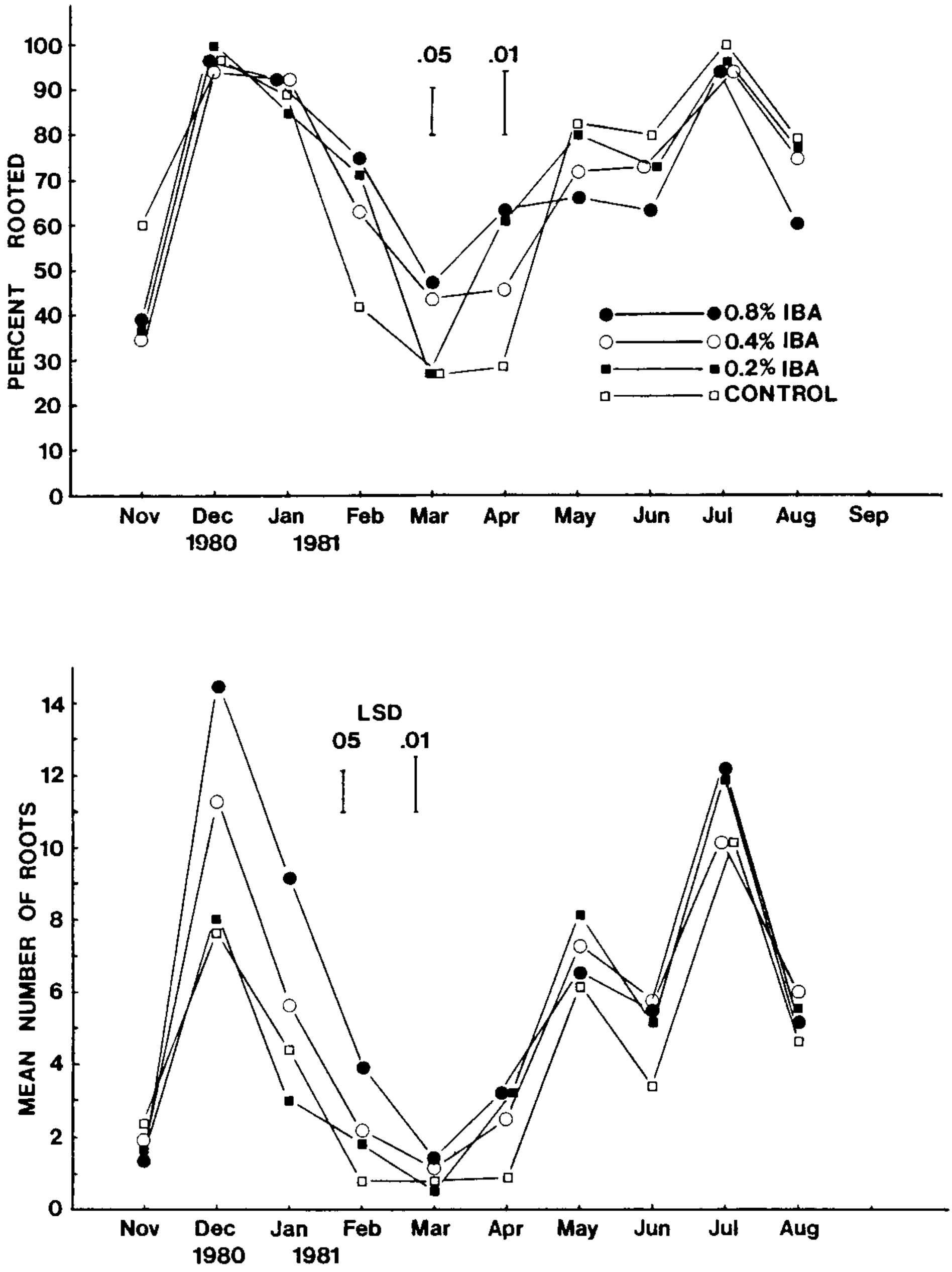

Figure 2. Percentage of cuttings that rooted (upper graph) and mean number of roots per cutting (lower graph) for cuttings of 'Hetzii' juniper taken from November 1980 to August 1981

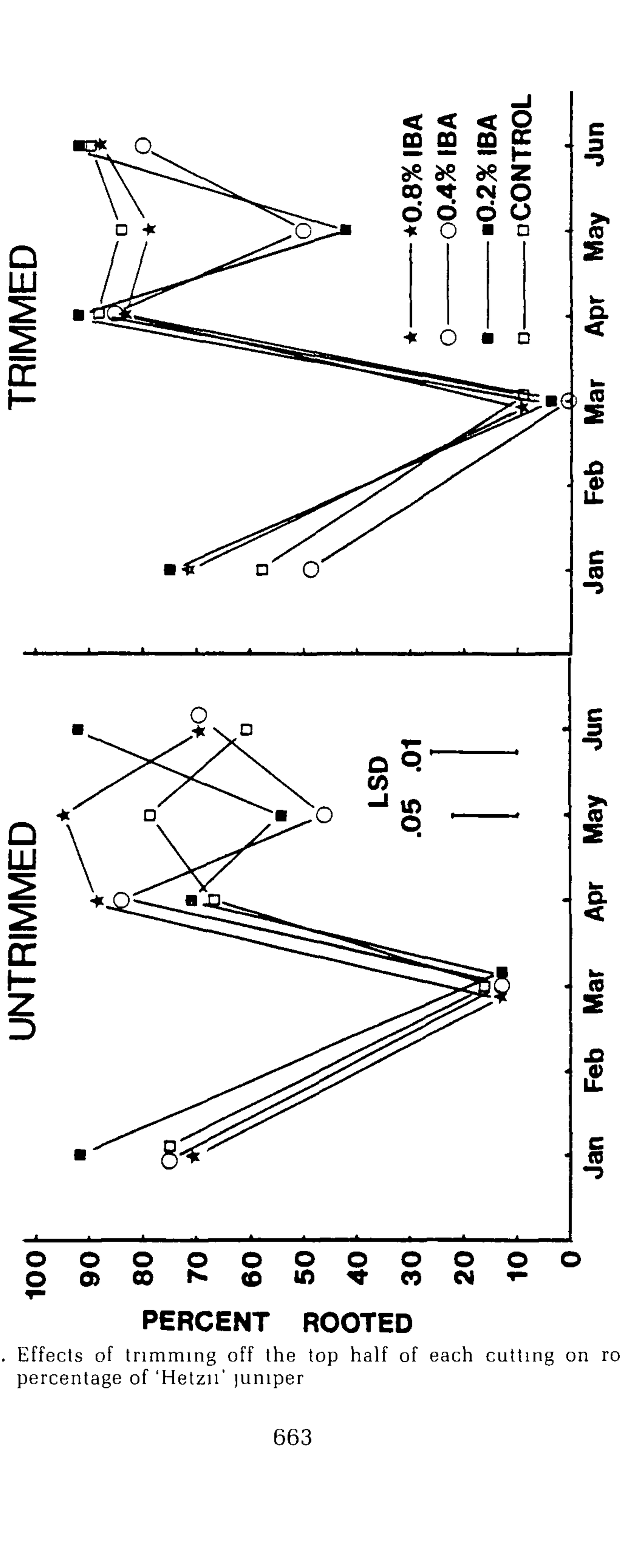

Figure 3. Effects of trimming off the top half of each cutting on rooting percentage of 'Hetzii' juniper

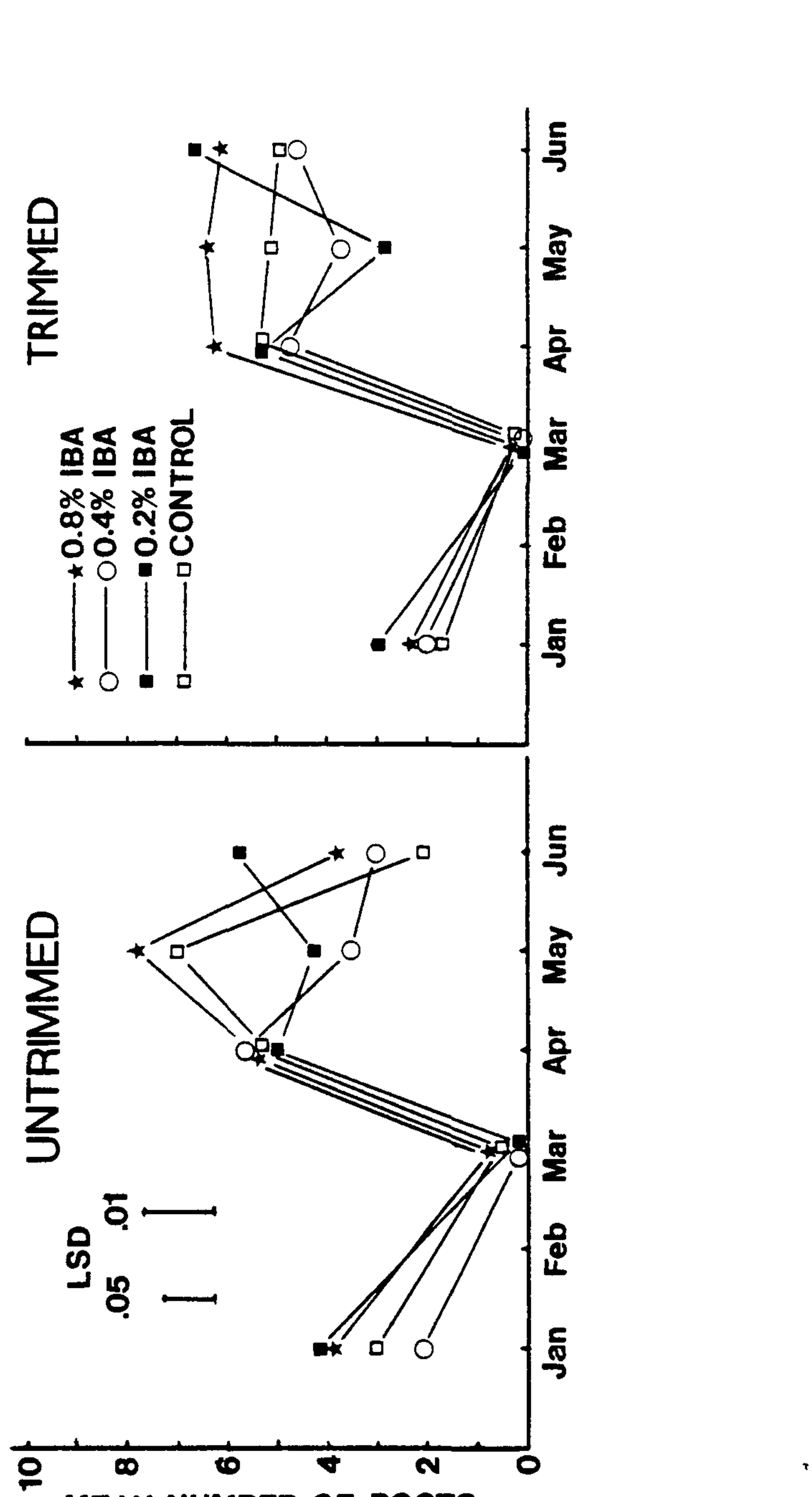

Figure 4. Effects of trimming off the top half of each cutting on mean number of roots per cutting of 'Hetzii' juniper

fit. Only with 'Skyrocket' juniper at 15°C did IBA appear to improve rooting This effect was not evident at higher temperatures. Leyland cypress rooted equally well at all temperatures evaluated, with or without IBA.

Table 1. Effects of medium temperature and IBA on rooting of juniper and Leyland cypress cuttings

		Mean rooting index[1]		
		15°C	20°C	25°C
'Skyrocket' juniper	IBA[2]	3 0	3 0	3 0
	No IBA	1 8	3 2	2 8
Leyland cypress	IBA	1 8	3 1	3 3
	No IBA	1 4	2 9	2 9
Hollywood juniper	IBA	2 8	3 7	3 3
	No IBA	2 8	3 2	2 5
Leyland cypress	IBA	2 8	3 3	3 1
	No IBA	3 2	3 0	3 0

[1] Rooting index 1=no roots, 2=poor root system, 3=moderately well rooted, 4=heavily rooted 50 cuttings per treatment were used
[2] 2000 ppm IBA in 50% ethyl alcohol applied as a 5-sec dip

DISCUSSION

The time of year when cuttings were taken had a marked effect on rooting of 'Hetzii' juniper cuttings. The most notable feature of the seasonal study was the consistently poor rooting in March. Although results for October 1981 have not yet been evaluated, the 1979-80 experiment and other preliminary experiments have shown October to be a good time to take juniper cuttings in Virginia. Poor rooting has occurred in November, and both poor and good rooting in December and January of different years. These results contrast with what was reported by Lanphear and Meahl on Andorra juniper, which was characterized by high rooting percentages and root numbers from November through April and poor rooting from May to October. These differences may be due to species differences or environmental effects.

IBA generally was not effective in improving rooting during the months that rooting was poor; however, IBA may cause some increase in root numbers under conditions when rooting is favorable. This agrees with what was found for Andorra juniper (1).

The three junipers tested responded favorably to moderate bottom heat. In most cases 20°C was optimum. Increasing to 25°C had little additional effect. With 'Skyrocket' juniper IBA seemed to compensate for low root temperatures, but this did not occur with the other cultivars. Temperature differences over the range tested had little effect on root quality of Leyland cypress.

In summary, the rooting capacity of juniper cuttings varies greatly throughout the year, and may be different for various localities and species. IBA has little effect when rooting capacity is low, therefore, optimum rooting periods need to be determined for each region and preferably, cultivar involved.

LITERATURE CITED

1 Lanphear, F O and R P Meahl 1963 Influence of endogenous rooting cofactors and environment on the seasonal fluctuations in root initiation of selected evergreen cuttings *Proc Amer Soc Hort Sci* 83 811-818

2 Nelson, S H 1959 Mist propagation of evergreens in the greenhouse during winter *Proc Plant Prop Soc* 9 67-76

3 Nelson, S H 1959 The summer propagation of conifer cuttings under intermittent mist *Proc Plant Prop Soc* 9 61-66

4 Snyder, William E 1953 The fundamentals of juniper propagation *Proc Plant Prop Soc* 3 67-77

TRICKLE IRRIGATION FOR FIELD PRODUCTION

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Much has been written about trickle irrigation and drip irrigation. So much has been written in fact, that there has arisen some confusion of how trickle irrigation relates to drip irrigation. The answer is that they are one and the same. Different authors generally choose one of the terms. In this country trickle irrigation seems to be the more popular term and, in fact, more accurately describes this irrigation system. This paper will henceforth use the term "trickle irrigation."

It is now time that we ask ourselves the question — What is trickle irrigation? One definition is that trickle irrigation is the daily maintenance of an adequate portion of the root zone of a plant at, or close to, field capacity during the growing and production cycle (1) For a moment let's take a close look at what is really being said in this definition. First, trickle irrigation works on the principle of the prevention of drought stress, as opposed to correcting an existing water stress. Never allowing a plant to be under moisture stress maximizes growth. Second, it implies that only a portion of the root zone needs to be kept under optimum moisture conditions. Research has shown that ¼ of the root zone kept under good water conditions can sustain the whole plant. From this it can be concluded that the trickle system does not have to wet the whole root

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Much has been written about trickle irrigation and drip irrigation. So much has been written in fact, that there has arisen some confusion of how trickle irrigation relates to drip irrigation. The answer is that they are one and the same. Different authors generally choose one of the terms. In this country trickle irrigation seems to be the more popular term and, in fact, more accurately describes this irrigation system. This paper will henceforth use the term "trickle irrigation."

It is now time that we ask ourselves the question — What is trickle irrigation? One definition is that trickle irrigation is the daily maintenance of an adequate portion of the root zone of a plant at, or close to, field capacity during the growing and production cycle (1) For a moment let's take a close look at what is really being said in this definition. First, trickle irrigation works on the principle of the prevention of drought stress, as opposed to correcting an existing water stress. Never allowing a plant to be under moisture stress maximizes growth. Second, it implies that only a portion of the root zone needs to be kept under optimum moisture conditions. Research has shown that ¼ of the root zone kept under good water conditions can sustain the whole plant. From this it can be concluded that the trickle system does not have to wet the whole root

zone. These two principles are the foundation of trickle irrigation.

HISTORY OF TRICKLE IRRIGATION

Trickle irrigation is reputed to have been first developed in Israel in the 1930's by Dr. Symcha Blass. The story goes that Dr. Blass observed a tree growing faster than surrounding trees and upon closer inspection found that a water pipe was leaking water next to the tree. He didn't pursue the development of this principle because at that time only metal pipes were available and their expense made an irrigation system impractical. In 1947 another Dr. Blass in England developed what was probably the first trickle irrigation system, which was used on greenhouse tomatoes. In the late 1950's scientists in Israel began working on trickle for field use. By the 1960's trickle had spread into Australia and by the late 1960's had spread into the United States and South Africa Today trickle irrigation can be found throughout much of the world and its usage is continually expanding.

BENEFITS OF TRICKLE

The following are some of the benefits of using trickle irrigation: 1) Increases growth rate by preventing moisture stress; 2) optimizes water usage by placing water directly on the root zone and thereby reduces total amount of water used; 3) reduces weed growth because area between rows is not watered; 4) makes installation easy even for laymen; 5) cuts labor costs; 6) allows for some tailoring of the root system; 7) allows for a reduction in total fertilizer usage as fertilizer can be applied through the system; 8) allows for digging even during dry periods; and 9) wets roots not foliage, thus aiding in disease control.

At this point it might be helpful to briefly discuss a few of the above-mentioned points. It is well documented on several nursery crops that trickle irrigation accelerated growth. For example, on several tree species increased caliper growth has been reported with trickle (2) and on these same trees it was also reported that trickle constricted the root system closer to the trunk (3). The increased caliper will increase the value of the trees and the constricted root system should result in better livability upon transplanting because more of the trees' roots will be retained during digging. Trickle irrigation also allows for easy fertilizer injection through the system. Research has been conducted which would seem to indicate that by injecting fertilizer through the system the total amount of fertilizer used may be reduced by one-half (4) Injection of fertilizer reduces the labor cost of application and the total

fertilizer cost for a nursery Trickle also allows for digging during periods that would otherwise be too dry for digging. This allows for more efficient use of labor and extends the digging season.

The benefits of trickle should be carefully considered when contemplating the installation of an irrigation system.

INSTALLATION

Although trickle is used to some extent in greenhouse production systems, its main use is in the field. Having an adequate water source is essential with regard to any type of irrigation including trickle. Trickle, however, uses considerably less water than conventional irrigation systems and consequently the water source does not have to have near the capacity. Some of the commonly used water sources are ponds, streams, and wells. As an example of how much less water trickle requires, some nurseries that used 4-inch wells for overhead sprinkler irrigation systems found that 1½-inch wells were adequate for trickle. With trickle, water capacity is usually discussed as gallons per hour (gph) rather than the more commonly used irrigation terminology of gallons per minute (gpm), and usually 2500 to 4500 gph area to be watered is used. Plants generally receive 1 to 2 gph per plant.

It is desirable to have as clean a source of water as possible. Excessive trash in the water can cause plugging with trickle To minimize the chance of plugging, every system should have a filter, preferably one that is self-flushing. In the Eastern States, where the water is fairly clean, a 100 mesh in-line screen is generally all that is needed. The in-line screen should be in the main line before the solenoid valve. When irrigating from a pond or stream sometimes a wooden box covered with nylon mesh is used over the intake as an additional filter

In the Southwest, where they are using Colorado river water, more sophisticated filtration systems are needed. These systems usually consist of sand filters, which are often large and fairly expensive.

Two inch inside diameter (I.D.) black polyethylene pipe or PVC pipe is usually used to convey water to the field. There is nothing magical about using 2-inch pipe, but it is a good general purpose size large enough to accommodate most situations. Once the pipe reaches the field, it should run perpendicular to the rows along one side of the field. This line that runs perpendicular is usually called the header line. Lateral lines are then run down each of the planting rows. The lateral lines are usually ½-inch I.D. 80- to 100-lb test black polyethyl-

ene pipe. None of these pipes have to meet drinking water standards

The main line and header lines are generally buried just deep enough to get them out of the way of traffic. The lateral lines are generally left on the surface. Buried lateral lines create problems because of the difficulty in detecting leaks. It is also important to "snake" the line to allow for shrinkage. The line can be laid out and allowed to go through some cold nights and, therefore, shrink before the emitters are installed. If emitters are installed without these precautions, they will not be in the proper locations.

Pump size for a trickle system depends on the acreage and number of plants to be watered. Generally, a 2 or 2½ horsepower pump is adequate.

The system is automated by using solenoid valves and time clocks. Normally-closed 2-inch solenoid valves are installed in the main line. If several fields are involved in which main lines are run to each field, there would be a solenoid valve per main line. The solenoid valve is wired to a time clock, which opens and closes the valve. Very simple inexpensive clocks are available. Also available are multistation zonal time clocks that will switch the water from one field to another. Other hydraulically controlled valves for switching water are available for places where there is no electricity.

An important question is what type of emitter to use. Simply defined, an emitter is a water outlet. There are literally scores of different emitters on the market and this tends to present confusion when it comes time to select an emitter. To lessen the confusion emitters can be broken down into several broad classifications. The first is those emitters which are built into the lateral lines. The buyer can prescribe what distance apart and what flow rate per emitter is desired. These emitters have the advantage of already being in the line, therefore saving the installation labor. They are also a part of the line and don't have parts that could be broken off sticking above the line. The disadvantage of these emitters is that if they malfunction they are difficult to replace. The second type of emitter is those that the individual installs into the line. These emitters have the advantage of allowing the individual to place each emitter exactly where he wants it. They can also be replaced fairly easily if individual emitters fail.

Emitters can further be divided into pressure-compensating and non-pressure-compensating. With non-pressure-compensating emitters flow will vary with changes in elevation since elevation changes cause pressure changes in the lateral. These emitters are fine on flat land, and they are cheaper than

pressure-compensating emitters But pressure-compensating emitters provide the same flow rate even with changes in elevation, and even with their additional initial cost they should be used on undulating terrain.

The whole trickle system is put together with elbows, tees, risers, C-clamps, and end plugs All of these components are held together by friction fits supported by the C-clamps.

In summary, the installation of a trickle system is not a complicated process and can be handled by most anyone with a basic understanding of trickle.

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PRELIMINARY NOTES ON DESICCATION AND VIABILITY OF LIVE OAK ACORNS

DAVID L. MORGAN[1] and EDWARD L. McWILLIAMS[2]

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Abstract. Acorns of the live oak (*Quercus virginiana* Mill) failed to germinate when frozen or stored in dry peat moss Stored in moist peat moss at 5°C (41°F), and at 21-30°C (70-86°F), they germinated but were heavily infected with soil-borne fungal pathogens at 3 months, rendering them unsuitable for planting Acorns dried at 34°C (93°F) lost viability as they desiccated A 15% weight loss reduced viability to 66%, and 20% weight loss reduced germination to 4% Acorns collected fresh from tree limbs germinated at higher rates than those collected from the ground, where they presumably had dried over time There was an inverse linear relationship between CO_2 evolution (an indicator of respiration) and percent weight lost through drying Implications of seed storage in controlled atmospheres and at near-freezing temperatures are discussed

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Due to convenience and tradition, Southern nurserymen propagate the live oak (*Quercus virginiana* Mill.) from seed

(acorns). The live oak seed is not easily stored, and in years when few seeds are produced, nurserymen have to travel throughout the southern United States in search of sufficient quantities of acorns to provide trees Growers commonly sow live oak acorns immediately after collecting them to avoid loss of seed viability. Live oak acorns commonly remain on the tree for sometime after they are mature; in fact, they often germinate while still attached to tree limbs (4), particularly during a rainy or humid autumn season. Moisture content, insects, disease, temperature and storage atmosphere affect viability of all seed types during storage (2), although seed of different species vary in their responses to these conditions. The majority of seeds benefit from drying, and lowering moisture content is one way of increasing the life span of many seeds (1). Dry storage in sealed containers at 0 to 2°C (32-36°F) has been used for some white oak species, but attendant to such storage there has been great loss of viability due to loss of moisture (3).

Hartmann and Kester (2) agree with Schopmeyer (3) that the large, fleshy seeds of many oaks are difficult to store for periods over a year Schopmeyer reported that although seeds of one species (*Q. robur* L) have been stored dry up to 3 years, most white oaks will not germinate after loss of 30 to 50% of seed moisture content.

Crocker and Barton (1) suggested that the best storage conditions for seeds of any species are those which best preserve the complex nuclei and the mitotic mechanism of the cells of the embryo, critical determinations that may relate to moisture loss and temperature. The following experiments were designed to determine the effects of water loss on live oak seed germination, and to determine the effects of selected storage techniques on seed viability.

MATERIALS AND METHODS

All seeds were collected from trees in Dallas, Texas, with the exception of one lot which came from trees growing on the Texas A&M campus at College Station. The College Station seeds were a year old and had been stored at room temperature of 21° to 30°C (70°-86°F) in a laboratory. Immediately after collection, seeds from all sources were immersed in water. The "floaters" were discarded, as were those with obvious physical defects, weevil holes, and those that had already germinated. The seeds from each tree were separated into lots of equal weight and number.

Seed Germination and Moisture: Eight hundred seeds from Tree "A" and 600 from Tree "B" in Dallas were sorted

into groups of 100 seeds each of uniform weight in October, 1975. One hundred seeds of each tree were selected for control and placed immediately in a germinator. The remainder were dusted with Spectracide (40% diazinon) insecticide in an attempt to kill weevils and Captan-Thiram 43-43 seed-protectant fungicide and dried to 5 or 10% intervals of weight loss in a commercial seed drier (Precision Scientific Co.). After drying the groups of seeds to preselected weights, each lot was placed in a seed germinator at 26 ± 2°C (79 ± 4°F) for 30 days.

Seed Storage: Seeds were collected in November, 1975 from 6 trees for an experiment involving 2 levels of moisture, 3 levels of temperature, and 4 time periods in storage. After storage, seeds were placed in a germinator at 26 ± 2°C (79 ± 4°F), for 30 days. The seeds from each tree were randomly assigned to each combination of treatments, and then were sealed in 3 mil polyethylene bags. Conditions of storage were: (a) 21° to 30°C (70 to 86°F) room temperature; (b) 5°C (41°F) in a seed storage coldroom; and (c) frozen at −10°C (−18°F). Storage periods were: (a) control, immediately after adjusting for equal weight; (b) 1 month; (c) 3 months; and (d) 5 months in storage. The seeds were dusted with Spectracide (40% diazinon) insecticide and Captan-Thiram 43-43 seed protectant fungicide. Seed sources included.

No 1 - collected from ground
16 seeds per treatment
32 6g average weight of lot of 16
No 2 - collected from tree limbs
7 seeds per treatment
7 7g average weight per lot of 7
No 3 - collected from ground under the tree
6 seeds per treatment
11 6g average weight per lot of 6
No 4 - collected from ground
13 seeds per treatment
27 7g average weight per lot of 13
No 5 - collected from ground (College Station), kept in paper bag for a year in room conditions
9 seeds per treatment
15 8g average weight of lot of 9
No 6 - collected from tree limbs
9 seeds per treatment
12 7g average weight of lot of 9

CO_2 Evolution: To assess the effects of moisture loss on respiration, lots of seeds were dried to 0, 5, 10, 15, and 20% weight loss, and CO_2 evolution was measured by gas chromatography. Acorns were picked from the branches of a single tree in Samuell-Grand Park in Dallas in December, 1980, returned immediately to the laboratory, sorted into 24-seed lots of equal weight, and dried at 20°C (68°F) to desired weights.

They were then allowed to remain in a sealed flask for 90 minutes, after which CO_2 was determined using a gas chromatograph (Gow Mac Series 500) with thermal conductivity detector to take air samples

RESULTS

Seed Germination and Moisture: In both seed sources "A" and "B", germination decreased sharply after 20% weight loss. In seed source "A" (in which observations were recorded after 5% increments), moisture loss of 15% reduced germination to 66% (Figure 1).

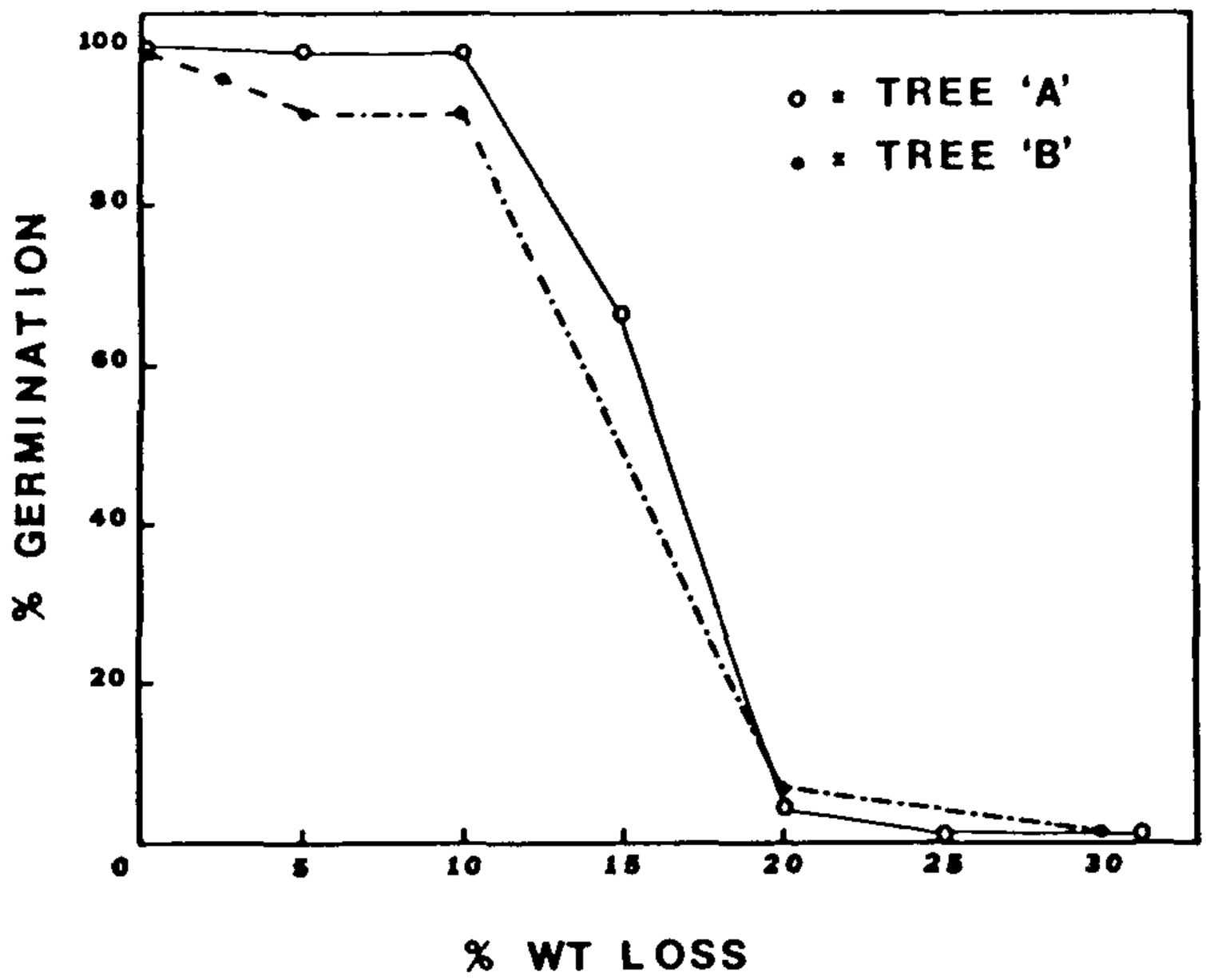

Figure 1. Percent germination of acorns as a function of weight loss by drying 100 acorns per treatment group

Seed Storage: Germination percentage was highest in acorns maintained in moist peat moss at room temperature, 21-30°C (Table 1) and at 5°C (Table 2). Under these conditions, moisture uptake was greater than other methods tested, and these seeds uniformly germinated in the storage media even before they were placed in the germinator. The College Station seeds, No 5, stored for a year failed to germinate, as did source No. 3, also collected from the ground.

Frozen live oak seeds and those allowed to dry in peat moss failed to germinate, regardless of seed source. Freezing also totally inhibited subsequent moisture uptake as did placing them in dry peat.

Table 1 The influence of storage on germination of live oak seeds held at room temperature (21-30°C) in moist peat moss

	Control	1 Month		3 Months		5 Months	
Tree No [1]	Percent Germination	Percent Germination	Percent Moisture Loss (−) Gain (+)	Percent Germination	Percent Moisture Loss (−) Gain (+)	Percent Germination	Percent Moisture Loss (−) Gain (+)
1 (ground)	6 2	25 0	+19 4	0	+16 5	12 5	—
2 (limb)	100	85 0	+29 2	85 0	+68 9	85 0	—
4 (ground)	23 1	23 1	+11 4	0	+17 8	46 2	—
6 (limb)	100	88 9	+20 9	100	+49 6	100	—

[1] Seeds from trees 3 and 5, collected from the ground, failed to germinate

Table 2. The influence of storage on germination of live oak seeds held at 5°C in moist peat moss

	Control	1 Month		3 Months		5 Months	
Tree No [1]	Percent Germination	Percent Germination	Percent Moisture Loss (−) Gain (+)	Percent Germination	Percent Moisture Loss (−) Gain (+)	Percent Germination	Percent Moisture Loss (−) Gain (+)
1 (ground)	6 2	31 3	+14 6	0	+20 6	12 5	—
2 (limb)	100	85 7	+17 8	100	+46 2	85 7	—
4 (ground)	23 1	61 5	+8 6	61 5	+11 8	0	—
6 (limb)	100	100	+21 6	100	+28 3	77 8	—

[1] Seeds from trees 3 and 5 collected from the ground failed to germinate

Differences due to the location of the seeds at the time of collection were apparent. Seeds collected directly from tree limbs (no 2 and no. 6) germinated at a higher rate both in storage and in control than those collected from the ground (no. 3, 4, and 6). All seeds absorbed water during moist storage (Tables 1 and 2) except those that had been frozen.

While all seeds in moist media gained weight, nearly all in the dry storage conditions lost weight as a result of loss of water. Rehydration failed to promote germination.

CO_2 Evolution: The inverse linear relationship between CO_2 evolution and weight loss in drying ($r = -0.96$, $\hat{y} = -9\,60x + 30.86$) indicates the negative effect of drying on CO_2 evolution (Figure 2).

DISCUSSION

In these preliminary studies, seeds of two live oak trees lost viability dramatically as they were dried at temperatures coinciding with expected seasonal high temperatures. At the 34°C drying temperature, tree "A" lost 15% weight, likely vital liquids and leakage of electrolytes, at 46.5 hours, resulting in the 34% loss of viability A 20% weight loss — 4% germination — occurred after 70 hours of drying. The corresponding decrease in respiration, as measured by CO_2 evolution, further

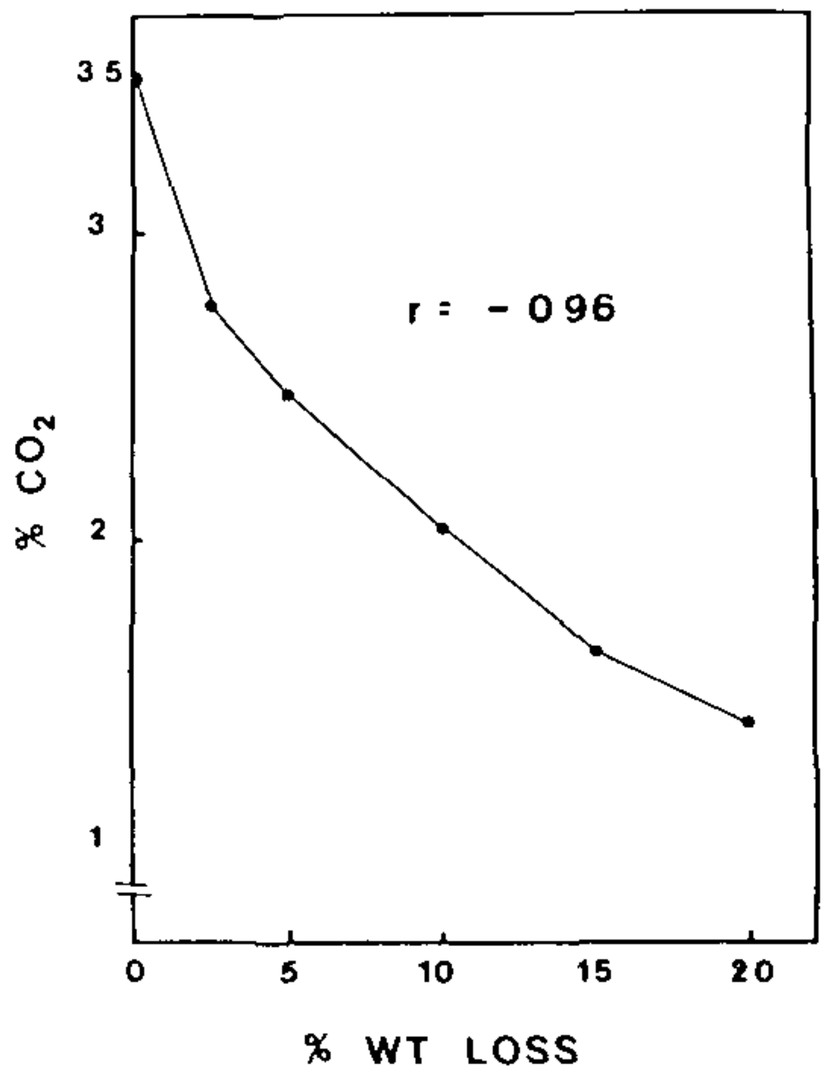

Figure 2. CO_2 evolution from acorns, as determined through gas chromatography, as a function of weight loss by drying

corroborates the loss of viability. Clearly, these data suggest that nurserymen could collect seed with assurance of quality by gathering only those acorns that remain on the trees, instead of scooping those that have fallen to the ground and begun to dry

Dry storage of seeds had the same effect as did desiccation; germination was reduced. Seeds stored in moist peat at 5°C and at a 21 to 30°C range germinated immediately in storage but the seedlings decayed by fungus after 3 months in moist storage, those that germinated after 3 months did not survive after transplanting. Neither the seed-protectant fungicide nor the insecticide was of apparent benefit. In addition to the fungal involvement, weevil (*Curculio* spp.) larvae emerged from the acorns in greater numbers from those collected from the ground than from those taken from the tree limbs (Nurserymen commonly attempt to kill these insect pests by immersing acorns in 120°F water for 30 minutes (4). The effects of this treatment on the seed are unreported.)

Seeds stored frozen, moist or dry, died due possibly to destruction of the enzymatic system or the complex nuclei and mitotic mechanism of the cells of the embryo, as suggested by Crocker and Barton (1), or simply due to massive tissue destruction by ice crystals.

The present findings present opportunity for further investigation. Germination may be inhibited at temperatures lower

than 5°C without freezing or drying the seed, minus 2°C likely would not freeze the seeds but would suppress germination as well as fungal activity. Manipulation of relative humidity above the percent moisture of the seed should be a related effort Mixtures of O_2, CO_2 and N_2 could be manipulated in a controlled atmosphere chamber such as those used for fruit storage, to find a suitable atmosphere. CA is reported to be used in China to store the fleshy fruit of the litchi (*Litchi chinensis* Sonn) (from correspondence with L D. Tukey)

Means by which the acorn can be freed of insect damage by chemical or other means should be investigated, as should the effects of the presence of the larvae on germination and post-germinated seedling growth.

Whether seed size (i.e., fresh weight) and year of collection influence the effect of moisture loss on germination should be considered, and identification of possible electrolytes subsequently lost after drying would be of interest.

Acknowledgment. The authors wish to thank P F Colbaugh for the use of the Gow Mac Series 500 gas chromatograph

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4 Stockton, A and D L Morgan 1979 Commercially producing live oaks from seed *The Texas Horticulturist* 6 13

QUESTION BOX

The Southern Region Question Box was moderated by Charles Parkerson and Frank Willingham.

CHARLIE PARKERSON. We have had trouble controlling *Thielaviopsis* in our nursery and feel containers may be one source of infection We are wondering about a container made to collapse like the separators in old-fashioned egg cases. It could be made of light-weight plastic and thrown away after one use. That would eliminate the necessity of attempting to sanitize used containers with methyl bromide or by other methods that may or may not be effective. In addition, the collapsible feature would make storage easy and the fact that many cells could replace many separate pots would cut down tremendously on handling and filling time. Is anything like

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this on the market; and if not, would there be enough demand to justify its manufacture?

BRYSON JAMES: Are all other parts of your system clean? I have found *Thielaviopsis* in peat pots.

ROBERT LAMBE: I have often found it in the soil mix It produces a very resistant spore and seems just to wait for a holly root. I have even put bark in the micro-wave oven and still been able to isolate it.

JAMES BERRY: Could it be we just don't use a strong enough dose of methyl bromide?

ROBERT LAMBE: Once this fungus gets started in a nursery, it is very hard to control Certainly, disposable pots could help if that is one source of infection But if it is already present, perhaps even in the roadways, just changing pots cannot solve the problem.

CHARLIE PARKERSON: Steam would kill the fungus, but melts plastic pots. Formaldehyde would also kill the fungus but is highly toxic. We would prefer to set up a production line system using a one-way pot. We had the idea of a fast production-line method using a micro-wave to sterilize the pots. We melted the pots and as Bob said, we still found viable *Thielaviopsis* in the bits of used bark that had remained in the pots from their previous use.

HUGH STRAIN: Is anyone using milky instead of clear poly for plant protection? We've heard it recommended but haven't heard results from people trying it.

BUTCH GADDY: We liked the fact that it didn't allow heat build-up. However, we did lose some hollies under milky plastic because the soil was too cold.

HUGH STRAIN. We have tried it in our propagation section and it seems to work.

GARY HUTT We use it for winter storage over container stock.

CHARLIE PARKERSON. You lose tensile strength, through, as you don't have 4 mils of poly when it's impregnated with something else.

HUGH STRAIN· The milky copolymer doesn't seem to tear on the low structures.

DENNIS McCLOSKEY. We like the heat. After all, that's why we're covering. If it gets too hot, we simply open the door.

JOHN HOPKINS We tested clear and milky plastic side by side. We found that when the temperature during the day was 90°F under clear plastic, it was only 70°F under the milky. Yet

at night it was 5°F to 10°F warmer under the milky covering.

HENRY NIENHUYS: White has less fluctuation, and that's what kills the plants

CHARLIE PARKERSON: There has been interest in knowing something about the marketing strategy that the Hines people will use for, let's say, the next two years Specifically, are the people making the decisions actually plant-oriented people?

BILL BARR: At the presidential level, administrative expertise is what is important. However, the Weyerhauser Corporation has a long history of plant-growing operations and their expertise is well recognized

FRANK WILLINGHAM In contrast, Ralston-Purina was forced to sell Green Thumb because of a lack of that knowledge and expertise.

CHARLIE PARKERSON: How difficult is it for a large corporation to make changes in production and marketing plans?

BILL BARR It is probably not too much more difficult than for a smaller concern, especially since most decisions applying to a specific location are made there. The market is evaluated once or twice a year, which may be more frequently than with some smaller concerns.

FRED MAY· Do you think the corporate mind can accommodate, so to speak, the idea of dumping plants?

BILL BARR Yes. They would be as concerned as a corporation as we are personally when such a thing is necessary.

JAKE TINGA. I would agree with Bill since if they make a mistake it is a big one. Look at GM.

DENNIS McCLOSKEY. Over-production is a fact of the economy, not of the corporate mind. People in a corporation can make a decision as quickly as I can

CHARLIE PARKERSON· Question to Earl Robinson. Earl, could you comment on Amfac's marketing strategy and plans for the near future?

EARL ROBINSON. We are trying to integrate production and marketing. We are looking carefully at cultivars and trying to evaluate their potential Expansion is the name of the game today in the nursery segment of Amfac especially since returns on other holdings have felt the pressure of low prices. Sophisticated data processing techniques are being used more and more In general, the organization is regrouping and refining its overall operation

JUDSON GERMANY. Is anyone propagating *Magnolia soulangiana* from softwood cuttings?

JOHN ROLLER. The soft tips will wilt, but *M. soulangiana* can be propagated from cuttings taken farther back on the stem You have to keep the humidity high and burn them up! We test Chloromone at the recommended strength as well as at other dilutions and then use what works best. You must keep your propagation house hot and tight, then open it gradually. Fungus can be a problem so sanitation is critical.

CHARLIE PARKERSON: John, what is in Chloromone?

JOHN ROLLER: I don't know as the company does not give this information, but it is good on broad-leaved evergreens. It's present price is $40/g.

DENNIS McCLOSKEY. We have also had excellent results using Chloromone on broad-leaved materials but have never been able to find out what's in it. Extremes in temperature destroy it.

GERALD SMITH. Do you follow the direction sheet that gives suggested dilutions for various species?

DENNIS McCLOSKEY· In general, yes. However, we stay away from full strength.

PHIL BEAUMONT· We put the entire cutting in Chloromone, then dip the tip in Hormodin This seems to prevent heavy callus formation on photinia.

S.I. PATEL. Related plants that have the same characteristics will react in the same way.

GARY HUTT. Dennis, what concentration do you use for azaleas?

DENNIS McCLOSKEY: We use a weak 4:1 dilution.

PETER VAN DER GLESSEN· We use 5:1 dilution on just about everything but dwarf yaupon.

FRANK WILLINGHAM. Chloromone is apparently a triacontanol alcohol compound. The research results look good.

BILL CURTIS: It is widely used in Canada.

HUGH STRAIN: It is also used extensively in the Mobile area.

TED GOREAU: Could it be willow extract?

JIM BERRY· I tried willow juice both in ethyl alcohol and in water I feel it did affect rooting, regardless of the solvent.

JOHN ROLLER. There is a good paper by Charlie Hess on cofactors, which describes tests that show plants do contain compounds that affect rooting.

BRYSON JAMES: The levels of hormones and other growth factors in the cutting seem to be related to the juvenility of the stock plant.

PHIL BEAUMONT. Has anyone tried using Atrinal[1] to encourage branching of cleyera?

BILL BARR. Yes, but it was not too effective.

JIM BERRY: It seems to give us some winter protection.

HENRY CLAY: Three oz/g gave response on photinia. The salesman recommended 2 applications.

JIM BERRY. Gary Cobb[2] at the Auburn University Ornamental Horticulture Field Station, Mobile Alabama, has tested Atrinal on photinia.

PETER VAN DER GLESSEN· We have used it on Carolina yellow jessamine, *Gelsemium sempervirens*, applied June 1 and again in September. We use 2½ oz/gal.

JAKE TINGA: I'm interested in knowing about the demand for variegated plants.

EARL ROBINSON: We don't plan to do any more than we are. We must decide 2 or 3 years in advance and consider costs in relation to expected selling price.

CHARLIE PARKERSON· The idea is to produce as long as the customer buys, and then quit. They are not our bread-and-butter items.

BILL BARR. Color is important. People here want it. Since it's almost impossible to grow blooming plants during hot Texas summers, variegated foliage is used instead

JOHN HOPKINS: Does anyone here have variegated *Osmanthus ilicifolius*?

BILL BARR: We (Hines) may have it at our West Coast facility. Monrovia Nursery does have it.

TED GOREAU: We take 2¼ in tip cuttings in June that are fairly soft and use Hormodin #3. There's nothing special about what we do, and we get 80 to 85% rooting.

JUDSON GERMANY: Is anyone propagating black-stemmed bamboo? *(Phyllostacchys japonicus)*?

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[1] Atrinal (dikegulac), Hoffman La-Roche, Inc , Nutley, N J

[2] Gary Cobb, P O Box 8276, Mobile, Alabama 36608

COMPARISON OF VARIOUS TREATMENTS IN ROOTING OF RHODODENDRON 'ENGLISH ROSEUM' CUTTINGS

TOM SAUNDERS[1], LAWRENCE LEGG[2], and JAMES COARTNEY[3]

Abstract. Rooting of *Rhododendron* 'English Roseum' was most successful when the cuttings were basally wounded on two sides and were treated with Hormex #30 (3 0% IBA) Removal of the terminal bud also increased rooting and was additive to the response caused by wounding Foliar applications and terminal bud applications of growth regulator were generally ineffective

According to a 1980 survey by Nursery Business (1), Virginia was ranked 12th in the United States in the area of nursery production. Virginia's favorable climate and proximity to major markets should favor increased nursery production. Rhododendrons are becoming an increasingly popular landscape plant. In the past Virginia has not been a major producer of rhododendrons. Rhododendrons sold in Virginia have been imported from the West Coast or from the South. There are several nurseries in Virginia producing rhododendrons and increasing energy and shipping costs should encourage further rhododendron production in Virginia.

Saunders' Nursery is inexperienced in the area of rhododendron production. The object of this study was to examine a variety of treatments, both chemical and physical, in order to determine their relative influence on rooting of cuttings of *Rhododendron* 'English Roseum'. It was also conducted during the winter months using dormant plant material as this is a time when labor is readily available for propagation.

METHODS AND MATERIALS

All *Rhododendron* 'English Roseum' cuttings were taken from healthy 15-18 in plants grown under full sunlight and in two gallon containers. Cuttings were taken on February 2, 1981 and stored at 40°F until February 4, 1981 when they were stuck in the mist bed All cuttings were 3 in long and were trimmed to uniform size leaving 4 to 6 terminal leaves. All cuttings were dipped in a benomyl suspension (1 tbsp. of Benlate 50w/gal. of water) prior to sticking. Five cuttings were used for each treatment and each treatment was replicated four times making a total of 20 cuttings per treatment. Each replication was randomized within the propagating bench

Wounding was accomplished with a sharp knife. Two

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sides of the cutting were wounded. An individual wound was 1 in long and extended through the cambium layer

Basal application of hormone was made by using either commercially available powder formulation or by preparing liquid formulations from crystalized IBA dissolved in 40% ethanol. Application of hormone to the leaves was with a five second dip method similar to that used for making basal liquid applications. Similarly, bud applications were made by folding the leaves back and dipping the terminal bud or bud scar.

The propagation medium was peat-perlite (50/50) with bottom heat cables set at 70 to 72°F and misted 10 sec./5 min. from 8:00 am to 5:00 pm. The greenhouse air temperature was regulated at 68 to 72°F.

The rating scale used to evaluate cuttings was as follows: 0 - Dead; 1 - No roots (callus may or may not be present); 2 - Few roots, 3 - Root ball 1-2 in in diameter; 4 - Root ball 2-4 in in diameter, and 5 - Root ball greater than 4 in in diameter.

The treatments used in this study are listed in tables 1 to 4 The entire group of treatments was fully randomized within the bench and the untreated controls are therefore the same within each table

RESULTS AND DISCUSSION

As this particular study looked at a number of variables it is divided into four groups based upon the location of where growth regulator was applied. Table 1 includes basal applications, Table 2 includes foliar applications, Table 3 applications to the terminal bud, and Table 4 applications to both the

Table 1. Influence of wounding, terminal bud removal, and basal growth regulator application on rooting of *Rhododendron* 'English Roseum' cuttings *

	Growth Regulator	Basal wound	Bud excised	Rooting response
1	Untreated	−	−	2 8
15	Untreated	−	+	3 7
2	Untreated	+	−	3 1
16	Untreated	+	+	3 6
3	1 6% IBA powder	+	−	2 6
4	2 0% IBA powder	+	−	3 4
5	3 0% IBA powder	+	−	3 3
6	3 0% IBA powder	+	+	4 2
7	4 5% IBA powder	+	−	3 0
8	4 5% IBA powder	+	+	3 9
9	5,000 ppm IBA liquid	+	−	3 2
10	10,000 ppm IBA liquid	+	−	2 8

* Cuttings stuck 2/4/81 and rated on 4/24/81 Growth regulators by basal applications of commercial powder or five second liquid dip Wounding on two sides of cutting

foliage and the terminal bud. Statistical analyses were not performed on the data but the variation between replications was minimal.

The data in Table 1 shows that removal of the terminal bud and wounding each increased rooting. Removal of the terminal bud continued to increase rooting when used in conjunction with hormone treatment. This shows at both the 3.0 and 4 5% IBA concentrations. Hormone concentrations of 2.0% IBA and 3.0% IBA gave higher rooting values than the 1.6% or 4.5% concentrations A liquid quick dip of 5,000 ppm IBA dissolved in 40% ethanol gave results nearly equal to the 2.0 and 3.0% IBA powder. It is not known if removal of the terminal bud would further increase rooting of the liquid treatments.

Table 2. Rooting response of *Rhododendron* 'English Roseum' cuttings following foliar application of growth regulator *

Growth Regulator	Basal wound	Bud excised	Rooting response
Untreated	−	−	2 8
Untreated	−	+	3 7
Untreated	+	−	3 1
Untreated	+	+	3 6
5,000 ppm IBA liquid	−	−	2 6
10,000 ppm IBA liquid	−	−	2 1
10,000 ppm IBA liquid	−	+	2 6
10 000 ppm IBA liquid	+	+	3 9

* Cuttings stuck 2/4/81 and rated 4/24/81 Wounding two sides of cutting. Growth regulator applied by dipping the upper 1″ of leaves as a five second dip

In an earlier study McGuire and Sorenson (2) found that terminal application of IAA was effective in promoting rooting of *Rhododendron* 'Dr. Dresselhuys'. The foliar application of IBA to *Rhododendron* 'English Roseum' did not give a positive response in this study. Various reasons could be responsible

Table 3. Rooting response of *Rhododendron* 'English Roseum' cuttings following application of growth regulator to the intact or excised terminal bud *

Growth Regulator	Basal wound	Bud excised	Rooting response
Untreated	−	−	2 8
Untreated	−	+	3 7
Untreated	+	−	3 1
Untreated	+	+	3 6
5,000 ppm IBA liquid	−	−	2 0
10,000 ppm IBA liquid	−	−	2 0
10,000 ppm IBA liquid	−	+	2 4
10,000 ppm IBA liquid	+	−	3 7

* Cuttings stuck 2/4/81 and 4/24/81 Growth regulator applied to intact terminal bud or to wound created by terminal bud removal

for the lack of response with *Rhododendron* 'English Roseum' There is no way of knowing how much chemical enters the plant as a result of such applications However, these data indicate that the IBA may have been applied at supraoptimal concentrations. The greater reduction in rooting at 10,000 ppm IBA would support this hypothesis and the fact that application to both the foliage and terminal bud reduced rooting response more than foliage application alone would further support this hypothesis.

In summary, there are many factors that control rooting. Hormone application is well accepted as an aid to rooting. In this study with *Rhododendron* 'English Roseum' wounding and removal of terminal bud are shown to be equally as important as the hormone treatment.

Table 4. Rooting response of *Rhododendron* 'English Roseum' following application of growth regulator to both the foliage and the intact or excised terminal bud *

Growth Regulator	Basal wound	Bud excised	Rooting response
Untreated	—	—	2 8
Untreated	—	+	3 7
Untreated	+	—	3 1
Untreated	+	+	3 6
5,000 ppm IBA liquid	—	—	1 8
10,000 ppm IBA liquid	—	—	2 0
10,000 ppm IBA liquid	—	+	2 4

* Cuttings stuck 2/4/81 and rated on 4/24/81

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1 Morey, Dick 1980 The Wholesale Nursery Industry — 1980 *Nursery Business* Sept 1980

2 McGuire, John J , and David C Sorenson, 1966 Effect of terminal applications of IBA on rooting of woody ornamental plants *Proc Inter Plant Prop Soc* 16 257-260