THE HAWAIIAN ENVIRONMENT

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The Hawaiian Islands consist of many individual islands located in the Pacific Ocean, extending from 154°45' to 179°15' west longitude, a distance of over 1600 miles, and from 16°30' to 28°30' north latitude, a distance of over 850 miles. This circumscribes an area of over 1 1/3 million square miles — the only trouble is that there is so much of it underwater.

Scientists tell us that the Hawaiian Islands are of volcanic origin but the date of the formation of the islands above the surface of the ocean is still unknown. For centuries limestone and coral deposits accumulated to form the islands as we know them today, extending from Kure Island just northwest of Midway to Hawaii Island on the east and Johnston Island on the southern extremity. The mineral content of the volcanic material has made the soil of the islands tremendously fertile and productive.

Hawaii, as most of us think of it, is comprised of six major volcanic islands between 19 and 22°15' north latitude and 2,700 miles from the nearest continent. Northeast tradewinds prevail and, combined with topography and altitude, provide environmental conditions ranging from wet tropical to dry subtropical and desert, to temperate and even alpine. Crop plants and people came only very recently. The 790,000 people here today are primarily of Japanese, Caucasian, Chinese, Filipino, and Polynesian ancestry, in that order.

The state is comprised of 4.1 million acres, of which "jungle" forest is 49%; brushy grasslands, 17%; mountains, new lava, canyons, 17%; agricultural crops, 8%; parks, 6%; and urban, industrial, military, 3%.

The present total agricultural area, including grazed lands and croplands, comprise 38% of the total state area. However, only one-fifth of the agricultural lands, or 325,000 acres, are croplands. And of this area, 300,000 acres are devoted to plantation culture of sugar cane and pineapple. This leaves about 25,000 acres for all diversified crops, of which 13,000 are devoted to orchards, 2,500 to vegetables, and 2,500 to field crops.

Present gross state product is approximately $4 billion. Agriculture is approximately $525 million; comprised of sugar,

Ed. Note: Dr. Bullock showed a series of slides illustrating the propagation and culture of the many agricultural crops of Hawaii, such as sugar cane, coffee, pineapple, macadamia, papaya, and guava.

$210 million; pineapple, $135 million; livestock and diversified crops, $180 million.

The controlling factors which decrease the intensity of land use are rough topography, high elevation, presence of lava rock, thin and infertile soils, and inadequate and unfavorable rainfall distribution. Lack of rainfall or water for irrigation excludes extensive low-elevation areas from intensive cropping. Under the prevailing economy in Hawaii, lands and supporting facilities are utilized first for the plantation crops of cane and pineapple with a steady worldwide demand and a fair margin of profit for sugar on a gross income of $600 to $800 per acre. Second choice goes to the small, fluctuating market crops of fruit and vegetables, which gross $2,000 to $3,000 per acre per year. Third choice goes to field crops, which because of mass production elsewhere, will gross $100 to $500 per acre per year. The last land-use category is range or cattle grazing, which averages only $10 per acre per year. While increasing rapidly, more intensive greenhouse crops and ornamental nursery crops still comprise a small percentage of the total.

The military and other federal government activities contribute 125,000 to the population and nearly 1.5 billion dollars in annual expenditures in the state. The visitor industry brings to the state over 2 million people annually who leave with us $700 million. To keep up with this activity, a construction industry is completing $700 million worth of building annually.

These are some of the characteristics, advantages and constraints of the Hawaiian environment. Changes are coming fast and we in Hawaii are moving rapidly to accommodate these changes.

MODERATOR WARNER: Thank you, Dr. Bullock. Our next speaker was born and raised in Honolulu in a family which specialized in floriculture. He received his Bachelors and Masters degrees at the University of Hawaii and his Ph.D. at Cornell University. His field is in breeding and culture of ornamental plants, particularly in breeding anthuriums. You can witness the examples of his work on the table outside. Through his efforts the College of Agriculture has released several new anthurium cultivars of superior quality. He is chairman of the Department of Horticulture, University of Hawaii, and is eminently qualified to speak on the subject, "Hawaiian Ornamental Industries." Dr. Kamemoto:

HAWAIIAN ORNAMENTAL INDUSTRIES

H. KAMEMOTO

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Prior to the Second World War, the ornamental industries of Hawaii were limited to the local trade. The standard cut flowers — roses, carnations and gladioli — regularly graced our flower shops. Some chrysanthemums were grown but were insignificant because control of flowering was still unknown. Flowers such as asters, gerberas, marguerite daisy and zinnias were also available. Relatively few anthuriums, orchids, heliconias and other tropical ornamentals were seen. Landscape nurseries were few in number.

From around 1941, interest in tropical ornamentals expanded rapidly, both among hobbyists and commercial growers. The exposure of many of these ornamentals to servicemen stationed here, and the improvements in air transportation provided the initial impetus for the expansion of the export of ornamentals to continental United States.

In 1951, the University of Hawaii and the Floral Association of Hawaii co-sponsored the First Floral Clinic. Some mainland experts were invited including O. Ben Haley, Manager of Denver Wholesale Florists; Edward Goeppner of Podesta Baldocchi, San Francisco; James Sykora, Manager of Amling Co., Chicago; and John Dudley, President of the Society of American Florists. Many problems and possible solutions were discussed. The general conclusion reached was that the ornamental industries of Hawaii showed great promise for growth but that there were numerous problems which needed to be resolved.

Eighteen years later, in 1969, an industry-wide agricultural planning conference was held to prepare the State Agricultural Development Plan. The development of the plan was mandated by the 1968 State Legislature for the purpose of determining what the future holds for agriculture in the State of Hawaii. Ornamental horticulture was one of 14 enterprise or commodity groupings. The planning committee on ornamental horticulture was comprised of 13 industry representatives and three University personnel. It was noted that the ornamental horticulture industries were rapidly evolving from backyard operations to large-scale enterprises and that new technology was replacing the older practices. The committee expressed considerable optimism for the continued growth of the ornamental industries. The factors cited which favor this expression were:

1. Hawaii has the highest per capita consumption of ornamental plants and flowers in the United States. With the projected increase in population, including tourists, the total value of the ornamental industries is expected to increase proportionately.
2. The exotic nature of Hawaii's products such as anthuriums, orchids and other tropical flowers has created a demand for these products on the mainland market. With improvements in jet transport, Hawaiian floral and plant products can be placed on the mainland market in a matter of hours.
3. Ornamentals are intensive crops yielding high returns per unit area; consequently, the competition for large parcels of land is not as intense as with other agricultural crops.
4. Urban development, resort development, highway construction, and the national interest in the beautification of man's environment place the ornamental industries in a favorable position for substantial growth.

VALUE OF ORNAMENTAL INDUSTRIES

The census figures for 1949 placed the wholesale value of ornamentals at $1,274,000. The value rose to $1,958,000 in 1959, and to $4,022,000 in 1969. The value for 1971 was $4,484,000. The actual value would probably be much higher than the census figures indicate because many part-time or backyard operations are involved. The annual growth recorded has been about 10 percent. Another interesting statistic is the relatively high percentage of export sales. In 1971, over half of the total sales of ornamentals comprised out-of-state shipments.

ANTHURIUM

With the foregoing as an introduction to the ornamental industries of Hawaii, let us now look into the components or commodity groupings.

Anthuriums, the most important cut flower crop of Hawaii, have experienced a phenomenal growth within the past 10 years. In 1959, the value was $216,000. In the early sixties, large-scale operations were initiated. In 10 years, the value had risen to $1,019,000, which represented an average growth of 20% per year for the ten-year period. During the last couple of years, growth has leveled off to about 10% per year. In 1969, anthuriums represented about 60% of out-of-state shipment sales.

At the present time, there are approximately 200 farms and about 230 acres in cultivation. About 90% of anthuriums are grown on the island of Hawaii.

Anthuriums cannot tolerate full sunlight and, therefore, shading is required. Generally about 75% shade is provided through various means. Anthuriums can be grown under trees, tree fern fronds, lath or saran.

Anthurium andraeanum is native of Colombia. It was first introduced into Hawaii from England in 1889. During the late 1930's, interest in anthuriums began to mount, and today, Hawaii has developed into the major anthurium production center of the world.

Anthuriums are propagated from suckers or cuttings. Because a single lead produces about six leaves per year, which means six nodes or six potential growths per year, vegetative multiplication is slow. Mist propagation of two- to three-leaf terminal cuttings is effective. Successful meristem or tissue culture should be a boon in increasing new cultivars, but unfortunately this mode of propagation is still in the experimental stage.

For the production of new cultivars, sexual propagation is necessary. Pollination is effected by grasping the pollen-laden spadix with fingers and then rubbing the pollen onto the stigmas of other flowers. Six months are required from pollination to fruit maturity. After separating the pulp, the seed is planted on finely shredded tree-fern fiber. In six months, the seedlings are transplanted into flats and six months later are moved into individual pots or in ground beds. Some seedlings will begin to flower in 15 months from seedage, but usually two years must be allowed for the entire progeny to flower.

The important commercial cultivars are Ozaki, Kaumana, Kozohara and Nitta. Some of the University releases are Marian Seefurth, Anuenue and Manoa Mist.

ORCHIDS

Hawaii is well known as a center for orchid hybridization, and many fine hybrids have found their way into international markets. The following sales were generated in 1970: *Vanda* 'Miss Joaquim' — $565,000; cattleyas — $52,800; dendrobiums — $60,800; and cymbidiums — $116,000.

Flowers of *Vanda* 'Miss Joaquim' are used primarily for leis. About 50 acres are presently in production. It is easy to propagate from cuttings. Increase in plantings can be easily accomplished, since considerable acreage is in production.

In the Volcano region on the island of Hawaii, cymbidium production is increasing. Plants grow well, and flowers are produced a couple of months ahead of the normal flowering time in California. Meristem culture has made possible the commercial cropping of superior clones from the standpoint of productivity, seasonality and quality. Practically all of the flowers produced in Hawaii are marketed on the mainland.

Dendrobium orchids are beginning to receive increased attention. Flowers come in assorted colors and shapes. The flower sprays have a long vase life. Plants are productive, and flowers are easy to pack and ship. The successful meristem culture technique developed for dendrobiums in Dr. Sagawa's laboratory makes possible the rapid increase of superior clones for commercial cropping.

The dendrobium industry is still in its infancy, emerging from hobby or backyard status to commercial enterprises. There are signs of increased activity to explore the export market.

The University of Hawaii has been evaluating dendrobium clones as well as producing new clones through breeding in order to promote the development of the industry. It has mericloned and released *Dendrobium* 'Jaquelyn Thomas' (0580), D. 'Neo Hawaii' (Y972), and D. 'Lady Hay', and recently released a tetraploid seedling strain of D. 'Jaquelyn Thomas' (UH44).

FLOWERS AND FOLIAGES

Hawaii grows the standard cut flowers — roses, carnations, chrysanthemums and gladioli — for the local market. Because these are well known to all ornamental horticulturists, I will not delve into these except to mention that in Hawaii carnations are grown primarily for their flower heads for use in leis, rather than for cut stems.

A new potential export crop for Hawaii is ornamental proteas. Experiments initiated in 1963 and expanded by Dr. Parvin at our Kula Research Station on Maui have revealed their desirable qualities as cut flowers. These proteas are exotic, have a long vase life, and flower ahead of those produced in California. *Leucospermum cordifolium*, the Pincushion Protea, appears to be most promising, but others like *Protea nerifolium*, the Pink Mink, and the White Mink, and *Protea grandiceps*, the Princess Protea, also have exciting possibilities.

Heliconias, gingers and ti leaves provide livelihood for some of our growers. Also, potted flowering plants such as chrysanthemums, poinsettias, bougainvilleas and azaleas are produced for local sales.

FOLIAGE PLANTS

Foliage plants appear to offer tremendous potentials for our export market. New and expanded developments are in evidence. Expansion of plantings for stock material, construction of greenhouses to produce certified plants, improvement in mass propagation, and development of artificial soil mixes have been receiving appropriate attention. The ti, *Cordyline terminalis*, both normal size and dwarf, dracaenas, dieffenbachias and dwarf brassaia are but a few of the many tropical ornamentals which can be exploited.

LANDSCAPING AND TURF

Turf and landscape services are integral parts of the ornamental industries, but their actual monetary value is difficult to assess. Both of these areas are expanding rapidly, for they are closely related to urban and resort developments, and improvements of parks and recreation facilities. Also, they are in complete consonance with our national efforts to enhance our environment.

CONCLUSION

The ornamental industries of Hawaii are now undergoing rapid evolution and expansion. They are evolving from essentially hobby, backyard and family operations to large-scale commercial enterprises, and are beginning to attract young men and new capital. The recent announcements of the establishment of the Kohala Nurseries and Orchids Pacifica at Kohala on the island of Hawaii are positive signs of the viability of ornamental horticulture. We can certainly look forward with optimism to the growth of the ornamental industries, and hope that the 1989 goal of 76-million-dollar ornamental industries set in the State Agricultural Plan will become a reality.

BOB WARNER: Thank you very much, Dr. Kamemoto; that was excellent. I am going to call next on another Oahu-born Hawaiian. He got his Bachelors and Masters degrees in plant physiology at the University of Hawaii. He grew up with the macadamia industry at the Royal Macadamia Hawaiian Nut Company and worked later at the C. Brewers Hawaiian Orchards. In recent years he has been with the College of Tropical Agriculture, working with nutrition and pollination of macadamia as well as on mechanical harvesting of guavas. He is a resourceful and enthusiastic horticulturist and is going to speak on "Hawaii — Land of Exotic Fruits." Gordon Shigeura. Gordon:

HAWAII, LAND OF EXOTIC FRUITS AND NUTS

GORDON T. SHIGEURA

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INTRODUCTION

Most visitors to the Islands do not realize the Hawaiian Islands are made up of a series of islands in the North Pacific anchored in the southwest by our Big Island (Hawaii) and extending 2000 miles in the northwesterly direction toward Japan with Wake Island at the very tip of the chain. Excepting for the 12 major islands in the southwestern end of this chain and in the vicinity of Honolulu, the other islands are coral atolls, reefs or sand bars on top of volcanic mountain peaks arising from the ocean floor.

Unlike the shifting land masses of Europe, Africa, and the Eastern Americas drifting apart in the Atlantic Ocean, the ocean floor of the Pacific has been relatively stable for millions of years. Thus, the volcanically created Hawaiian Islands have been isolated from the greater land masses of Asia and the Americas for millions of years. This isolation resulted in an endemic plant population in Hawaii found nowhere else in the world. More than 85% of the plant species found in Hawaii are endemic. Others came to these shores in pre-historic time either floating on the surface of the ocean, carried by migrating birds, or were windblown. Still others were brought in as food by the seafaring Polynesians as they emigrated to these shores, and by later explorers and adventurers who came since Captain Cook discovered the islands in 1779. One of the most prominent horticulturists during this time was Don Francisco de paula Marin, who settled in the islands in 1791. Unfortunately, in spite of the huge population of endemic plant species, there is no endemic fruit or nut species in Hawaii which is commercially important. The early Hawaiians brought in with them edible crops like taro, breadfruit, coconut, banana, sweet potato, sugar cane, papaya and kukui nut. Don Marin is given credit for having introduced, among other things, coffee, guava, pineapple, avocado, tamarind, mango, and cactus (panini). The Kona orange was introduced in 1792 to the Kona area of Hawaii. During the "Gold Rush" in California, the Kona oranges were even exported to California. The Chinese brought the litchi in 1873 and the macadamia was introduced by the Jordan brothers in 1888 from Australia.

The following list gives the common and scientific names and the source of origin of some fruits and nuts grown in Hawaii, and are categorized as: I. Plantation crops; II. Semi-commercial or backyard crops; III. Endemic plants; and IV. Other exotics.

Common name	Scientific name	Source
I. Plantation Crops —		
1. Avocado	*Persea americana*	Trop. America
2. Banana	*Musa sp.*	Trop. America
3. Citrus		S. E. Asia
a) Grapefruit	*Citrus paradisii*	
b) Lemon	*Citrus limon*	
c) Lime	*Citrus aurantifolia*	
d) Orange	*Citrus sinensis*	
e) Tangerine	*Citrus reticulata*	
4. Coffee	*Coffea arabica*	Trop. Africa
5. Guava	*Psidium guajava*	Trop. America
6. Macadamia	*Macadamia integrifolia*	Australia
7. Papaya	*Carica papaya*	Trop. America
8. Passion fruit	*Passiflora edulis*	America
9. Pineapple	*Ananas comosus*	Brazil
II. Semi-commercial or backyard crops —		
1. Breadfruit	*Artocarpus incisus* [*A. altilus*]	Malaysia
2. Cherimoya	*Annona cherimola*	Trop. America
3. Coconut	*Cocos nucifera*	Shores of the Indian Ocean
4. Litchi	*Litchi chinensis*	S. China
5. Mango	*Mangifera indica*	India
6. Methley plum	*Prunus cerasifera*	S. Africa
7. Persimmon	*Diospyros kaki*	E. Asia
8. Poha	*Physalis peruviana*	S. America
III. Endemic fruits —		
1. 'Akala (berry)	*Rubus hawaiienis*	Hawaii
'Akala	*Rubus macraei*	Hawaii
2. 'Ohelo (berry)	*Vaccinium reticulatum*	Hawaii
IV. Other exotics —		
1. Barbados cherry	*Malpighia glabra*	Central America
2. Blackberry	*Rubus sp.*	S. E. Asia
3. Cacao (Cocoa)	*Theobroma cacao*	Trop. regions
4. Cactus	*Opuntia megacantha*	Mexico
5. Carambola	*Averrhoa carambola*	Malaysia
6. Cashew	*Anacardium occidentale*	Trop. America
7. Egg fruit	*Lucuma nervosa*	South America
8. Fig	*Ficus carica*	Asia Minor, S. W.
9. Grape	*Vitis* sp.	S. E. Europe to India
10. Hala	*Pandanus odoratissimus*	Isles of Pacific, Australia, S. Asia
11. Jaboticaba	*Eugenia cauliflora*	India, Malaya
12. Jak fruit	*Artocarpus heterophyllus*	S. India, Malaysia
13. Java plum	*Eugenia cuminii*	India, Malaya
14. Kukui	*Aleurites moluccana*	Malaysia
15. Loquat	*Eriobotrya japonica*	Central China
16. Guiana chestnut	*Pachira aquatica*	Trop. S. America
17. Mangosteen	*Garcinia mangostana*	Malaya
18. Monstera	*Monstera deliciosa*	Central America

19. Mountain apple	*Eugenia malaccensis*	India, Malaya
20. Mulberry	*Morus nigra*	Asia Minor, Persia
21. Naranjilla	*Solanum quitoense*	Trop. & temperate regions
22. Rose apple	*Eugenia jambos*	India, Malaya
23. Roselle	*Hibiscus sabdariffa*	Trop. America
24. Sapodilla, chicle	*Achras zapota*	Central America
25. Soursop	*Annona muricata*	Trop. America
26. Strawberry	*Fragaria sp.*	Europe
27. Strawberry guava	*Psidium cattleianum*	Brazil
28. Surinam cherry	*Eugenia uniflora*	India Malaya
29. Tamarind	*Tamarindus indica*	Trop. Africa, Trop. Asia
30. Watermelon	*Citrullus vulgaris*	Trop. Africa

MODERATOR WARNER: Thank you very much. Our last speaker this morning will be Dr. William S. Stewart. He has a PhD from Cal Tech as a plant physiologist. He has worked as a plant physiologist in a number of areas in citrus and has spent three years here in Hawaii with the Pineapple Research Institute. He was called back to Riverside to be chairman of the Horticulture Department in the U. C. Citrus Experiment Station. Later he was Director of the Los Angeles City and County Arboretum. He is now Director of the Pacific Tropical Botanic Garden in Kauai. Today he is going to share some of his experiences with us.

TROPICAL PLANTS ADAPTABLE TO MAINLAND LANDSCAPES

WILLIAM S. STEWART

Pacific Tropical Botanical Garden
Lawai, Kauai, Hawaii

As you will discover here in Hawaii, the "tropics" are not always just hot, humid, lands that abound in luxuriant vegetation, as in lowland equatorial rain forests, but may have a wide range of climates. For example, there are large areas within the tropics that are deserts with desert plants or, at higher elevations with temperate climates and dry forests; and, going still higher, areas with winter snow, alpine plants and, here in Hawaii, even skiing on Mauna Kea on the island of Hawaii.

In Hawaii, the 50th state of our United States, all of these conditions are represented and all are conveniently accessible. For these reasons it is important to recognize the climatic zone within the tropics where a plant is growing to evaluate where on the mainland it might be adaptable. On the mainland under

19. Mountain apple	*Eugenia malaccensis*	India, Malaya
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In Hawaii, the 50th state of our United States, all of these conditions are represented and all are conveniently accessible. For these reasons it is important to recognize the climatic zone within the tropics where a plant is growing to evaluate where on the mainland it might be adaptable. On the mainland under indoor or conservatory conditions almost any tropical species can be grown if ingenuity is used to modify the environment. An excellent reference for this field of work is Exotica 3, "A Guide to Care of Tropical Plants Indoors."

The greatest success outdoors on the mainland with tropical plants will occur when they are grown under conditions that are most similar to their habitat in the tropics (4, 5, 6). This means that the subtropical, mainland, areas offer the most favorable conditions. There can be many surprises as to the adaptability of tropical plants for outdoor mainland gardening and, rather than theorize — if there is no prior information — it is wise to make a test planting. As you all know, even within your own small garden or yard there are many microclimates.

Lists of tropical plants adaptable to mainland outdoor landscapes are available in the landscape horticultural literature. One of the most useful of these is Hoyt's "Reference Handbook of Check Lists for Ornamental Plants of Subtropical Regions" (3). Here are listed — for "Tropical Effects" — 33 species of trees, 48 different kinds of shrubs, 28 vines, and 55 herbaceous plants. He also lists tropical plants for humid regions on the mainland as, for example, the gulf coast and bayou areas with high water tables — and another category is designated, "Borderline South." His opening sentence to these lists states, "This is where one approaches the tropics to find scant literature — and less instruction — in an almost untouched field of ornamental horticulture"; and later he says: "These tropical plants, as used northerly into subtropical regions, should not be hurried out of the unaccustomed winter chill. Do not fertilize or otherwise stimulate them until late spring or early summer — wait for some sign of interest."

Another source of information for tropical plants in subtropical regions is "Sunset Magazine" and the "Western Garden Book" by the editors of Sunset Magazine. The yearly indexes to Sunset Magazine have one section on "Subtropical and Tropical Plants." Their garden book names 67 plants with "dramatic leaves" to add a tropical feeling to the garden.

Most of the tropical plants cited in both Hoyt and the Sunset books for mainland landscapes are found around the world throughout the low, humid tropics. These are, to mention a few: palms, *Brassaia*, *Papaya*, *Ficus*, *Strelitzia*, *Dracaena*, *Erythrina*, banana, bamboo, *Gunnera*, *Cycas*, *Hibiscus*, *Ixora*, *Tetrapanax*, *Macadamia*, *Plumeria*, *Thevetia*, *Tibouchina*, *Beaumontia*, *Bougainvillea*, *Monstera*, *Fatshedera*, *Hoya*, *Philodendron*, *Petrea*, and such herbaceous material as *Anthurium*, *Begonia*, *Clivia*, *Kalanchoe*, *Peperomia*, *Sansevieria*, *Spathophyllum*, and so on — and, of course orchids. Species of most of these genera are available from nurseries.

Many of these tropicals lend themselves to bonsai and, as container plants, create much interest in addition to the more traditional temperate climate bonsai plants (8).

In addition to these more common, usual, "pan-tropical" species there are, however, some plants of our native Hawaiian flora that are absolutely unique and which have never been used in mainland subtropical landscaping. First a little background about our native plants.

Because of the isolation of the Hawaiian Islands by vast ocean areas many of those plants that finally made their way and established themselves here in the early times found an area ideally suited to their growth. Lacking their former natural enemies, some of the characteristics required for survival in their original environment were unnecessary. Other features gave the plants survival advantages in Hawaii and were preserved by natural selection while certain mainland characteristics, such as thorniness, were reduced or eliminated altogether. The Hawaiian flora presents a veritable laboratory for seeing evolution in action with the expression and survival of new, unique, species found nowhere else in the world. These are called endemic species. Dr. Harold St. John in his forthcoming book, "List and Summary of the Flowering Plants of the Hawaiian Island", being published by the Pacific Tropical Botanical Garden (7), points out that endemism in the 2,600 native species is 97.3%! The exotic flora (introduced plants) adds 5,000 species for a total count of 7,600 kinds of plants in the relatively small area that is Hawaii.

Growing these plants on the mainland must be considered as experimental. However, eleven different Hawaiian native plant species have been reported by Sherwin Carlquist (2) in the Pacific Tropical Botanical Garden's Bulletin, Vo. II, No. 3, as having been successfully grown in California.

Among many of the Hawaiian plants I suggest as worthy of trial plantings on the mainland are the following:

1. *Metrosideros collina* subsp. *polymorpha*. For mainland subtropical landscapes where soil is on the acid side *Metrosideros collina* subsp. *polymorpha* may be an interesting addition. In Hawaii it is known as ohia-lehua, or Lehua. It is found on all of the islands between elevations of 1000 to 9000 feet. It is extremely variable as recognized by its botanical name, *polymorpha*. On the island of Hawaii it may be seen as trees nearly 100 feet tall while in the Alakai Swamp on Kauai small plants bloom that are only 10 inches high. In addition to the conspicuous flowers with brilliant red stamens, the young leaves also are an attractive reddish color. The 'ohia-lehua' is well-known in Hawaiian songs, legends,

and mythology. Very appropriately the Hawaiians made the red 'ohia-lehua' groves sacred to Pele, goddess of volcanoes. One other story about 'ohia-lehua' is that if the flower is plucked on the way to the mountains it will rain. This is a fairly safe bet since in many areas where the 'ohia-lehua' grows it rains very frequently.

2. *Freycinetia arborea.* The 'ie'ie (its Hawaiian name) is a strong climbing plant with branches every several feet. Each lateral terminates in leaf clusters with the leaves being about an inch wide to three feet long. From the center of each cluster a gaudy scarlet red inflorescence is formed up to six or seven inches in diameter. 'Ie'ie is found at elevations up to 3500 feet and was considered a sacred plant by the early Hawaiians. They tell the following story: Laukaieie (leaf of the 'ie'ie), was a beautiful maiden cared for by the goddess Hina. Laukaieie was given to a lonely couple, and her playmates and servants were the birds and flowers. She married a bird man, and soon the time came for her to change form. Her eyes flashed fire, leaves sprouted on her tender body, and her husband carried her to the woods with the words, "You cannot stand alone. Climb trees! Twine your long leaves around them. Let your blazing red flowers shine between the leaves like eyes of fire! Give your beauty to all the 'ohi'a trees of the forest." And so the maiden became the 'ie'ie vine(5).

3. *Acacia koa.* Koa is one of the most common of the Hawaiian forest trees. Probably depending on both its environment and genetic strains it may be a tall monarch of the forest as on the island of Hawaii where at elevations of 1500 to 4000 feet it may be over 50 feet in height; or in other less favorable sites, it may be a twisting smaller tree to twenty feet whose branches form an eye intriguing, intricate pattern. It is this latter form that may be of particular interest for mainland landscaping, as it would provide another source for a contrast in stem texture and pattern. The so-called "leaves" (actually broad petioles functioning as leaves) are smooth, stiff, and have an interesting crescent or sickle shape. The flowers are small puff balls of pale yellow and are not spectacular. It is the intricate growth habit of the stems that make this species a candidate for mainland landscape test planting. It also is fairly drought resistant. Koa may be propagated readily by seed.

4. *Erythrina sandwicensis.* The coral tree or flame tree is found in the drier parts of nearly all of the islands. Most

other species of this genus have red flowers; the Hawaiian species, however, is unique in having flowers varying by tree to tree from a chartreuse green to orange. It is readily propagated by seed or cuttings. The Hawaiian name for this tree is wiliwili, so the harbor on Kauai named Nawiliwili means "the Erythrinas."

5. *Kokia kauaienis.* This tree at flowering time is very spectacular with its brilliant canopy of orange-red blooms borne at the branch tips. It is usually in full bloom in June or July and, if it proves hardy on the mainland, would offer real horticultural possibilities. It is closely related to the hibiscus being a member of the Malvaceae. It is found only on Kauai and even there is not very abundant. It is propagated by seed.
6. *Hibiscus rockii.* A potential hibiscus ground cover seldom seen as growing much above 2 1/2 feet in height and, when grown on banks, it is usually much lower and more prostrate. Flowers are a clear lemon yellow. This is one of the 300 endangered native species and is from Kauai. Hibiscus is the official state flower of Hawaii.
7. *Hibiscus waimeae.* On Kauai, where this is a vigorous grower, there are some very old plants with main stems or "trunks" ten to twelve inches or more in diameter. It grows in the wild at about 3,500 feet elevation. At sea level in gardens on Kauai it produces large shrubs in a short time. In addition to the red staminodal column contrasting with the pure white petals, one of the very nice features of this hibiscus is the delightful fragrance of its flowers. The perfume is not as strong as gardenia or plumeria but is most pleasant.
8. *Hibiscus saintjohnianus.* The special orange color of the petals of this medium-sized flower is its particular feature. It does not seem to grow as vigorously as *Hibiscus waimeae* but possibly may be more drought tolerant. On Kauai it grows at an elevation of about 1,800 feet on a ridge west of Kokee in a rainfall area of about 25 inches per year.
9. *Dianella sandwicensis.* If this botanical name for an endemic species bothers you, you may prefer the Hawaiian name of 'uki'uki. The interesting feature of this fairly hardy, grass-leaved member of the lily family is the conspicuous bright blue berries which once were used by the Hawaiians to dye tapa. In growth habit it may be suggestive of a two to three foot high version of Mondo grass [*Ophiopogon japonicus*] although the leaves are not as dark green.

10. *Wilkesia gymnoxiphium*, or if you prefer the Hawaiian name — iliau. It is closely related to the famous silversword plant [*Argyroxiphium sandwicense*] of Haleakala. It also is a member of the Compositae family and quite closely related to the tarweeds of California. The interesting story of evolution of the silverswords and their relatives is given in Carlquist's fascinating book, "Hawaii, A Natural History" (1). While silverswords and greenswords are found only on Maui and Hawaii, their counterpart — the iliau, is found only on Kauai. It grows as a perennial and is suggested for mainland landscapes as it is found in the drier portions of Kauai. It has a curious growth habit with a rosette of green, almost sword-like, leaves at the top of a spear-like stem extending above the surrounding vegetation. Then the flower stalk grows out of the rosette and, in appearance, resembles that of yucca but with yellow flowers instead of white. It has been grown successfully from seeds in gardens on Kauai and in Santa Barbara.

    Another iliau species, more recently discovered, is *Wilkesia hobdyi*. It, too, has particular landscape potential. It is almost as if it were a scaled-down version of the iliau so that instead of a stem 3 to 4 feet in height, with a flower stalk of about three feet, this new species of iliau has a shorter branching stem of about 2 feet and a flower stalk of another two feet. No garden experience has been obtained with *Wilkesia hobdyi* but it seems to me it has as much interest for mainland gardening as the larger iliau. Both of these species offer a new dimension for landscaping.

In summation: There are many tropical plants adaptable to subtropical mainland landscaping, particularly if special micro-climatic locations are sought for their culture. References to lists of these tropical plants are given. In addition, ten of the many native Hawaiian plants with horticultural potential are suggested for trial plantings. The native flora as yet has not been used for mainland landscaping and offers real possibilities for exciting new landscaping materials. Horticultural interest in the native flora also will serve to make laymen and plantsmen alike aware of these treasures of Hawaii and should help to preserve many of the nearly 300 endangered species of our rare and fragile native Hawaiian flora.

I would now like to show you a brief film that will give you a feeling for some of the more remote and seldom seen areas on Kauai where the native plants just mentioned are found growing. Kauai also is the location of the main garden of the Pacific Tropical Botanical Garden.

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MODERATOR WARNER: We certainly appreciate your talk, Bill. Thank you very much.

Saturday Morning Session, August 11, 1973

GEORGE OKI: I think one of the most fascinating things about plant propagation is the subject of tissue culture. In 1967 I had the pleasure of visiting Hawaii and the University of Hawaii's Plant Science Department and had the occasion to go through their tissue culture laboratory and I was immensely impressed. Of all the things happening in our world today, I think this is one of the most fascinating subjects.

It is my pleasure at this time to introduce Richard Maire, our past President, who will be moderator for this session on tissue culture. Dick:

RICHARD MAIRE: Thank you, George. The speakers that we're going to have in this session are outstanding in the field of propagation. I remember one of the first IPPS meetings that I attended fascinated me the most. I have never forgotten a talk by Dr. Nitsch from Paris on tissue culture. At that time it seemed almost like something in the Twenty-first century, way beyond our possible realm of using. Now we have within the group at the University of California at Riverside, one of the leading educators and research people in the field of tissue culture, Dr. Toshio Murashige. Toshio has been on the UC campus at Riverside since 1964. He came there from the University of Hawaii. Tosh, you have held tissue culture seminars and lectures for the nurserymen and many of them are practicing tissue culture in their own labs and nurseries; this is all due to your fine work, so come on up and tell us about what is new in tissue culture.[1]

[1] Dr. Toshio Murashige and Ms. Jeanne Jones, U.C. Staff Research Associate, discussed their work in the field of tissue culture.

TISSUE CULTURE OF BROMELIADS[1]

MARION O. MAPES

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Abstract. Numerous pineapple [*Ananas comosus* (L.) Merr. variety Smooth Cayenne] plantlets and protocorm-like bodies were produced from shoot tips when a combination of orchid shoot tip technique and callus method for organogenesis was applied sequentially and in correct order. Initially, explants from shoot tip, stem and root tips failed to grow in 42 different media. Meristematic protocorm-like bodies and plantlets were produced from pre-shaken shoot tip cultures in Murashige and Skoog's basal medium plus adenosine, 30 ppm, or adenine, 20 ppm. Ornamental bromeliads were more recalcitrant in culture, but, with slight modifications of cultural media, the same procedures appeared applicable. *Portea petropolipana* and *Guzmania* sp. have shown positive response and a wild pineapple, *Ananas erectifolius*, L.B. Smith has produced several lateral shoots and protocorm-like bodies.

REVIEW OF LITERATURE

The bromeliads, in recent years, have gained popularity as indoor and rock garden ornamentals. They range in appearance from the dull gray *Tillandsia usneoides* (Spanish moss of Florida) to the brilliantly colored flowering aechmeas, billbergias and vriesias. They belong to the pineapple family, Bromeliaceae.

In most bromeliaceous plants, seeds are produced when pollinated but among the best horticultural varieties, only 1 or 2% of the seedlings come true (observations forwarded by Howard Yamamoto, Honolulu bromeliad nurseryman). Then there are other plants like the commercial pinneapple (*Ananas*

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comosus] which do not form seeds. Asexual propagation is by lateral (axillary) shoots or offsets which develop on the stem below the inflorescence axis but these are sometimes limited in number to only a single lateral shoot per plant. The pineapple is unusual in that it produces several planting materials including the *crown*, which surmounts the fruit, and lateral shoots called the *slip*, *hapa* and *sucker*, depending on their position on the stem. Multi-propagation on a commercial scale is made from stump sections, based on early works of Walters (1932), MacLuskie (1939), Skoog (1939 unpublished data) and Siu (1941), and from stem-leaf base techniques subsequently developed by researchers H. Clark, B. Krauss and K. Kerns of the Pineapple Research Institute of Hawaii (unpublished data). Both procedures depend on stimulating the lateral bud, which normally lies dormant at the axil of a leaf, to grow and develop into a shoot. The maximum number of shoots obtained by these methods was 80 per plant (Kerns, unpublished data). When numerous plants of desirable quality are needed, therefore, the utilization of the tissue culture technique appears highly advantageous. Its role in plant multiplication is well known.

Since the principles and aseptic procedures of culturing plant tissues and organs for proliferation of new tissues and organogenesis have been reported earlier to this Society by Murashige (5) and Marston (2), only a brief description of the procedures adapted for culturing bromeliaceous plants will be given.

MATERIALS AND METHODS

Preliminary cultural tests were carried out on September 6, 1970, with 12 rooted crowns of pineapple, *Ananas comosus* (L.) Merr., cv. Smooth Cayenne. Each crown was cut into longitudinal halves, and the shoot apex, the subapical stem tissues, and root tips were cultured aseptically into 26 different media, as shown in Table 1. Solid media of Murashige and Skoog's (6) basal medium (M) and White's (13) basal medium (W) were used with the addition of growth promoting substances to induce callus formation in the tissues. Treatments 1 and 2, as shown, were inoculated with duplicate halves from crown No. 1. Treatments 3 and 4 were from crown #2, etc. Crown No. 12, however, was cut longitudinally twice (quartered) so that 4 shoot tip regions, 4 stem tissues and root tips were available for culturing (Treatments 23-26). The media were poured into the snap-on type of Falcon plastic dishes and one each of the three culturing materials mentioned above was placed on each plate.

After 10 weeks (November 16, 1970) when none of the tissues showed signs of new growth or callus formation, the shoot tip tissues were transferred to other media (shown in Table 2)

Table 1. Growth of pineapple explants from crown shoot tip, sub-apical stem tissue, and root tips in Falcon agar plates with two basal media and growth regulators, with (30 ppm) and without adenosine.

Treatment No	Source Crown No.	Cultural material	Culture Media	Results after 10 weeks
1	1	Shoot tip,	M + CM 10% (V/V) = MCM	No further
2	1	stem and	W + CM 10% (V/V) = MCM	growth in all
3	2	root tip	MCM + NAA 2.5 ppm	treatments.
4	2	on each	WCM + NAA 2.5 ppm	Explant
5	3	treatment	MCM + NAA 5.0	surface
6	3	medium	WCM + NAA 5.0	brown,
7	4		MCM + IAA .5	internal
8	4		WCM + IAA .5	tissues
9	5		MCM + 2,4-D 2.5	white.
10	5		WCM + 2,4-D 2.5	Roots
11	6		MCM + 2,4-D 5.0	white.
12	6		WCM + 2,4-D 5.0	
13	7		Treatment 1 + adenosine	
14	7		Treatment 2 + adenosine	
15	8		Treatment 3 + adenosine	
16	8		Treatment 4 + adenosine	
17	9		Treatment 5 + adenosine	
18	9		Treatment 6 + adenosine	
19	10		Treatment 7 + adenosine	
20	10		Treatment 8 + adenosine	
21	11		Treatment 9 + adenosine	
22	11		Treatment 10 + adenosine	
23	12		Treatment 11 + adenosine	
24	12		Treatment 12 + adenosine	
25	12		MCM + 2,4-D 5 ppm + adenosine	
26	12		MCM + 2,4-D 5 ppm + adenine	

Abbreviations used: Basal media M = Murashige and Skoog's; W = White's.
IAA = indoleacetic acid; NAA = naphthaleneacetic acid;
2, 4-D = 2, 4-dichlorophenoxyacetic acid; ppm = parts per million.
pH of basal media: pH 5.8.

chiefly to induce shoot formation with kinetin or callus formation with coconut milk and 2,4-dichlorophenoxyacetic acid (2,4-D). Both M and W basal media were used and compared. After 2 months lateral shoots appeared in three of the treatments (No.s 29, 34 and 50, indicated with asterisks in Table 2). Two of the treatments (29 and 34) contained kinetin at 10 ppm and one (34) contained, in addition, an auxin, naphthalene-acetic acid (NAA), at 2.5 ppm. Treatment 50 contained coconut milk, 10% by volume, + 2,4-D, 5 ppm + adenine, 20 ppm. The development of the shoots in these media might have been due to chance only or to other factors including the stage of development of bud primordia at transfer, sequential effects from prior treatment (10), etc., but the significant fact was that these buds did emerge and developed into shoots.

Table 2. Subcultures of pineapple shoot tip tissues from Falcon agar plates (Table 1).

Treatment No.	Source	Culture Media	Results
27	Trt 1 (Table 1)	M basal medium = M	No further
28	Trt 2 (Table 1)	W basal medium = W	
*29	Trt 3 (Table 1)	M + kinetin 10 ppm	growth
30	Trt 4 (Table 1)	W + kinetin 10 ppm	
31	Trt 5 (Table 1)	M + kinetin 20	except in
32	Trt 6 (Table 1)	W + kinetin 20	
33	Trt 7 (Table 1)	M + kin. 10 + NAA 2.5ppm	treatments
*34	Trt 8 (Table 1)	W + kin. 10 + NAA 2.5ppm	
35	Trt 9 (Table 1)	M + kin. 10 + NAA 5.0	29, 34 and
36	Trt 10 (Table 1)	W + kin. 10 + NAA 5.0	
37	Trt 11 (Table 1)	M + kin. 20 + NAA 2.5	50 with
38	Trt 12 (Table 1)	M + kin 10 + adenosine	
39	Trt 13 (Table 1)	W + kin. 10 + adenosine	lateral
40	Trt 14 (Table 1)	M + kin. + NAA 2.5 + adenosine	
41	Trt 15 (Table 1)	W + kin. + NAA 2.5 + adenosine	buds
42	Trt 17 (Table 1)	M + kin. + NAA 5.0 + adenosine	
43	Trt 19 (Table 1)	MCM + 2,4-D 5 + adenine	
44	Trt 20 (Table 1)	MCM + 2,4-D 5 + adenine	
45	Trt 21 (Table 1)	WCM + 2,4-D 2.5 + adenosine	
46	Trt 22 (Table 1)	MCM + 2,4-D 5.0 + adenosine	
47	Trt 23 (Table 1)	WCM + 2,4-D 5.0 + adenosine	
48	Trt 24 (Table 1)	MCM + 2,4-D 5.0 + adenosine	
49	Trt 25 (Table 1)	MCM + 2,4 D 5.0 + adenosine	
*50	Trt 26 (Table 1)	MCM + 2,4-D 5.00 + adenine	

*Emergence of lateral bud in culture.
See Table 1 for the explanation of abbreviations.

When these aseptically grown shoots became available for study, a switch to an approach used in orchid culture and termed "mericloning" (3, 4, 14) seemed appropriate. One of the shoots, however, was first transferred to M + coconut milk, 10% by volume, agar medium (MCM). It continued to grow to a size suitable for transplanting into soil and greenhouse conditions. No lateral shoots or calluses were formed and thus there was no increase in plant number. The two remaining shoots were treated like orchid shoot tips, employing the method described by Sagawa, et al. (7). They were cultured in modified Knudson's liquid medium which was supplemented with coconut milk, 20% by volume, and adenine, 20 ppm (designated KCM20). The medium was prepared in 50 ml. Erlenmeyer flasks with 15 ml. of the medium in each flask. The flasks were shaken on a gyrorotary shaker under continous light for several weeks. One of the shoots was lost from bacterial contamination; the remaining shoot tip culture from Treatment 50 responded remarkably well.

RESULTS

A typical nodular growth associated with orchid shoot tip cultures appeared on the cut end of the shoot in 8 weeks while on the shaker. The shoot tip was then transferred to an agar tube of M + adenosine, 30 ppm. A medium with coconut milk was avoided since it was good for plant growth but not for callus formation in pineapple tissues. Adenosine was found to be beneficial in growing several of the cultures under study. Fortunately, this medium helped to trigger off the production of meristematic globular bodies (Fig. 1) which were reminiscent of protocorms in orchid cultures. Each globular body, here termed a protocorm-like body, contained a shoot apex which subsequently developed into a shoot. Numerous plantlets developed in the older part of the culture while the meristematic protocorm-like bodies were formed at the advancing margins. Pineapple plantlets in various stages of development are shown in Figures 2 and 3.

In recent studies, adenine, 20 ppm, was substituted for adenosine and produced similar results (Fig. 4).

Some of the protocorm-like meristematic cultures were transferred to various liquid media in T-shaped tubes and rotated at 1 rpm, as carried out by Dr. F. C. Steward and associates at Cornell University (11). Abundant plantlets were obtained in a liquid medium of Schenk and Hildebrandt (9) and in modified basal medium of Murashige and Skoog. Effects of pH, sucrose concentrations and growth regulators are under study.

When it appeared feasible to produce numerous pineapple plantlets in culture, the ornamental bromeliads were also tried but with limited success. The recalcitrant ornamental bromeliad tissues seem to require additional stimulants for growth. The cultures under investigation are: *Viesia* spp., *Neoregelia* hybrid, *Aechmea racine* and *Guzmania* sp. from H. Yamamoto and *Ananas erectifolius* (a wild pineapple), *Portea petropolipana* and *Bromelia* sp. from Pineapple Research Institute of Hawaii. *Portea and Guzmania* cultures look promising with positive response in modified Knudson's medium with 20% coconut milk and adenine. *Ananas erectifolius* is further along with several lateral buds (Fig. 5) and protocorm-like bodies in culture.

SUMMARY

Based on the results with pineapple cultures, a feasible procedure for culturing and multiplying bromeliaceous plants is a combination of the orchid shoot tip technique and the callus method, applied sequentially and in correct sequence. After prior shaking in a liquid medium, the shoot tip cultures are grown on a medium which stimulates the induction and growth of protocorm-like bodies and subsequent development into plantlets. Cloning of

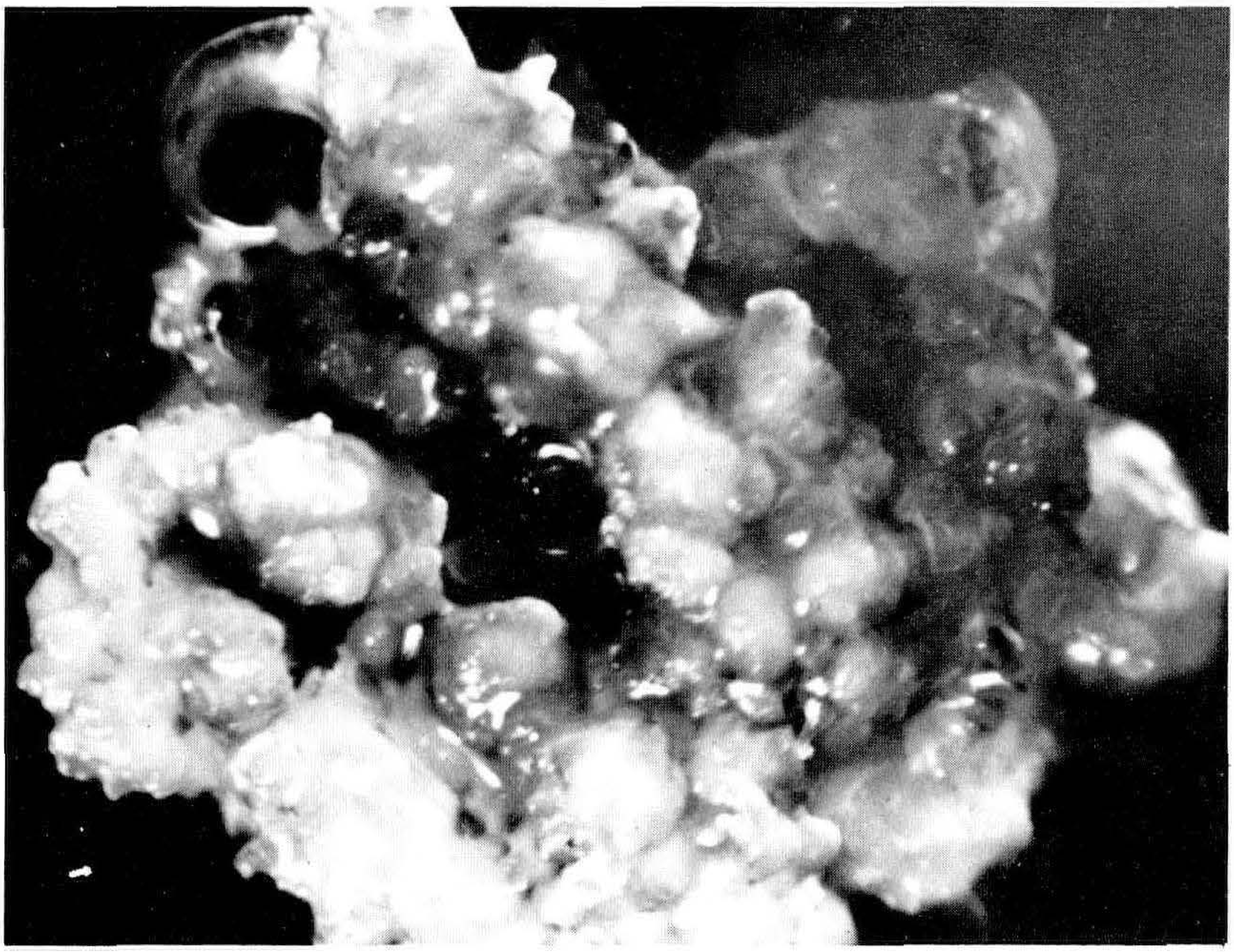

Figure 1. Growth of callus-like tissues and protocorm-like bodies in pineapple on Murashige and Skoog's basal medium plus adenosine, 30 ppm.

Figure 2. Growth of protocorm-like bodies and subsequent development of shoots and pineapple plantlets in Murashige and Skoog's solid basal medium plus adenosine, 30 ppm, after 2 months.

Figure 3. The pineapple culture in Fig. 2 at higher magnification to show the protocorm-like bodies and early stages of shoot development.

Figure 4. Profuse growth of pineapple plantlets and protocorm-like bodies in Murashige and Skoog's solid basal medium plus adenine, 20 ppm, after 3 months.

Figure 5. Shoot tip culture of *Ananas erectifolius* showing two lateral buds and a callus-like growth formed laterally across the stem. One of the shoots on the back was removed prior to photographing. Age 3 months in culture.

desirable, high quality plants in great numbers should be possible.

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VICE-PRESIDENT OKI: Thank you, Marion, and thank you, Dick, for a good job of moderating. Going on now to the second part of this morning's program we are going to change moderators. Edsal Wood, would you please take over now?

MODERATOR WOOD: Our first speaker in the second half of this morning's session graduated from the University of British Columbia about 16 years ago in plant science and then started a nursery business with his father. They are general ornamental growers, with many species and varieties, but their specialty is in propagation of plant liners. Les Clay:

PROPAGATION OF DOGWOODS BY CUTTINGS

LESLIE K. C. CLAY

Les Clay & Son Ltd.
Langley, B.C. Canada

Last year, as many of you may remember, I spoke generally on the propagation of dogwood. This year I intend to limit my comments solely to the propagation of dogwood by cuttings.

With all species of dogwood, we take the cuttings in late June and early July. The cuttings are placed in flats in a medium of ⅓ sand, ⅓ peat moss, and ⅓ coarse perlite. Several flats of cuttings were prepared with medium of pure washed concrete sand. These, however, did not root nearly as well as those in our standard mixture. The cuttings are taken only from the current season's growth. In the case of *Cornus alba*, and varieties, if the growth is long enough, cuttings from secondary growth may be used. With *Cornus florida* and its cultivars and *Cornus kousa* only tip cuttings are used. The cutting length is four to six inches and the lower leaves are removed. Following removal of leaves, cuttings of *Cornus florida* and varieties, and *Cornus kousa* are given a wound of ½ to ¾ inch in length. The cuttings are then given various hormone treatments prior to placing in the rooting medium. Generally 96 to 120 cuttings are placed in each flat dependent on the size of the cuttings. Prior to setting, cuttings of *Cornus alba* and *Cornus stolonifera* varieties are given a hormone treatment of Seradix No. 2 powder (0.3% IBA). Several flats were given a treatment of No. 2 Seradix plus Benlate. The Benlate was added to the hormone powder at the rate of one ounce Benlate to ten ounces hormone powder. Following treatment, cuttings are placed over bottom heat at 72ºF. and under intermittent mist controlled by a moisture leaf. The cuttings are usually well rooted within a three week period. They may then be hardened off and left in the flat or potted. The potted cutting, however, will develop to a larger size than those left in the flat. Flats in which cuttings were allowed to remain over winter developed a considerable amount of damping off, while those treated with a hormone and Benlate showed very little. With *Cornus florida* and cultivars and *Cornus kousa*, we used Seradix #3 (0.8% IBA), or Jiffy Grow diluted 1:5. In some cases the Seradix #3 was mixed with Benlate as above. Where Jiffy Grow was used, the cuttings were given a quick dip to the depth of the wound. The rooting is slower than with *Cornus alba*, taking five to six weeks. We have found once rooting has taken place it is better to let these cuttings remain in the flat until after dormancy, then pot prior to growth in the spring. In all cases, except where Benlate was used, there was some incidence of damping off during the rooting period. The use of Benlate also seemed to encourage the development of a heavier root system. When we have potted *Cornus florida* cultivars or of *Cornus kousa* prior to dormancy, we seem to have trouble getting the potted liners to start growth in the spring, while if potted after dormancy no such trouble is encountered. A comparison of some of the results obtained the last two years is shown in table 1.

Table 1. Rooting results obtained with cuttings of five species of *Cornus* during 1971 and 1972.

Cultivar	Year	Cuttings Prepared	Hormone Treatment	Number Rooted	Percent Rooted
Cornus alba	1971	1,260	Seradix #2	1,230	97.7
'Argenteo-marginata' ('Elegantissima')	1972	1,140	"	1,095	96.0
Cornus alba	1971	1,440	Seradix #2	1,394	96.8
'Gouchaultii'	1972	600	" *	591	98.5
Cornus stolonifera	1971	300	Seradix #2	295	98.3
'Flaviramea'	1972	420	"	402	95.7
Cornus florida	1971	290	J. G. 1:5	227	78.3
'Rubra'	1972	190	Seradix #3*	174	91.5
Cornus florida	1971	290	J. G. 1:5	217	74.8
'Cherokee Chief'	1972	380	"	291	76.5
Cornus florida	1971	390	Seradix #3	264	67.7
'Sweetwater'	1972	190	"	122	64.2
Cornus kousa	1971	200	Seradix #3	109	54.5
	1972	280	" *	182	65.0

* Seradix and Benlate (1 oz. Benlate to 10 oz. Seradix)

I think it is evident from the results shown above that, without the addition of Benlate, the result of the two years were quite consistent; however, the addition of Benlate to the hormone powder improved rooting.

MODERATOR WOOD: After your cuttings were rooted you say you didn't want to transplant them until after dormancy. How much new growth had developed prior to transplanting when they were dormant?

LES CLAY: With *Cornus florida* and *C. kousa* we found, after rooting, very little initial top growth the first year.

MODERATOR WOOD: While they are in the flat, before you transplant them, but after they are rooted — you allow new growth to develop, then they go dormant, then you transplant them. Is there much new growth put on in the flat?

LES CLAY: No — not much new growth in the flat. It seems if we transplant prior to the cutting losing its leaves we have trouble making the buds break the next spring. But if the leaves stay on and they remain in the flat until the leaves normally drop, then there seems to be no trouble whatsoever.

MODERATOR WOOD: Bruce Briggs was born and raised in the industry, in his father's business of Brigg's Nursery, Olympia, Washington. Bruce is one of the most innovative people in our industry. If there is anything around to try, Bruce is going to try it. When anyone in the industry, whether it be in Oregon, Washington, or any place else needs any help, all they have to do is yell for help and Bruce is right there at the front of the line. Bruce Briggs:

RESEARCH AT THE NURSERY LEVEL, II

BRUCE A. BRIGGS

Briggs Nursery
Olympia, Washington 98501

At the 1969 Eastern meeting, I gave a paper entitled, "Research at the Nursery Level"(1) My talk today pursues some of these ideas further and will be in a similar format (mostly slides with some discussion and, hopefully, some questions at the end).

ROOTING IN AIR

We first constructed an air rooting chamber several years ago as a teaching device and the basic structure was described in the 1965 and 1966 IPPS Proceedings (2,3). We have continued using the chamber as a research tool because it offers a quick observation of the rooting progress without, in any way, disturbing its continuance.

Rooting in the air chamber has always been poor in the late fall and winter months. We have decided that this is not only a temperature factor, but that light intensity is much more critical with cuttings under these conditions than when they are struck in a solid medium. This year, even in the long days during July, when the tops were shaded 60%, cuttings which rooted in seven days in full light took over 14 days to root in the shade.

As mentioned in earlier articles, one factor which has needed improvement in this air chamber is a safety provision, in case of a power or water failure. An IPPS member in our area, Warren Berg, used a tray of water under the cuttings to keep them moist. We have been using this method, keeping the mist above and the water-filled tray about an inch or so from the bottom of the cuttings, with the water heated by an electric cable to around 20 trouble making the buds break the next spring. But if the leaves stay on and they remain in the flat until the leaves normally drop, then there seems to be no trouble whatsoever.

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DISTILLED WATER FOR HORMONE DILUTIONS

How many times have you failed to achieve the same rooting response, even though carefully following the prescribed directions of another member? Timing (3), condition of stock plants, rooting medium, calcium and other chemicals, light and temperature are just a few of the variable and sometimes limiting factors involved.

For example, we found at our nursery that the effect on a cutting dipped in a 27°C hormone solution in the afternoon, could be *twice* as great as on a similar cutting dipped in the same hormone solution at 10°C in the morning! This effect becomes even stronger as the temperature of the room rises along with the temperature of the solution.

We have has some difficulty in getting clear rooting solutions when testing new combinations of chemicals. Apparently the slight mineral content of various water supplies can greatly affect these dilutions. We finally found that we could produce clear dissolved solutions with the use of either distilled or deionized water. It has proved well worth the small extra expense to buy the mineral-free water for this purpose.

A short note, while we are on the subject of rooting solutions: when we used rutin (5) in the quick dip, our results were that it retarded the rooting of the usually fast and easy-to-root items, while it enhanced the rooting of the usually slow and hard-to-root items.

CEDAR SAWDUST AS A ROOTING MEDIUM

Earlier discussions on the work of John Roller on direct rooting in pine sawdust outside with Rainbird sprinklers was the basis for additional work we continued along this line.

Years ago, we used a layer of any kind of sawdust on the bottom of the flat underneath the other media, as we found that many plants which were to be left in the flats for an extended time responded with better growth. Plants which were normally difficult to transplant, such as *Daphne cneorum*, responded very well, having a much better root system by spring. Then we were able to transplant them directly from the flats into the field. To obtain the same effect, we tried various combinations of sawdust, peat and perlite, etc. but found that we were creating a real watering problem with so many different media, especially when the plants were put into mixed blocks in the greenhouse.

So, to create a longer water column, we changed from the 2 to 3" deep flat to a 6" deep box. For ease in moving them with our equipment we went to a very large box, 10' by 4', which we filled with a coarse uniform cut of cedar sawdust.

In our Pacific Northwest area, the term cedar sawdust refers to the sawdust from our native *Thuja plicata*. Freshly-cut cedar sawdust must be leached by water before cuttings can be stuck. If put into the boxes fresh, the sawdust can be watered heavily several times and then it would be safe for planting within a couple of days. If left outside in a pile, it can be leached by the normal rainfall over a longer period of time. The sawdust cannot be used fresh, put directly into a peat pot, as adequate leaching does not occur.

We did get excellent rooting with the straight cedar sawdust on some plants. However, the rooting was enhanced with the addition of peat, up to ¼ volume, for ericaceous plants such as rhododendrons and heathers. The addition of up to ¼ volume of coarse perlite enhanced rooting for most conifers and plants requiring good drainage (except *Chamaecyparis obtusa*). Coarse sand could be used to create this better drainage but we did not want to add the extra weight in our large boxes. Additives of calcium in the form of dolomite lime and superphosphate (0-20-0) have also proved beneficial. If the pH is not too low, we try to substitute gypsum for some of the dolomite to improve drainage. On our latest mixes, we are trying a complete fertilizer, including iron and some other minor elements.

USING FERTILIZERS WITH CEDAR SAWDUST

We have found that the cedar sawdust is stable enough and breaks down slowly enough so that we can mix fertilizer with it and apply fertilizer overhead on it without causing too rapid a breakdown. There is some gradual change in medium structure caused by the formation and growth of some algae on the particles, but this is less of a problem with cedar or redwood sawdust than with the softer woods. We would recommend having a chemical analysis of the water, sawdust, and other proposed ingredients before it is decided what chemicals need to be added.

We apply our liquid fertilizer over the tops of the plants (which are rooting directly in the large boxes) through fairly fine watering nozzles, rather than the usual misting nozzles. To date, we have had no chemical build-up or clogging of these nozzles. This overhead application of fertilizer seems to be particularly beneficial to the broadleaved evergreens as well as deciduous and quick-to-root plants. It seems to have less of an enhancing effect on the conifers and other slow-to-root plants.

EFFECT ON WINTER HARDINESS

An interesting feature of rooting in cedar sawdust, which we have not yet checked out completely, is that it *seemed* to result in a better survival of plants through severe winter conditions. Last summer the *Euonymus* 'Emerald 'n Gold' and 'Emerald Gaiety' cuttings rooted faster and had better color when rooted in cedar sawdust rather than in peat and perlite, perlite, or Douglas-fir (*Pseudotsuga menziesii*) sawdust. During the winter, these plants were left outside in the boxes where they were exposed to temperatures of -18°C. All plants died, *except* those which had been rooted and were still in the cedar sawdust. We need to do additional checking to see if this will hold true on other plants and to see if we can isolate the factor which made the difference. In the meantime, we are becoming increasingly interested in the potentials of cedar sawdust.

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JOHN EICHELSER: I noticed you mentioned cedar sawdust. Have you tried fir sawdusts? Is there a reason for using cedar instead of fir?

BRUCE BRIGGS: A few years ago we did a lot of work with fir and fir combinations. The reason we have gone to cedar is two-fold. First, because we had a more uniform grind, which is very essential when you are working with a sawdust. Our work with fir years ago was fair; this year we ran cedar sawdust with rhododendrons and other plants; it was a little better. Our results were superior; this again may be due to uniformity of grind, plus good drainage. But it was better. This is about the only reason for us doing that; we felt we want a medium that would not break down fast, because when it breaks down you have more drainage problems. And with cedar, like redwood in California, breakdown is slow. So we are getting to a product that remains more stable, especially when it is to be used for a long, long period of time.

MODERATOR WOOD: Our next speaker took his undergraduate work at Utah State, then to Michigan State for his Ph.D., then to Washington State at Pullman about 14 years ago, where he has been working in Pomology. Fenton Larson:

SUCCESSFUL DEFOLIATION OF NURSERY STOCK WITH CHEMICALS[1]

FENTON E. LARSEN[2]

Washington State University
Pullman, Washington 99163

Work on chemical stimulation of leaf abscission of nursery stock started at Washington State University in 1962. Some work had been done elsewhere in the United States prior to that time (1,2,12,13,14). Since 1962, sporadic attention has been given to this problem by others in the United States and Western Europe. Apparently somewhat more consistent attention has been given in Eastern Europe. Much work in Europe, however, has been with materials which are more desiccants than defoliants.

In 1967, a report to the International Plant Propagator's Society (IPPS) covered the findings of the early work in Washington (4). Since 1967, several additional reports have been published concerning the most successful treatments (5,6,7,8,9,10) under central Washington conditions. Other materials have been tried which might be useful elsewhere. It is the purpose of this report to briefly present information gathered since the above mentioned report to IPPS (4) and to describe the currently most successful approaches to nursery stock defoliation in Washington.

[1]Received for publication August 11, 1973. Scientific Paper No. 4112. College of Agriculture Research Center. Washington State University. Work was conducted under project 1690. The contributions and assistance of the following nurseries are gratefully acknowledged: C and O, Chervenka, Columbia Basin, Heath, Hilltop, May, Milton, Pacific Coast, Van Well, Willow Drive. Contributions of chemicals from various companies is also appreciated.

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MATERIALS AND METHODS

Defoliate sprays were applied at commercial nurseries and experiment station plots using trombone-type hand sprayers. Replicated plots of 3 or more plants each for budded stock or plots of about 1 meter in length for seedlings and rootstock stoolbeds were used. Single, double, and triple applications were tried, using apple, pear, cherry, plum, and peach. Sprays were usually begun the first half of October, but late September sprays have been used. Plots were examined weekly and visually rated for defoliation until the time of digging. After storage, treated plants were replanted and observed the first season for after-effects of sprays.

Chemicals used were: 1967 — KI (potassium iodide), DEF (S, S, S-tributyl phosphorotrithioate), Nacconol NR (an alkylaryl-sulfonate), Bromodine (a bromine-iodine complex), DEF + KI, Bromodine + KI, iodoacetic acid, chloroacetic acid, bromoacetic acid, ethephon [(2-chloroethyl) phosphonic acid]; 1968 — ethephon, Bromodine, abscisic acid (ABA), ethephon + napthalene acetic acid, ethephon + urea; 1969 — Bromodine, ethephon, Bromodine + ethephon 1970 — KI, D-WK (Dupont-WK surfactant, the dodecyl ether of polyethylene glycol), ethephon, Bromodine, sodium iodide, iodide, ioxynil (4-hydroyy-3, 5 diiodobenzonitrile), KI + ethephon, D-WK + ethephon, Bromidine + D-WK; 1971 - D-WK, Bromidine, ethephon, D-WK + ethephon; 1972 - D-WK, ethephon, D-WK + ethephon, Fisons 9565, Dupont 1840, Mobil-leaf (an anti-transpirent) + ethephon, Amchem 72-29 (*an ethephon + KI formulation*), KA (potassium azide), and cycloheximide.

RESULTS

Specific data for only 1967 (Table 1), 1970 (Table 2), and 1972 (Table 3) are presented here since the major findings for 1968, 1969, and 1971 have been published elsewhere (5, 6, 7, 8, 9, 10).

DISCUSSION

Experimental Results.

The 1967 tests included the most successful chemicals from the previous 5 years' tests plus some previously untested chemicals. From the 1967 tests, Bromodine was judged to have the most potential for further testing.

While several chemicals produced significant amounts of leaf abscission in the tests of 1967 through 1972, those that gave the most favorable results under central Washington conditions were Bromodine, D-WK, ABA, and D-WK + ethephon. These materials were considered most useful because of the degree and speed of

Table 1. Percent[1] defoliation induced in the nursery at digging time by chemicals applied to several tree fruit cultivars (1967)

Chemical	Conc (ppm)	PLANT d'Anjou pear	Oregon Spur Delicious apple	Golden Delicious apple	Rome Beauty apple	Elberta peach	Bing cherry	Italian prune
		Observation Date						
		11/9	11/9	11/9	11/9	10/26	11/2	11/2
Potassium iodide (KI)	1000[2]	41	5	19	7	82	94	99
	2000	49	13	29	10	86	91	99
DEI	2500[2]	38	2	21	10	88	97	92
	5000	79[4]	11	21	13	89	66	91
Nacconol NR	5000[2]	27	0	9	0	90	69	84
	10,000	45	0	11	6	91	62	87
Bromodine	10,000[2]	91[4]	27	71	57	95	95	100
	15,000[3]	99[4]	51[4]	92	98[4]	97	93	100
DEF + KI	2500 + 1000[2]	92[4]	16	61	36	90	99	100
	5000 + 2000	87[4]	36	56	43	92	100	100
Nacconol NR + KI	5000 + 1000[2]	59	6	42	7	93	98	100
	10,000 + 2000[3]	89	19	62	26	95	95	100
Bromodine + KI	10,000 + 1000[2]	95	35	84	65	97	98	100
	15,000 + 2000[3]	97	50[4]	91	96[4]	98	96	100
Iodoacetic acid	500[2]	85	15	65	45	95	95	95
	2000[2]	100[4]	95	95[4]	85[4]	100[5]	95[5]	95[5]
Bromoacetic acid	500[2]	25	0	45	5	95	85	95
	2000[2]	95[4]	15	65	45	100	95	95
Chloroacetic acid	500[2]	95[4]	15	55	15	85	85	95
	2000[2]	95[5]	85	85	95[4]	95[5]	65[5]	95[5]
Control		5	0	0	5	80	45	50

[1]Figures represent means of 10 plots of at least 3 plants each.

[2]Application on 10/11

[3]Application on 10/19.

[4]Damaged bark and buds on 2 to 5 cm of the tips of some shoots at digging time.

[5]Similar to 4 but also with desiccated leaves attached to some terminals

Table 2. Percent[1] defoliation induced in the nursery by 10/29/70 by chemicals applied to several tree fruit cultivars.

Chemical	Conc (ppm)	PLANT						
		Ottawa 292 apple	MM 106 apple stoolbed	M 7A apple stoolbed	Goldspur apple	Earlistripe Delicious apple	Winesap apple	Old Home pear
Potassium iodide (KI)	1000	15,20,25	12,22,25	5,15,60	25,30,42	18,20,25	10,15,22	55,72,97
	1500	15,20,25	22,27,32	25,25,25	80,87,90	37,47,60	37,40,55	89,94,94
Dupont-WK (D-WK)	10,000	65 88,95	32,67,77	40,60,60	85,85,96	25,27,32	20,40,60	69,86,96
	20,000	99,99,99	60,92,99	90,98,98	90,98,100	80,82,90	70,79,80	99,100,100
Bromodine	2500	10,10,10	12,18,25	5,10,10	15,17,22	12,22,25	17,20,25	37,40,62
	5000	10,15,15	30.35,40	10,15,20	32,50,82	20,25,30	20,20,25	57,70,86
Ethephon	500	30,48,60	15,17,28	20,25,30	70,90,94	42,50,52	5, 5, 7	20,25,40
	750	45,55,70	20.38,48	20,30,40	92,98,98	47,57,67	10,10,10	75,75,75
Bromodine + D-WK	2500 + 10,000	60,79,89	38,47,57	50,75,85	90,95,96	45,47,70	52,57,72	87,87,96
	2500 + 20,000	98,98,99	50,94,98	90,95,95[3]	98,99,99	90,94,96	55,90,95	100,100,100
D-WK + ethephon	20,000 + 500	99,100,100	99,100,100	90,100,100	99,100 100	95,99,100	55,99,99	100,100,100
	20,000 + 750	100,100,100	100,100[2],100[2]	100,100,100	100,100,100	99,100,100	80,100,100	100,100,100
KI + ethephon	1000 + 500	17,25,30	40,55,60	35,50,50	87,94,97	45,50,50	25,30,37	67,75,60
	1000 + 750	30,62,65	45,62,62	35,50,60	96,98,98	47,60,72	32,40,45	92,96,94
Sodium Iodide	1000	17,17,17	27,35,42	10,20,25	85,90,95	47,50,50	45,62,75	95,99,99
	1500	15,15,17	38,38,43	30,30,30	87,92,96	75,82,85	75,85,92	100,100,100
Ioxynil	600	27,32,32	17,30,47[3]	15,20,30[3]	22,25,35[3]	12,15,15	25,25,25	30,40 50
	1200	37,37,32	47[3],60[3],65[3]	60[3],75[3],95[3]	52 55[3],62[3]	15,17,17	25,25,27	60,70,70
Control		7	7	10	10	10	5	25

1 Figures represent means of duplicate plots of at least 3 plants (about 1 m for stool beds) each The means in each series of 3 figures represent the results of single, double, and triple applications made on 10/8, 10/8 and 10/15, 10/8, 10/15 and 10/22 respectively

2 Damaged bark on 2 to 5 cm of the tips of some shoots at digging time

3 Similar to 2 but also with desiccated leaves attached to some terminals.

Table 3 Percent[1] defoliation induced in the nursery by 10/26/72 by chemicals applied to tree fruit nursery stock

Chemical	Conc (ppm)	PLANT: Golden Delicious apple	Wellspur Delicious apple	domestic apple seedling	Prunus mahaleb seedling	Hi Early Delicious apple	Ottawa 292 apple	Bartlett pear
Dupont-WK (D-WK)	10,000	30 38 55	20,20,60	17,85 90	48,55 65	23,75,99	83,100,100	28,30,48
	15 000	35,60,99	25,89,99	33,78,98	65,80[3]95[3]	30,100,100	89,100,100	28,35,63
Ethephon	100	20 20 20	8,10,10	5, 8, 8	13,13,18	5, 5,20	24,32,32	25,33,33
	200	20,20,20	8,13,15	5, 8,15	13,15,25	5,25,35	28,32,40	25,43,63
D WK + ethephon	10 000 + 100	28,48 78	15 35 99	25 80[2],97[2]	30 55 78	45 100,100	59,90,100	53 75,98
	10,000 + 200	38 55 50	30,58,99	90[2],97[2],99[2]	30 63,73	92,100,100	89,99 100	53,74,95
	15 000 + 100	50,90,100	87,99,100	63[2],93[2],100[2]	30,78,95	58,100,100	65,100,100	70,70,100
	15,000 + 200	43,95,100	55,90,100	92[2],100[2],100[2]	65,95[3],98[3]	80,100,100	87,100,100	63,73,99
Dupont-1840	100	20,20	30, 0	10, 5	15,10	—	—	—
	1000	20,20	15,25	15, 5	25,15	—	—	—
Mobil-leaf + ethephon	30,000 + 200	25,20	13,18	3,18	20,15	—	—	—
	80,000 + 200	20,28	8,25	8,13	20,40	—	—	—
Potassium azide	100	15,18	10,10	0, 0	13,13	—	—	—
	400	20,20	13,10	0, 0	13,10	—	—	—
Fisons 9665	500	20,20	65,40	50,15	5,15	—	—	—
	2000	20,20	65,30	50,30	25,35	—	—	—
Amchem 72-29	400	33 30	13,10	25, 8	55,13	—	—	—
	600	30,25	15,15	38[2],63	60,50	—	—	—
Cycloheximide	25	70,75	98,99	75[3],35	80,75	—	—	—
	50	95,98	100,100	95[3],30[3]	85,65	—	—	—
Control		20	18	8	70	5	30	35

[1] Figures represent means of 2 to 4 plots of at least 3 plants (about 1 m for seedling) each The means in each series of 3 figures represent the results of single, double, and triple applications made on 9/28; 9/28 and 10/5, and 9/28, 10/5 and 10/12 respectively Means in each group of two figures represent the results of single applications applied on 9/28 or 10/12 respectively

[2] Damaged bark and buds on 2 to 5 cm of the tips of some shoots at digging time.

[3] Not more than 2 cm of some shoot tips desiccated

leaf abscission produced and the absence of or low degree of injury evident prior to and after storage. ABA has not been commercially tested because of its high cost but it appears to have considerable potential. Bromodine has been used commercially for about 4 years.

As experimental work has proceeded, commercial tests of D-WK and D-WK + ethephon have been very favorable and commercial use of these materials is now occurring. Experimental and commercial tests indicate that these chemicals are usually superior to Bromodine.

Another chemical, cycloheximide, deserves further experimental trial as demonstrated by the 1972 tests. This material produced a high level of abscission in 2 to 4 weeks with little or no injury from single applications of 25 or 50 ppm. Sprays of 100 ppm did not produce significantly better abscission but injury to shoot tips was significant at this higher rate.

While some chemicals have not been considered sufficiently satisfactory for Washington use on tree fruit nursery stock, testing in other areas and on other stock might be worthwhile. For example, KI was first tested in Washington on nursery stock and found to be useful (3). Later tests revealed better materials. As a result, KI has not been used commercially in Washington, but it has been commercially successful in Oregon on roses (personal communication with Fred Edmunds). Other chemicals which might be useful elsewhere include Bromodine + ethephon, ethephon + KI, NaI, Nacconol NR, DEF, and iodacetic acid.

Commercial Procedure

Commercial procedures with Bromodine in Washington have included 1 to 3 applications of 200 to 300 gal/A at 2500 ppm (of the formulation) at 3 to 5 day intervals for tender or more easily defoliated types (apricot, peach, pear, cherry). For more difficult types, such as apple and some plums, 2 to 3 applications of 5000 ppm have been used. Where tissues are not excessively succulent, or late in the season, higher rates up to 10,000 ppm have been used without damage on some apple cultivars. Apricot, peach, *P. mahaleb* seedlings, Rome apple, and M26 apple rootstocks are rather sensitive to damage with defoliants and are likewise sensitive to Bromodine. Consequently, application of defoliants to these types of stock should be conservative. Pruning wounds should be healed prior to Bromodine application since fresh wounds apparently absorb excessive Bromodine resulting in hypertrophied tissue around the wound.

Experimental and commercial trials show that 1 to 2 applications of 10,000 to 15,000 ppm (of the formulation) D-WK + 100 to 200 ppm (active ingredient) ethephon produce high degrees of leaf abscission in 3 to 4 weeks with little or no damage if applications are modified according to the above mentioned sensitivities of plants. These treatments have been tested in experimental plots on a number of apple cultivars, on P. *mahaleb* cherry seedlings, sweet cherry, pear, Early Red Haven peach and Early Italian prune. Commercial tests have been more extensive, particularly with apples. On the following sensitive plants, combination rates higher than those indicated should not be used. Rome apple and *P. mahaleb* seedlings - 10,000 ppm D-WK + *200 ppm ethephon; Early Italian prune - 10,000 ppm D-WK* + 100 ppm ethephon. D-WK *alone* at 10,000 ppm is excessive for peach.

D-WK can be used quite successfully alone at 10,000 to 20,000 ppm (except as noted) but defoliation is somewhat slower than when it is combined with ethephon. D-WK alone, however, is much safer for the plant, and for this reason some nurserymen favor it over the combination treatment with ethephon.

Influencing Factors.

While insufficient work has been done on conditions which influence the reactions to defoliants, evidence indicates that at least the following are important: temperature, humidity, precipitation, soil moisture, nutrition, species, cultivar, plant age, vigor and maturity, timing, chemical concentration, and adjuvants (11). At present, the prime considerations for the nurseryman seem to be:

1. weather—spray absorption is greater with high humidity. Defoliants work best if preceeded by one or more light frosts and if day temperatures at the time of application are 18°C (64°F) or higher. Rain should not immediately follow an application.

2. plant factors — applications should be adjusted appropriately for differences in species and cultivar sensitivity. Some damage may be expected if terminal buds have not been formed prior to treatment. Nursery stock that has grown vigorously is more difficult to defoliate than low vigor stock or an older, established tree.

3. application considerations— timing, concentration, and adjuants must be adjusted to give desirable results and avoid undesirable side effects. Timing should be regulated by weather and plant development. Concentration will vary with species, cultivar, and timing. Multiple applications probably should not be closer than 3 days in order to allow sufficient reaction time and to avoid the possibility of damage.

Of prime importance is the judgment and care of the applicator. The mixing and application should be at least as carefully done as with a herbicide or chemical fruit thinning spray. Ineffective treatments, plant damage and unnecessary costs are the inevitable result of careless, poorly timed application. On the other hand, very good results are obtained by nurserymen who carefully time and control their applications.

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SUNDAY MORNING SESSION
August 12, 1973

VICE-PRESIDENT OKI: Our session this morning will be chaired by our able program committee member from Hawaii, Bob Warner. Bob, will you take over now?

MODERATOR WARNER: Our first speaker this morning is Donald Watson. He is Professor of Horticulture at the University of Hawaii and is working in Urban Horticulture. He has been doing a lot to bring the beauty and freshness of living plants to the city dwellers. He has had a local newspaper column for over a year and has a television program every other week. His topic is "Plants are for People." He has written a book with this title that was published just a couple of months ago. It is a great deal of pleasure to introduce my associate, Don Watson:

PLANTS ARE FOR PEOPLE[1]

DONALD P. WATSON

University of Hawaii
Honolulu, Hawaii 96822

About a thousand years ago when the Polynesians first settled in Hawaii they were greeted with a forbidding shoreline, a blue ocean, and attractive beaches, but absolutely no plants. There was just no vegetation whatsoever. Anything that is growing on these islands has been brought in since. When they arrived in their outrigger canoes they gradually climbed into the areas where they might be able to grow things and they brought with them quite a number of the plants to which they were accustomed. In some areas there was so little rainfall that it was practically impossible to grow anything and in other areas there was so much rainfall that it was an absolute paradise that would later grow into a jungle.

Now the most common and perhaps the most necessary plant as far as the Polynesians were concerned was the taro [*Colocasia*

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esculenta]. Taro was basic in their diet. They had to have a good source of carbohydrate and today at the Lyon Arboretum there is a collection of many, many kinds of taro. Hawaiians had names for each clone and some of them were quite attractive. Some had a white root, some an orange root, and some quite red. They boiled the taro root, then pounded it into a paste. It is often misrepresented today at a luaua because people get the idea that they are supposed to sit there and eat taro and that is not exactly true. The taro is primarily used as we might use mustard, for instance, as a seasoning to eat with your food. Today it has become extremely expensive because there is not enough to supply the demand. It is being used by dietary manufacturers and baby food manufacturers to a large extent because it is a good source of carbohydrate and it is not made from wheat flour.

The second and perhaps equally important plant was the coconut [*Cocos nucifera*]. The coconut — to tropical and subtropical islands — is an absolute necessity because it is used as food. Most of our coconut meat comes from Fiji or Samoa or somewhere else. The coconut in Hawaii is primarily ornamental — in two kinds, a dwarf one and the tall one. From a landscape point of view, the dwarf one, called locally the Samoan coconut is useful. It is called Samoan because the ship that brought the original seeds apparently stopped at one of those islands on the way here. The coconut yields very heavily; with each new leaf, in the axil, there is one inflorescence and that inflorescence gives rise to quite a number of fruit. Of course, in many places it is still a source of income, but I think the most valuable part of the plant, as far as we are concerned, is the view that you get as you look down through the leaves toward the beach. It grows well along the beach in sandy soil as long as the salt water is filtered before it gets to the roots. The leaves have many functions. The webbing that has been made by the Fijians is commonly used to decorate stages or walls of houses. They are also made into coconut hats. At Christmas, the brim of the coconut is often used as a wreath and for a local Christmas decoration there isn't anything more simple or effective than a coconut leaf wreath with three red anthuriums on it.

Another plant which was extremely important to Polynesians is the breadfruit [*Artocarpus communis*]. Breadfruit is a common food of people who are not able to get wheat or rice. The fruit itself, when mature, is creamy colored inside; all that is done is to wrap the fruit itself in aluminum foil and bake it. It is used as a good source of carbohydrate and is a basic food of those who are brought up on it.

The next plant, which was one of the early Polynesian introductions, is the hala or pandanus [*Pandanus odoratissimus*]. Hala is still quite a common ornamental; it has both male and female flowers on the same plants. The roots are attractive in that they have a prominent prop-like structure which holds the tree firmly in the tradewinds. Mats are woven from leaves of the hala. They wear very well, and there are still quite a few of them being made. Many woven leaves are being sold as place mats. The early Polynesians used them as floormats; they put them on pebbles so that the air would come up through them. They would keep cool and dry and make a very good floor. The fruit itself is often called the "tourist pineapple" because it does resemble a pineapple. The little individual sections, if they are pulled apart, when ripe become quite orange in color and make attractive leis.

After the hala comes the ti. Ti seems to be quite a controversial plant. We think of all of the tis, the variegated or colored types or the green one, which is the more common, as *Cordyline terminialis*. I know that in Florida they call some of draecena's, ti, and there is confusion in the naming but actually it is based on the flower structure and as far as I can tell the bulk of all of the tis are *Cordyline terminalis*. They are used for the hula skirts, a relatively new custom. There are, nearly as I can tell, some 70 different clones of ti that are being grown, although not more than five are being grown commercially. There is quite a demand right now for cut ti leaves on the mainland, especially during winter months. More and more of this foliage is being shipped out of Hawaii. The fruit on the ti is attractive; it looks like a small red grape. Ti is a member of the lily family and it can be grown from seed; this is why we get so much variation.

The kukui [*Aleurites moluccana*] is the Hawaiian state tree; it produces nuts which are polished and made into necklaces. I am sure that you have seen a lot of these around. The flower looks a little like a lilac and the fruit a little like a walnut before it has the husk taken off. But if you take off the husk and start to polish them and work for at least a day on each nut you can get it highly polished and it will always remain shiny due to the oil in it. The name kukui comes from the fact that originally Polynesians strung them on coconut straws then used them as candles; they set fire to them to burn the oil to produce light.

Here are more introductions which I selected because they are some of the most common and, I think, most attractive. The hybrid "showers" are certainly at the top of the list. The pink shower [*Cassia javanica*] is one of the parents and the golden shower [*Cassia fistula*] is the other parent of the "rainbow shower tree." These hybrids vary, all the way from cream-colored to almost watermelon-colored. They are certainly one of the most prominent trees in Hawaii.

The lychee [*Litchi chinensis*] which, of course, is very popular with the Chinese has a delectable fruit; it is one which we do not export but it is grown quite widely.

The African tulip [*Spathodea campanulata*] is a good tree, because it flowers every month of the year. It has a huge inflorescence with many buds behind the flowers. It not only is an attractive flower but it also produces a very good pod.

Brassaia, the octopus tree, is grown a great deal in Hawaii. It is not only a good tree in the garden but also a good plant for decoration when grown in containers.

The sausage tree [*Kigelia pinnanta*], the flower of which has a vile odor, is popular because it is so unusual, with its big sausage fruit hanging down.

The monkey pod [*Samanea saman*] is one of our best shade trees. There are not many that get to be as large as they could because they are grown so often in the city where they don't have enough root space. The wood is popular; it is used a great deal for carving and making dishes, bowls, and ornamental objects. Some are carved in the Philippines and shipped in here but others are done locally.

A more recent introduction is the mussaenda [*Mussaenda erythrophylla*]. I don't know whether this is being grown much on the mainland but it was brought in here from the Philippines. I have a feeling that if it were properly grown, it could be used as a pot plant on the mainland and perhaps could become very popular, because the bracts adhere for a long time and it is certainly attractive.

Another plant which I think is interesting is the norantea [*Norantea guianensis*]. *I don't know where the name came from* but I always think of noren, which the Japanese use on an entrance to give an indication of just what is going on in the building or in the store. I think of it as having some relation to this noren because these little flowers hang down like a noren. We had just one norantea plant on the campus and everytime you went past you would see that someone had an air layer here or there. That was about eight years ago and now there are two or three other plants on the campus and I notice occasionally you see one turning up in someone's yard. It is not common, but it is different and I think quite attractive. It is quite vinelike in habit.

The next one is the desert rose [*Adenium obessum*]. It is closely related to plumeria; I wondered if, perhaps it might be crossed with plumeria. I don't know. It varies from pale pink and white to a deep rose. It is quite woody and requires a hot dry location.

More common is the shell ginger [*Alpina nutans*]. Frequently the torch ginger [*Phaeomeria magnifica*] is mixed with the red ginger. The torch ginger is attractive but it is awfully heavy and isn't used a great deal to ship out of Hawaii because of its weight — and it doesn't keep too long.

The *Musa coccinea*, or crimson banana, I think, has a tremendous future but there is so little of it available that it is hard to push as a marketable crop. The plants don't flower too profusely but certainly there is no difficulty selling them for a dollar per stem and they last for almost a month as a cut flower.

A flower that is most representative of Hawaii, because there are so very few other places that it grows, is the silversword [*Argyroxiphium sandwicense*]. The silversword, only grows in the mountains at 7,000 to 10,000 feet and especially in Haleakala, Maui. It belongs to the Compositae and is certainly unique.

I like the Jade vines. They are of Philippine origin. The flower of the green jade vine [*Strongylodon macrobotrys*] has an almost synthetic green color. It is certainly unusual; I don't know of any other plant which produces a flower of this color. It is not legal to take it to the mainland because it may have an insect in the pod. They are woven into leis but this is a little dangerous because the sap within the jade vine, if it hasn't been well dried, will stain a dress or a shirt. There is a red jade vine [*Mucuna bennettii*] which I think is not as attractive because the color isn't as unique; yet it is a very conspicuous plant with a large flower.

Now, a few of the agricultural crops. The most common, and the one which is really the symbol of Hawaii, is the pineapple [*Ananus comosus*]. I doubt whether there is any agricultural crop anywhere that is grown as scientifically and as effectively as the pineapple has been grown in Hawaii. I am not sure how long this will continue because pineapple land is certainly desirable for real estate subdivisions and more and more of it is going in this direction. However, the pineapple is an interesting Bromeliad; it is attractive even when it is a little fruit or when it gets to be a mature size.

The sugar cane [*Saccharum officinarum*] we must place in the same category as pineapple. You will notice as you go through the islands toward higher elevations the pineapple takes over and the sugar cane stops. The sugar cane flower is really attractive. I always thought how interesting it is when you come in by air and look down on the fields of sugar cane. If you are high enough it looks exactly like a golf course, because it is nothing but a field of grass. There has been a lot of criticism lately because of the burning of the sugar cane fields. It doesn't bother me really because as long as the trade winds are blowing off goes the smoke over the ocean. I don't think it is too serious.

Macadamia [*Macadamia integrifolia*], as you know, came primarily from Queensland in Australia but it is being grown here effectively. It has an attractive flower. Not as many fruits set as we would wish; from the long inflorescence we rarely get more than 3 to 5 nuts. Yet it is an excellent crop; practically all of the processing up to now has been done here. I understand there is a lot of macadamia planting going into Central America and other parts of the world, but as of today most of it is being grown in Hawaii. At Christmas, people even use the macadamia leaves, which have kind of a holly-like look, for decorations.

The wood rose [*Operculina tuberosa*] isn't exactly a commercial agricultural crop. There used to be a lot more wood roses grown than there are today. And when the capsules are almost mature they are cut and hung upside down in a hot, dry place, then they break open exposing seed cases which are usually sprayed with plastic so that they stay shiny. There are not enough being grown to satisfy the market.

Coffee [*Coffea arabica*] has been a big crop, especially on the island of Hawaii, but today there is difficulty in getting labor for harvesting so there is not as much coffee grown as there used to be. It is an attractive fruit when it is ripe. They're working on mechanical harvesting and, with the cost of coffee going up it may increase in production; I am not sure.

Mango [*Mangifera indica*] is a good fruit. The tree is attractive — the fruit is attractive and, of course, it is just delicious. But there are no mangos being shipped out of Hawaii; there is no mango orchard that is big enough to produce enough fruit to make it worthwhile and, of course, there is a restriction because of an insect that may be in the pit. Mangos may be shipped out after being processed but there are just not enough mangos growing to consider them a commercial crop. Someday there may be. I hope so.

Papaya [*Carica papaya*] production has increased tremendously in the last few years and many of them are being shipped out of the state, in both directions.

The anthurium [*Anthurium andreanum*] is one of our biggest flower crops and I think it is of interest, perhaps, to draw your attention to the fact that the spadix, the part that sticks up in the middle, like a pencil, is divided into many hundred little individual flowers. At a certain time, the stamens protrude and the pollen is shed and then later the fruit develops like a little pea on the outside. Anthuriums can be grown from seed but the use of seed is only for plant breeding. To make anthurium flowers keep well it is quite important to hold them at a high humidity. If you enclose the top in a plastic bag and don't even stand the stem in water it is much more likely to last longer than it would if the stem were just in water because you are preventing transpiration from the top.

The Vanda orchid 'Miss Joaquim', is perhaps the most common orchid. There are lots of these orchids being grown commercially, yet there are times in the year when you can't begin to get enough. The individual flower is indeed attractive. It has become so common that I don't think it is as well respected as it should be. It is especially good when the flower is pulled apart and it is made into what is called a Moanaloa lei.

There are quite a few bananas [*Musa* sp.] grown. However, there are a lot of bananas shipped into Hawaii from Central and South America and the West Indies.

The plumeria [*Plumeria sp.*] you might not think of as a commercial crop but it is becoming more and more commercial all the time because so many are being used for making leis. There is a great variety in plumerias — from the yellow to pink and all kinds in between, and the flowers keep well.

There is very little plant breeding or other work going on with the hybrid hibiscus. This seems too bad because the hibiscus grows extremely well in the islands. They are large and colorful, and they are certainly useful for decoration. There are a few growers who do some crossing and there are plenty of plants available but there is not as much breeding going on as there should be.

Now a few of the activities that are going on at the University. The breeding work that Dr. Kamemoto has done with anthurium is beginning to pay dividends. It has been a long, slow breeding program as you can understand. But he has just recently introduced the 'Red Elf' which has two spathes instead of one and it is gaining in popularity, but it takes time to produce enough to get them into the market. Similarly, work he has done with the dendrobium orchids is part of the plant breeding program that has been successful and certainly productive.

Dr. Parvin and I have been working with the introduction of proteas. The silver tree (*Leucodendron argenteum*) has excellent foliage and is coming into demand. Some are grown in Southern California; I think there is more of a future for some of the banksias than for the proteas themselves because they dry so well. I think that proteas, as a dried arrangement, have a great potential.

Dr. Criley has been working with plumerias, not only with breeding but with light intensity and with temperature. He has shown that with slight increase in temperature he can speed up the production of flowers considerably. Work with lettuce, much of which was done some time ago, some of it is still going on, has proven to be extremely valuable for the local market. Some of our introductions of lettuce are the best that I have ever eaten. I hope that you have eaten some of the local lettuce since you have been here because it certainly is delicious. We have a semi-head lettuce which is absolutely delicious and which we can grow extremely well.

Dr. Gilbert's work has influenced tomato production all through the tropics. He has developed new tomato varieties for the tropics. We have to be careful about our day lengths and we have to breed for resistance to nematodes and to disease.

For a number of years Dr. Robert Warner has been developing an arboretum of economic plants at Waimanalo Research Station. The cashew [*Anacardium occidentale*] isn't common in Hawaii but he has cashew trees out there. Here is a picture of the fruit with the nut on the end of it. Also cloves [*Syzygium aromaticum*] can be grown quite easily; they make an excellent clove if they are picked and used fresh. You see, it is nothing but the bud before the flower has opened. It is picked and dried or used fresh.

Now, in conclusion, I want to make it clear that in spite of the fact that our city has turned, like most cities, into high buildings with a lot of concrete, there is still quite a bit of appreciation of plants. The fact that the Hawaiian plants are related to the Hawaiian people is due to a great extent to the Polynesian upbringing and the Polynesian beliefs.

MODERATOR WARNER: Thank you, Don. Now we will have one more presented paper that was not on the program. Bill Barr of Monrovia Nursery will tell us about his experiences in rooting *Pinus radiata* cuttings. Bill:

ROOTING PINUS RADIATA CUTTINGS

WILLIAM BARR

Monrovia Nursery Company
Azusa, California 91703

The Monterey pine, *Pinus radiata*, is normally grown from seed. As a result the progeny are quite variable. Monrovia Nursery, in cooperation with Dick Maire of the Los Angeles County Extension Service, Dick Puffer, of the San Bernardino County Extension Service, and Fred Dorman, of Highland, California, have been experimenting with vegetative propagation of this pine. We are also observing these cutting-propagated plants in one and five gallon containers.

Our objective is to find a *Pinus radiata* clone, with good characteristics, that will root in a high percentage. Of major interest is smog resistance, color, shape, and compactness. These vegetatively propagated trees could be very desirable as Christmas trees and as general landscape plants in southern California.

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ROOTING PINUS RADIATA CUTTINGS

WILLIAM BARR

Monrovia Nursery Company
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The Monterey pine, *Pinus radiata*, is normally grown from seed. As a result the progeny are quite variable. Monrovia Nursery, in cooperation with Dick Maire of the Los Angeles County Extension Service, Dick Puffer, of the San Bernardino County Extension Service, and Fred Dorman, of Highland, California, have been experimenting with vegetative propagation of this pine. We are also observing these cutting-propagated plants in one and five gallon containers.

Our objective is to find a *Pinus radiata* clone, with good characteristics, that will root in a high percentage. Of major interest is smog resistance, color, shape, and compactness. These vegetatively propagated trees could be very desirable as Christmas trees and as general landscape plants in southern California.

The Monterey pines were rooted using these procedures: The cuttings were made five to six inches long with the needles on the bottom half of the cutting cut off. Tip and second cuttings were used. They were dipped into 3000 ppm of IBA and stuck into a mixture of eight parts perlite and one part peatmoss. The cuttings, in flats, were placed in an outdoor mist area with a bottom heat of 72° to 75° F. The cuttings were misted the same as our other conifers. We have not experimented with different techniques in propagation due to the large number of clones used and the relatively few cuttings per clone available.

The first trial began May 19, 1972 with cuttings from 17 trees. After 14 weeks, August 24, 1972, the cuttings were moved to a hardening off area. Two weeks later the cuttings were potted. The rooting percentage varied from 1.7% to 79%. Nine clones were above 43%.

The second trial began October 18, 1972; the cuttings were moved to the hardening off area on April 10, 1973. There were 18 clones in this trial. Seven of them were repeated from the first trial. The cold weather probably accounted for the fact that it took 25 weeks for this second trial to root. We also had poorer rooting this time; the range was from 2.6% to 56%. There was only one tree this time that rooted over 43%. In every case the clones repeated had a lower percentage in the second trial.

On June 6, 1973 and on July 16, 1973, we started additional trials. They are not completed at this time. We are attempting to determine the best time of the year to root *Pinus radiata*.

Ten rooted cuttings from the nine best rooting clones of the first trial were placed into one gallon containers. Later these plants were moved into five gallon containers. We have been observing these plants since the fall of 1972. There is considerable variability among clones. Four of the clones might be commercially feasible. The other five clones are too lanky, yellow, or not smog resistant. It appears that cutting-grown *Pinus radiata*, with the desirable characteristics, is commercially feasible for the nursery trade.

RON HUROV: I wonder if we could have a little discussion on various experiences in seed germination in general. I find there has been quite a bit of work done on rooting media and rooting cuttings but some of the work on seed germination, I think, is behind the times and backwards. I just wonder if you people could express your experiences in seed germination.

MODERATOR WARNER: Anybody have comments on seed germination?

DALE KESTER: This is a general comment about all seeds. One is always impressed by the significance of temperature in germination. This is probably the most important factor in controlling germination of seeds of various kinds. Either too high a temperature or too low a temperature can cause failure. A lot of the dormant seeds require chilling in the winter, but they should not have too high a germination temperature after the chilling is complete. This is a very critical factor. When you really get down to the individual seed species you have to know what its requirements are.

MODERATOR WARNER: Thank you very much, Dale. I would recommend to Ron Hurov that he check with Hartmann and Kester's book on plant propagation, where seed propagation is thoroughly covered.

BETTIE LAUCHIS: We have done quite a bit of research with seeds, particularly with tropical seeds. We think here in Hawaii it helps with the germination of many tropical seeds to use heat. Also you can create a magnetic field which, with some seeds that you can't germinate any other way, may help germination.

MODERATOR WARNER: I would like to mention that citrus seeds are very carefully treated — heat-treated, then dried and covered with a fungicide to prevent phytophthora attacks. This is very important and I imagine that it would hold also for other types of seeds also.

HOWARD BROWN: We have done a little experimental work on a grant we had from Sequoia Forest Products Company. For germinating seeds in flats, bedding plants, annuals, seeds of woody plants, we have come up with a mixture of 50% redwood compost, 30% perlite, 20% peat. To that is added dolomite lime plus fertilizers. It is a very economical mixture and one that produces a good root system and the seeds show very good germination.

RON HUROV: I am a dealer in tropical seeds. That is the reason I brought this up. We're getting seeds of about 450 species that I carry in my catalog. I find that a lot of species have never been listed before and each family — each particular species — seems to have its own requirements. Besides problems with germination, we also have some problems with storage. I would like to comment briefly on Araucaria seeds, which is one of my specialties. We are getting some seeds from the U.S. Forest Service in Georgia. Normally Araucaria has to be planted within a few days because it loses its viability very quickly. This is true of a number of tropical seeds. They managed to store Araucaria seeds for six months or longer by using a high moisture content — high humidity — in jars with nitrogen-controlled atmospheres at 20° F. I think that people who do research with some of the tropical seeds will show that we can extend their storage life. I would like to ask if anyone has done work on germination of palm seed;

they are quite difficult to germinate. Some get good results and some don't. I think use of bottom heat seems to be one of the best ways of breaking their dormancy.

MONDAY MORNING SESSION

August 13, 1973

VICE-PRESIDENT OKI: We will start this morning's session with Dr. Fred D. Rauch, University of Hawaii, in charge. Fred:

MODERATOR RAUCH: We will hear first from Dr. Horace F. Clay, Dean of Special Programs, Leeward Community College, Pearl City, Hawaii[1].

MODERATOR RAUCH: Our next speaker is a young man who graduated from Penn State, did his graduate work at UCLA, and arrived here in Hawaii about 5 years ago. I think he is also one who took the idea of his topic "Population Explosion," quite seriously — he is still a bachelor. He is a horticulturist working in growth regulators, media, and ground covers. So now I would like to call on Dr. Richard Criley.

[1]Dr. Clay showed slides and described the propagation methods of many of the unusual shrubs and trees grown in Hawaii.

POPULATION EXPLOSION[1]

RICHARD A. CRILEY

Horticulture Department
University of Hawaii
Honolulu, Hawaii 96822

Are you worried about the population explosion? Our national population is growing by about 2,000,000 persons a year. Our 1970 census tabulated 204.7 million people. About 74% of our people now live in urban territory — towns of 2,500 or more to densely settled suburbs of large cities. To some, it seems that the United States will need perhaps 400 or more new towns and cities accommodating 25,000 to 250,000 with space to grow.

The next 30 years will bring an explosion of urban growth in areas now largely rural. Cities will continue to grow upward. How congested we feel will depend on how we design and use our space.

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the United States, and that 59 out of every 100 people believe that "green grass and trees around me" are most important to their happiness. Everyone seems to enjoy plants and the effects that they create.

We are all familiar with the diverse uses to which plants have been put — in shopping malls, along city streets, as screens and barriers, in offices and homes, and on small lanais.

With all of these needs for plant materials, we must ask, where are these plants to come from? What we need — is a population explosion of plants! The rapid increase of plant materials represents a challenge to us all.

SYSTEMS

One of the newest tools of the plant propagator is tissue culture. Success has been achieved with a few plants such as orchids, carnations, and some foliage plants but research is still needed for many more. Tissue culturing facilities are expensive to set up, and the sanitation requirements are not practical for many growers.

A variety of conventional systems is still available to us. These include the use of single-node cuttings to make maximum use of limited amounts of plant material. Leaf cuttings, of course, have been used successfully to increase certain fleshy-leaved plants such as begonias, crassula, sedums, sanseviera, and African violets and gloxinias. Leaf-bud cuttings are more specialized forms of single node cuttings which have the leaf, an axillary bud, and a portion of the stem.

It is sometimes hard to break the traditions built up over the years. Here in Hawaii it is common practice to take a 2-3 foot long branch of plumeria and bury its base in soil and await root formation, which takes anywhere from 6 weeks to 6 months, depending on the reliability of the propagator's memory. On the other hand, I have found that 6 to 8-inch terminals will root under mist in 8 weeks if 2,000-3,000 ppm IBA is used. Dr. Rauch has gone even one step further using — for plumeria, anyway — what amounts to a "mini-cutting." A very soft, 3-inch long terminal kept under strict sanitation under mist in a foam block will also root in 6 to 8 weeks. One of the important implications to us, then, is a more efficient means of increasing new cultivars which we select.

There is no need to describe the systems of grafting and budding to a meeting of plant propagators. It is enough to be aware that small amounts of plant material can be increased quickly and efficiently using these methods.

However, we can point to these potential "explosions" for our Hawaii plant materials which use these increase methods.

The pummelo, a grapefruit relative, is a desirable citrus. Selections obtained through a competition for pummelos have been grafted by Warren Yee of our U. H. Horticulture Department to provide a source of propagating material for our growers.

The rainbow shower, [*Cassia javanica* x *C. fistula*] the city tree of Honolulu, is a sterile hybrid which has not been successfully propagated by cuttings to my knowledge. All of the trees in our parks show the crooked trunks of an air layer. Sometimes the root systems are inadequate because of insufficient post-planting attention. The parent tree stands mutilated after layers have been taken. I have found that the rainbow shower can be budded onto *Cassia fistula* seedlings in the fall using a T-bud. This is hardly new, but only a few "old-timers" have made use of the vigorous root system of one of the parent species of this hybrid to achieve the same kind of growth in 8 months that an air layer may take 10 to 12 months to acquire after a 6 to 8-month rooting period.

We find also that our plumerias are fairly easy to bud. Thus, if we can use every bud on a branch of a new selection, we can increase it all the more quickly. This leads me to the last part of my story — the aids to propagation in our pharmacy of plant chemicals.

CHEMICAL AIDS TO PROPAGATION

The use of auxins to stimulate rooting and of gibberellins to stimulate sprouting of a dormant bud have been described to IPPS members many times before. I would like to mention, then, some chemicals which may give us more plant material with which to work.

These are compounds which stimulate branching and the development of shoots from axillary buds.

A synthetic cytokinin, 6-(benzylamino)-9-(2-tetrahydropyranyl)-9-H-purine (PBA, code name SD8339), has been shown to stimulate greater bud initiation in red ti as shown in Table 1. A greater percent of the initiated buds went on to develop into sprouts. This affords us more plant material, especially of the attractive dwarf ti so popular in the foliage industry.

PBA also hastened plantlet development on begonia leaf cuttings. It also gives us more buds when applied to the cut stump of a plumeria branch. Thus, more buds are available for our increase system.

The compound, ethylene, has been known for a long time to stimulate root initiation on certain herbaceous plant material and to overcome apical dominance. A new ethylene generating compound, ethephon, now permits us to apply a spray to plants to stimulate more lateral branches.

Table 1. Effect of PBA on bud initiation and development in *Cordyline terminalis* 'Onomea'

Treatment		Buds initiated	Buds developed	% buds developed
PBA	500 ppm	4.1	2.8	68.3
PBA	100 ppm	4.7	2.8	58.6
PBA	50 ppm	6.0	2.2	36.7
Control		4.0	1.5	37.5

The morphactins are a strange class of compounds with many effects on plant growth. It is interesting, however, that low concentrations stimulate lateral bud break in a variety of plants. If some of the extra side shoots can be removed and propagated, as in the case of the pineapple, we have again found ways to augment a low population of a desirable plant.

For plants, unlike people, an increased population is to be sought after. Whether we take the laboratory route of turning out thousands of "test tube babies", or more conventional approaches, with or without chemical aids, we can meet the challenge of more plants for a more livable environment.

MODERATOR RAUCH: Thanks very much, Richard, for a good presentation. Our next speaker, Bettie Lauchis, has been a professional horticulturist for about 20 years, even though her training is in the area of botany. She has recently established a botanical garden on the island of Kauai. Many of you who will take the side trip to that island will have an opportunity to visit with Bettie at her garden. Bettie Lauchis:

ORNAMENTAL MUSACEAE

MRS. BETTIE E. LAUCHIS

Horticultural Director
Olu Pua Gardens
Kalahea, Kauai, Hawaii

Musaceae is represented in the Hawaiian Islands by four genera and many species, all of which are ornamental, as well as some being useful in other ways. The four genera are *Musa*, *Heliconia*, *Strelitzia* and *Ravenala*.

Probably the most useful and fascinating genus is *Musa* with its many types of edible bananas and fiber products. The Polynesians brought bananas with them when they migrated to Hawaii over 1,000 years ago; it was one of their main staples and generally eaten cooked. Until the kapu was broken about 1820, however, Hawaiian women were forbidden to eat most bananas under penalty of death. Probably more legends and proverbs evolved around the banana than any other plant. In sacrifices to the Gods sometimes a banana stalk was used as a substitute for a human sacrifice. Many bananas do not produce edible fruit but have such a strikingly colorful inflorescence that they are grown ornamentally or as oddities. One of the oddest is the mai'a hapai which is Hawaiian for pregnant banana. Instead of the banana bunch coming out of the top of the plant it is borne within the trunk. The trunk swells like a pregnant woman and eventually will split open to expose the bananas which are small but edible. This is not an "instant legend" and the plants can be found in a few specialized gardens. Bananas are propagated from suckers and seeds; usually the edible bananas sucker only whereas the ornamental ones sucker and/or set seed.

The heliconias, named after Mt. Helicon in Greece, mostly from tropical and South America, defy description and numerous species are now growing in Hawaii. Propagation is by suckers and seeds; the plants are cut to the ground after blooming and the new shoots will bloom the following year. They do best in shade or semi-shade.

Heliconia aurantica: Medium-sized plant to 4'; leaves small, lanceolate to 7" without a petiole. Flower spathe in several planes, upright inflorescence small, to 6", bracts orange, flowers lemon-yellow. This species is one of the more desirable inasmuch as it blooms in the winter while most heliconias bloom in the summer. It would lend itself to pot culture and should be considered by any nurseryman featuring tropical plants. Native to Mexico.

Heliconia psittacorum : Parrot heliconia: Another medium heliconia to 4', leaves small, accuminate to 9", without a petiole;

flower spathe in planes, small upright inflorescence to 5", bracts orange, flowers orangish-red. When the bud is just opening you can see the resemblance to a parrot thus accounting for both the specific and common names. This is another desirable potted plant because it blooms all year; as one plant is cut to the ground another shoot is already at the flowering stage. Planted out here, however, this plant can become a problem as it spreads in all directions. Native to tropical America.

Heliconia humilis: Lobsters claw heliconia: Large plant to 9' with large banana-like leaves with a long petiole, erect inflorescence with red bracts in several close planes to 12", flowers orange with green tips. This is probably the most vigorous and common of all heliconias in Hawaii as it is truly striking when in bloom all summer long. However, it is falling into disfavor as the bracts hold sufficient water to create a breeding place for mosquitoes. This is rather large for pot culture but perhaps with the use of a growth retardant it could become a valuable asset to the mainland grower. Native to tropical America.

Heliconia rostrata: Another medium plant to 6', leaf blades to 2' on a long petiole, 1' inflorescence hanging in several planes, spathes strongly reflexed; bracts brilliant red with chartreuse tips. This summer bloomer is not too common in Hawaii but it's bound for popularity because of the hanging inflorescence and the brilliant color combination. This inflorescence also dries perfectly for dried flower arrangements with the two-toned effect becoming beige and brown. This could be a dramatic addition for the tropical plant specialist. Native to Peru.

Heliconia flava: A smaller heliconia to 4' with 2' leaf blades on a long petiole. The 8" upright inflorescence is in several planes with the upper bracts opening white but eventually turning vivid yellow. This species is new to Hawaii and as yet very rare but is headed for popularity because it is more adaptable to the home garden than many of the larger species. The inflorescence stays very showy for about three months when it blooms in the winter, giving it great possibilities for mainland pot culture.

Heliconia marantifolia, (syn. *H. metallica:*) A rather rangy and large plant to 8' with 3' leaf blade purple beneath, green above, atop a long petiole. Upright inflorescence in several planes with 3" green to reddish bracts on long peduncles, flowers red. This species is not as popular as many but it does have merit if a contrast in foliage is desirable. Also probably not desirable as a pot plant because of the size of the plant and smallness of bracts and flowers. Native to Columbia.

Heliconia caribaea: A vigorous plant much too large (to 12') for the home garden so is seldom seen throughout the Islands. The large banana-like leaf blades are to 5' with a long petiole. It has a brilliant yellowish-orange upright 1' inflorescence with overlapping bracts, extremely handsome when in bloom in the summer but at its peak for only about one month. Not recommended for pot culture except perhaps as a tub specimen. Native to the West Indies.

Heliconia illustris (syn. *H. insignis*): A magnificent plant to 4' with large multi-colored leaf blades atop 1' petioles. The leaves feel like skin, in colors ranging from whitish to reddish, with reddish veins, the entire plant a kaleidoscope of hews of white, red, copper, pink and rose. It does have inconspicuous greenish bracts and flowers near the base of the plant but they are completely insignificant compared to the foliage. It has never become common in Hawaii, which seems a mystery to me, but it certainly has potential as a foliage plant for pot culture on the mainland.

Heliconia platystachys: One of the heliconias commonly called hanging heliconia, along with several other species. Plants large to 12' with waxy white powder on the underside of large leaf blades to 4', atop a very long petiole. Inflorescence hanging, to 1½', bracts not touching or overlapping, bracts reddish also with a waxy white powder. Neither in foliage or flower is this particularly outstanding but it does indeed serve a purpose where a tall whitish background plant is wanted as this heliconia does not spread as readily as some of the others. It is also a summer bloomer but would be considered too tall and rangy to make an acceptable potted plant. Native to Guatemala and Columbia.

Heliconia latispatha: Another large plant to 10' with 4' leaf blades atop long petioles; also a handsome summer bloomer and very desirable where a bright orange is wanted in an area that can accommodate large plants. The 1' erect inflorescence is in several open planes of orange bracts, flowers yellow and green. Of course this one, too, would probably be too large and open to make an attractive addition for a tropical plant collector on the mainland. Native to Central America.

Heliconia sp.: Tall plant to 12', large leaf blades to 4', 1' erect inflorescence of several planes with reddish orange bracts, flowers green and yellow. Also too large for the average small yard or effective pot culture.

Musa koa'e– Variegated maoli: While this is called one of the native bananas, this means that it was used and eaten by the early Hawaiian natives and not that the plant is native; the first bananas were brought by the Polynesians as mentioned earlier. This beauty produces very ornamental green and white striped leaves in addition to its unique green and white striped fruit which must be cooked before eating. It is fairly small, propably to 6', and a real addition to the tropical scene. It is thought to be a form of *Musa paradisiaca* which probably originated in India.

Musa ornata: A small ornamental banana growing in clumps to about 5'. Small inedible fruit is preceded by decorative inflorescences with showy bracts of pinkish-rose color, usually on erect stems. Once a clump is established there seem to be blooms most of the year consequently this would also be a fine plotted plant.

Musa velutina: A prize ornamental clumping banana to 5'; 3" bright pink fruit of a velvety texture, later splitting open forming what looks like a flower made of white cotton. The fruit is inedible except to the birds who scatter the seeds throughout the gardens. It makes an excellent potted plant because by the time one plant is through blooming and has been cut off another is ready to take its place. Native to India.

Musa coccinea: Probably the showiest of the ornamental bananas, a 4' clumping species with brilliant red upright inflorescences consisting of red bracts with yellow tips, total length about 1'. These hold up for several days in flower arrangements. It sometimes sets inedible 2" greenish-yellow bananas. This has a long blooming season throughout the spring and is unsurpassed as a potted specimen. Native to S. China.

Musa zebrina: This is a taller ornamental banana to 15' with handsome variegated leaves of green speckled with copper. It is a bit too tall and sparse to be of use in a small garden but might lend itself to pot culture with one of the growth retardants.

Musa arnoldiana: A large ornamental banana to 15', propagated from seeds rather than suckers. Good possibilities for pot culture with its decorative leaves, providing its growth could be limited. Originally from Africa.

Strelitzia reginae — Bird-of-paradise: This is not only well represented in Hawaii but in California and Florida as well; it's even the city flower for Los Angeles so I know you're all familiar with it. Some of you may not realize that when the flowers have dried they can be sprayed gold for stunning dried flower arrangements. Native to Africa. You may not be familiar with *Strelitzia nicolai*, a tree-like species to 20' with large white flowers enclosed in large brownish bracts, each weighing about four pounds.

Ravenala madagascariensis — Travelers' tree or travelers' palm: Unique with its gigantic fan-shaped cluster of leaves at the top of an unbranched woody trunk, to 30' It is commonly called travelers' tree because water will accumulate at the junction of the petiole with the trunk and could be a source of drinking water if you were stranded. This water reserve serves as an extra support to the leaves in a strong wind. From Madagascar.

MODERATOR RAUCH: Thank you, Bettie, for that fine discussion on bananas. We have some exotic happenings occuring on the mainland. Our next speaker from the "Evergreen State" also did his graduate work at UCLA and later went to Florida, then returned to the State of Washington. I would like to call on George Ryan to talk on "Chemical Control of Development." George:

CHEMICAL CONTROL OF SOME ASPECTS OF PLANT DEVELOPMENT[1]

GEORGE F. RYAN

Washington State University
Western Washington Research and Extension Center
Puyallup, Washington 98371

Abstract The use of growth retardants to induce flowering of ornamental plants, especially azaleas and rhododendrons (*Rhododendron* spp.), is reviewed Examples of recent data show approximately 200% increases in number of flower buds on outdoor container grown 'Anna Rose Whitney' rhododendrons treated with Alar, Phosfon or Cycocel in their second season of growth.

The relationship between nutrition and response to growth retardants is discussed Nitrogen levels probably are as important for the growth retardant response as reported for P levels. Data presented show a significant reduction in number of flower buds where N fertilization was reduced or omitted, with only a reduction in leaf N from 1 9 to 1.7%

Results are presented of the use of chemicals to prune and induce branching of *Photinia x fraseri* The number of side branches was increased from 0.6 to 8 4 per plant by treatment with a combination of the pruning agent Off-Shoot-O and the cytokinin SD 8339.

Nurserymen have become skillful in the use of nutrients, water, temperature, and sometimes supplemental light, to grow vigorous plants to marketable size in a minimum of time. This combination of factors for optimum growth rate does not always result in a plant properly developed in terms of shape, branching habit, or presence of flower buds. Much attention has been focused in recent years on the use of growth regulating chemicals to modify these characteristics of plant development.

CHEMICALS TO PROMOTE FLOWERING

Effects of growth retardants on flowering of azaleas and rhododendrons (*Rhododendron* spp.) were first reported by Stuart

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(28) and Cathey (2, 3). Rooted cuttings of rhododendrons were grown in a greenhouse with supplemental night lighting and treated by applying soil drenches of Phosfon (2,4-dichlorobenzyl tributyl phosphonium chloride), or Cycocel [(2-chloroethyl) triethylammonium chloride]. or by spraying each growth flush with B-Nine (succinic acid 2,2-dimethyl hydraside). Treated plants usually produced flower buds on the third growth flush. After three months of short photo-period followed by two months at 50°F, flowers were forced in a greenhouse with 65°F night temperature. Untreated plants remained vegetative until the ninth flush, which occurred in the third season of growth.

Cathey and Taylor (6) reported that the stems of Phosfon-treated plants were limber and yellow and the flowers were smaller and paler in color than normal. On Cycocel treated plants the vegetative growth subtending the terminal flowers developed and obscured the flowers. The leaves of Cycocel-treated plants developed brown margins during the forcing period. When further evaluated on 'Roseum Elegans', Cycocel failed to give satisfactory growth and its use was discontinued. B-Nine sprayed at an excessive rate (1.0%) greatly delayed flower development and reduced flower size and color intensity. As a soil drench it was highly toxic to rhododendrons.

Following the procedures of Cathey, Crossley (10) reported development of flower buds on Phosfon-treated 'Anna Rose Whitney' plants in less than 12 months from taking the cuttings. He did not observe a weakening of the stems from Phosfon treatment. He has had response from B-Nine and Alar but considers the results from Phosfon more dependable (11).

A number of other studies of the response of several cultivars to Phosfon and Cycocel drench, B-Nine sprays and supplemental lighting have been reported (8, 9, 12, 20, 27).

Ticknor and Nance (31) were the first to report studies with growth retardants on field grown rhododendrons. They recorded 100 to 300% increases in number of flower buds on 'Roseum Elegans' plants sprayed with B-Nine or Cycocel in the nursery during their third year of growth. No adverse effects on plant color or on flower development were observed. A slight advance in the blooming date of Cycocel-treated plants was reported. Two applications of B-Nine at 0.5% two weeks apart were less effective than Cycocel at 1844 or 3688 ppm. There was very little response from Cycocel at 1844 ppm on the same cultivar in 1967 experiments, even when two additional applications were made on the second growth flush (29).

Because of the early reports of unsatisfactory results with Cycocel and the weakening effect of Phosfon on plant growth, work in western Washington with retardants was initially confined to Alar (succinic acid 2,2-dimethyl hydraside) (25). Two sprays of 1 to 1.5% Alar were applied, the first one as soon as growth buds had expanded enough to expose new leaves, and the second one two weeks later. This treatment has greatly increased the number of flower buds on some cultivars. All of the work has been done with field nursery stock, or container plants outdoors or under lath shade.

'Humming Bird' plants, which had only 3 to 5 buds per plant in their second and third years without treatment, produced 18 to 22 buds with optimum rates of Alar. 'Anna Rose Whitney' plants in containers treated in their second or third season responded by producing up to 8 times as many flower buds as untreated plants. Cycocel sprays at 1844 and 3688 ppm on field-grown 'Anna Rose Whitney' in 1969 and 1970 were less effective than 1.25% Alar. A soil drench with Cycocel or Phosfon gave nearly the same response in 1971 as two sprays of Alar at 1.25% or one spray at 2.5% (Table 1).

In cultivars that respond to growth retardants, the effect apparently is additive to the influence of optimum nutritional status for flower bud formation. Myhre and Mortensen (22) reported that supplying an abundance of phosphorus to the roots of 'Cynthia' plants at the time of planting resulted in large increases in number of flower buds conpared with plants receiving only surface application of phosphorus. It was later reported that the number of flower buds was further increased by application of Alar on plants that received high levels of P (9, 25).

Nitrogen levels probably are as important for the growth retardant response as P levels. In one experiment with field grown 'Anna Rose Whitney', Alar increased flower buds 160% in plants fertilized by pre-plant incorporation of P and annual surface application of N (Table 2). Omitting the N application reduced flowering much more than omitting the P application. These plants were not obviously N deficient. Leaf N was reduced from 1.9% to 1.7%, but plant growth and color were good.

Alar, Phosfon and several other growth retardants increased the number of flower buds on deciduous azaleas (26). Application early in July reduced plant height approximately 20%. Later applications did not significantly affect plant height. Treatment in August, especially at the highest rate (20,000 ppm), delayed flower opening a week to 20 days the following spring.

Accelerated flowering from growth retardant treatment has been reported for various other ornamentals, including *Gardenia* (7), *Camellia* (13), *Bougainvillea* (14), *Begonia* (15), *Pyracantha* (17), *Ilex* (21) and *Impatiens* (23).

CHEMICALS FOR PRUNING AND INDUCING BRANCHING

The use of chemicals for pruning to control plant shape has become an accepted practice with a few kinds of plants, particularly evergreen azaleas and chrysanthemums. The action of methyl esters of C_8 to C_{12} saturated fatty acids and C_8 to C_{12} fatty alcohols on active meristems of a number of kinds of plants was first reported by Cathey, et al. (5). More detailed information on techniques and the response of more than 80 species and cultivars have been reported (4, 18, 19).

For chemical pruning to be effective in producing a well branched plant, growth of more than one axillary bud is essential. Many plants when pruned either mechanically or chemically have a tendency to resume growth from the uppermost axillary bud. Pruning of those plants only temporarily delays the elongation of the main axis or a few branches and does not result in the desired plant shape. One effect of the group of growth regulators known as cytokinins is to reduce apical dominance and promote growth of axillary buds. Cytokinins have been reported to increase branching of a number of floricultural crops, including induction of bottom breaks in greenhouse roses (1, 16, 24).

Branching of *Photinia x fraseri* was greatly increased by 3 applications of 6-benzylamino-9-(tetrahydropyran-2-yl)-9H-purine

Table 1. Effect of growth retardants on flower bud formation and height of 'Anna Rose Whitney' rhododendron[1].

Treatment	Number of flower buds[2]	Plant height[2] (cm)
Check	2.6 a	43.7 a
Alar 12,500 ppm 1 application	2.7 a	40.9 abc
Alar 12,500 ppm 2 applications	9.0 c	37.6 bcde
Alar 25,000 ppm 1 application	8.9 c	35.6 de
Phosfon L drench 0.4 g/plant	7.3 bc	41.7 ab
Phosfon L drench 0.8 g/plant	7.8 bc	35.8 cde
Cycocel drench 0.8 g/plant	3.6 ab	40.4 abcd
Cycocel drench 1.6 g/plant	7.7 bc	38.4 abcde

[1]Plants started from cuttings August, 1969; growing outdoors in 2 gal. cans; treated May, 1971.

[2]Treatments followed by the same letter are not significantly different at the 5% level

Table 2. Effect of nitrogen and phosphorus applications on response of 'Anna Rose Whitney' rhododendron to Alar[1].

Fertilizer rate[2] (lb/A)			
N	P	Alar application[3]	Number of flower buds[4]
40	105	—	5.9 bcd
20	105	—	4.0 ab
0	105	—	3.1 a
40	0	—	5.9 bcd
40	105	+	15.3 f
20	105	+	11.2 e
0	105	+	5.7 abc
40	0	+	11.2 e

[1] Rooted cuttings planted in Puyallup loam soil June, 1969.

[2] Nitrogen was applied annually as ammonium sulphate; P was applied by preplant incorporation of treble phosphate; K was applied annually in all treatments

[3] Two applications at 12,500 ppm May 28 and June 12, 1970.

[4] Treatments followed by the same letter are not significantly different at the 5% level.

Table 3 Effect of pinching, Off-Shoot-O and SD 8339 on branching of *Photinia x fraseri*[1]

Treatment[2]	Number of side branches per plant[4]
Check	0.6 a
Hand pinch[3]	1.1 a
Off-Shoot-O	1.3 a
Hand pinch + SD 8339	3.5 bc
Off-Shoot-O + SD 8339	8.4 d
SD 8339	1.9 abc

[1] Rooted cuttings in 1 gal cans.

[2] Treated July 9 SD 8339 at 1000 ppm; second and third applications of SD 8339 July 16 and 23; Off-Shoot-O applied only July 9, at 4.2% fatty acids.

[3] Soft tips removed July 9.

[4] Treatments followed by the same letter are not significantly different at the 5% level

(SD 8229). The greatest response was in combination with the chemical pruning action of the methyl esters of C_6 to C_{12} fatty acids (Off-Shoot-O) (Table 3). Leaves on one or two growth flushes following treatment were smaller, especially in length, than normal. Later growth was normal in appearance, resulting in an attractive, well-branched plant.

Chemicals such as these can help to eliminate some of the hand labor required to properly shape a developing plant. As they become available commercially, and as experience in their use increases, they should find a place in nursery practice.

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MODERATOR RAUCH: Thank you, George. I am now going to call on Clyde Elmore, Agriculture Extension Specialist, University of California, Davis, to talk on pollution by weeds. Clyde: .

WEED POLLUTION

CLYDE L. ELMORE

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Davis, California 95616

Plants are a necessary complement of our environment and lend much beauty and pleasure to man. Plants may also be detrimental in many ways to the health, wealth and well being of man and animals.

Much physical harm and discomfort arise from man and animals contacting thorny bushes and trees such as thistles, starthistle, gorse, or *Opuntia sp.*, cactus, as well as plants with lesser armament. Others of this type include members of the families *Cactaceae* and *Euphorbiaceae*, generally of the desert regions of America, Africa and Asia. Plants also are poisonous to man and animals. In the western United States sheep losses from feeding on halogeton are great. In one reported case in Idaho 1,620 sheep were lost in a single day.

The expenditure of funds and lack of crop return for the control of weeds cost the people of California over 374 million dollars for a year (over 1 million/day). In the U.S. a staggering 2.5 billion figure was suggested in 1968.

Although the total costs of weed control in ornamentals (Table 1) appear small in proportion to large acreage crops such as corn, the dollar per acre figure is one of the highest of any crop. As in other crops, costs increased considerably during a period from 1959 to 1968. With increased labor costs, costs have undoubtedly continued to rise.

Plants are not always weeds. They are considered to be weeds when they interfere with land or water resource utiliza-

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Plants are not always weeds. They are considered to be weeds when they interfere with land or water resource utilization, or adversely affect human welfare. A plant is a weed only in terms of human attitude; thus, a plant that is a weed to one man may be a wildflower to another. All plants may be weeds in given circumstances but no plant is always a weed, although it is difficult to imagine when poison oak or ivy would not be considered weeds.

Unwanted plants in nursery plantings (containers, field plantings, and ground covers) can be considered pollutants. They often are considered pollutants in the midwest and eastern United States when ragweed (a hay fever plant) is shedding pollen.

The principal weed pollutants in the California container nursery industry are *Oxalis corniculatis*, yellow woodsorrel; *Senecio vulgaris*, common groundsel; *Poa annua*, annual bluegrass; *Euphorbia maculata*, prostrate spotted spurge; *Sonchus oleracea*, common sowthistle; and *Cardamine oligosperma*, lesser-seeded bittercress. (Table 2) Susceptibility to some of the newer herbicides are given. In a study of weed control costs to growers in Massachusetts in 1967, O. Johnson[1] reported that few nurserymen knew how much weeds are costing them. In field plantings, however, costs ranged from $123/A to $600/A among seven nurseries. In transplant beds costs jumped to $2,916/A to $6,256/A.

In a presentation made in 1971 at the Western Region IPPS meeting in Santa Barbara, I reported the cost of hand weeding newly-planted ground covers was $2,941 per acre where no herbicide was used. On some herbicide-treated areas costs for hand weeding including herbicide ranged from $281 to $388 per acre. These costs were for weeding two months after, treatment; little additional hand weeding was needed during the remainder of the season. An additional trial was conducted at the South Coast Field Station, Tustin, California, during 1972 and combined hand weeding and herbicide costs were determined for the full year of establishment (Table 3). While these costs appear quite high, the plot area was perhaps no weedier than some roadside plantings.

Weeds can compete for light and nutrients with ornamental plants so severely that increases in growth of ornamentals of 50% or more can be realized where weed control measures are employed. Hand weeding is not a complete answer to eliminating or even greatly decreasing weed populations. In four California container ornamental tests in 1972-73, hand weeding decreased weeds over a three month period an average of 29%. (Table 4). By contrast, several herbicides reduced weeds on the average from 53 to 88 percent over the sample period. The most effective herbicide was oryzalin (SURFLAN®) a new material not yet on

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[1]Johnson, Oscar, "*Costs of Nursery Weed Control*", *The Rhode Island Nurserymen's Newsletter*, September, 1967, No. 31.

the market but one of particular interest to nurserymen. Oryzalin, a soil-active herbicide, should be available by fall of 1974. Oryzalin appears very safe to established ornamental plants (Table 5), and it is also controlling some of the more important weed species (Table 4). Weeds such as oxalis (Table 6), annual bluegrass as well as other annual grasses are controlled. Control has been less effective with spotted spurge and common sowthistle. Oryzalin, like trifluralin, nitralin, and DCPA are quite weak on common groundsel and lesser-seeded bittercress.

Another herbicide of particular interest is oxadiazon (RONSTAR®). This compound also appears to be safe on most woody ornamental plants and ground covers and should find a place in ornamental weed control (Table 5).

Although alachlor (LASSO®) and dibutalin (AMEX 820®) appear safe enough to use in ornamentals grown in containers, they do not afford control of those weeds that are tolerant of available herbicides. The residual control is shorter than nitralin or oryzalin.

Residual control of annual weeds in containers may be from 3 to 4 months following treatment. This short residual control of weeds is principally due to the high adsorption capacity of the organic potting mix and the excessive amount of water needed by plants grown in containers. In ground cover field plantings, residual control may last 6 months or longer. The residual characteristics of the newer herbicides are similar to simazine. Safety to ornamental plants (Table 4) is many fold greater with herbicides like trifluralin, nitralin, DCPA, oryzalin, dibutalin, than simazine. Mammalian toxicity, like simazine, is quite low.

Although new herbicides are being developed that appear safe to use in ornamental crops, usage may be slow to develop. Registrations for use in ornamental crops are more difficult and labeling by the chemical companies must be reviewed and implemented for use. Herbicides must also be used as a tool in addition to good management and cultural practices that decrease seeding of weeds and introduction of foreign seeds.

Table 1. Cost of Chemical Weed Control in the United States. 1968

Crops	Total (1,000 dollars)	Avg/Acre (dollars)
Ornamentals	1,810	20.26
Lawns	112,708	29.46
Corn	204,483	4.18

Table 2. Relative Control of 12 Weed Species Common to Container Ornamentals With 8 Herbicides

	Preemergence Control[1]																	
	trifluralin 2 lb/A	trifluralin 4 lb/A	nitralin 2 lb/A	nitralin 4 lb/A	oryzalin 2 lb/A	oryzalin 4 lb/A	dibutalin 4 lb/A	dibutalin 8 lb/A	DCPA 10 lb/A	DCPA 15 lb/A	oxadiazon 2 lb/A	oxadiazon 4 lb/A	alachlor 2 lb/A	alachlor 4 lb/A	simazine 1 lb/A	simazine 2 lb/A	Na-propamide 4 lb/A	Na-propamide 8 lb/A
Amaranthus retroflexus (pigweed)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Cardamine oligosperma (bittercress)	●	▲	●	▲	●	▲	●	▲	●	●	⊕	⊕	▲	▲	●	●	●	●
Chenopodium album (lambsquarters)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	▲	⊕	⊕	⊕	⊕	⊕
Conzya (marestail)	●	●	●	●	●	▲	●	●	●	●	▲	▲	-	-	⊕	⊕	●	▲
Digitaria sanguinalis (crabgrass)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	▲	⊕	-	-	●	●	⊕	⊕
Echinochloa crusgalli (barnyard grass)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	▲	⊕	●	▲	▲	⊕	●	▲	⊕	⊕
Euphorbia maculata (spotted spurge)	●	▲	●	▲	●	▲	●	▲	▲	⊕	-	-	-	-	●	●	▲	⊕
Poa annua (annual bluegrass)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	▲	⊕	▲	▲	▲	▲	⊕	⊕	⊕	⊕
Portulaca oleracea (purslane)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	▲	⊕	⊕	⊕	-	-	⊕	⊕	-	-
Oxalis corniculatus (weeping woodsorrel)	●	▲	●	▲	▲	⊕	●	▲	●	●	-	-	●	●	▲	▲	-	-
Senecio vulgaris (common groundsel)	●	●	●	●	●	▲	●	●	●	●	▲	▲	●	●	▲	⊕	●	●
Sonchus (sowthistle)	●	●	●	●	●	▲	●	●	●	●	▲	▲	●	●	▲	⊕	●	▲

⊕ - good to excellent control 70% or higher; ▲ - fair to good control 50-70%; ● - poor to fair 20-50%; - not sufficient data

*lb/A is pounds active ingredient per sprayed acre

Table 3. Field Grown Ground Covers Weed Control Costs (Dollars)

Herbicide	lb a.i./A	Herbicide* cost	Weeding cost/A	Total cost/A	Total cost per 1000 sq. ft.
diphenamid + trifluralin	10 & 2	82	551	632	15
nitrofen	4	38	1,892	1,930	44
alachlor	4	38	853	890	20
dibutalin	4	32[1]	954	988	23
oryzalin	2	36[1]	515	550	13
oxadiazon	2	40[1]	396	435	10
nitralin	2	36	1,275	1,311	30
nitrofen + nitralin	4 & 2	66	533	600	14
hand weeded control	-	-	5,063	5,063	116

*Herbicides applied 7/13/72; 3/9/73 ($7.50 application cost)

[1]estimated price (no market price established)

Table 4. Average Over-all Weed Control from 4 Trials - Percent

Herbicide	Rate* lb a.i./A	1	2	3	4	AVG
DCPA	10	42	58	65	49	53.5
DCPA	15	50	75	76	36	59.3
trifluralin	2	26	81	88	59	63.5
trifluralin	4	51	64	98	76	72.3
alachlor	2	53	68	64	46	57.8
alachlor	4	52	55	75	56	59.5
alachlor	8	42	75	92	68	69.2
oxadiazon	1	54	69	77	78	69.5
oxadiazon	2	64	73	88	78	75.8
oryzalin	2	50	55	99.3	82	71.6
oryzalin	4	75	80	99.6	82	84.2
oryzalin	8	90	72	99.7	92	88.4
hand weeded	-	20	64	4	29	29.3

*lb a.i./A = pounds active ingredient per sprayed acre

Table 5. Plant Species Tested by Herbicide[1]. Number - Maximum 1b a.i./A Applied without injury.

Plant Species	simazine	trifluralin	nitralin	oryzalin	alachlor	oxadiazon	DCPA	Na-propamide	pronamide	nitrofen	dibutalin
Ajuga reptans	S	-	2*†	-	-	-	8*	8*	2*†	4*	-
Berberis darwinii	-	4	4	4	8	4	-	-	-	-	4
Buxus microphylla var. *japonica*	2*	4	-	-	2*	-	15	16*	2*†	-	-
Callistemon citrinus	2	8	8	8	8	2	15	-	-	-	8
Carpobrotus edulis[2]	S	2	2	4	8	4	8	4	2	4	8
Ceanothus gloriosus	-	-	4	4	4	4	-	-	-	-	4
Cotoneaster lacteus (*c. parneyi*)	2	4	-	8	8	2	15	-	-	-	-
Delasperma alba	S	2*	2*	4*	8*	2*	8*	4*	2*†	4*	8*
Erica canaliculata 'Rosea'	0.5	-	2	-	8	-	-	16	2	-	-
Escallonia 'Fradesi'	-	4	1	8	8	2	15	-	-	-	-
Eucalyptus sideroxylon	-	4	-	8	8	2	15	-	-	-	-
Euonymus japonica 'Aureo-variegata'	2	4	-	8	8	2	15	-	-	-	-
Gazania splendens	S	2	2*	4*	-	-	8*	8*	2*†	8*	-
Grevillea 'Noelli'	0.5*	2	2*	-	8*	-	-	16*	2*	-	-
Hebe buxifolia	0.5*	2	2*	-	2*	-	-	8*	2*†	-	-
Hedera canariensis	0.5*	2*	2*	4*	8*	4*	8*	8*	2*†	8*	8*
Hedera helix	0.5*	2	2*	-	-	-	8*	8*	2*	8*	-
Hypericum calycinum	S	2	2*	-	-	-	8*	4*	2*†	4*	-
Ilex aquifolium 'San Gabrial'	3	4	-	8	8	2	15	-	-	-	8
Ilex cornuta 'Rotunda'	3	4	-	8	8	2	15	-	-	-	-
Juniperus chinensis 'Torulosa'	4	4	-	8	8	2	15	-	-	-	-
Juniperus chinensis 'Wiltonii'	2	4	-	8	8	2	15	-	-	-	-
Juniperus sabina 'Tamariscifolia'	4	4	-	8	8	2	15	8	2*†	-	8
Ligustrum japonicum	2	4	4	8	8	4	15	-	-	-	8
Hymenocyclus luteolus [*Malephora luteolum*]	S	2	2*	2*	8*	-	8*	4*	2*†	8*	-
Myrtus communis	-	4	2	8	4	1†	15	-	-	-	4
Nerium oleander	2	4	4	8	8	2	15	-	-	-	-
Osteospermum fruticosum	S	2*	2*	4*	8*	4*	8*	8*	8*	8*	8*
Photinia x fraseri	1	4	-	8	8	2	15	-	-	-	-
Pinus thunbergiana	8	4	-	8	8	2	15	-	-	-	-
Pittosporum tobira	1	4	-	8	8	2	15	-	-	-	8
Pyracantha coccinea	2	4	-	8	8	4	20	8	-	-	-
Rhaphiolepis indica	8	4	-	8	8	2	15	-	-	-	-
Sedum brevifolium	0.5*	2*	2*	4*	4*	2*†	8*	4*	8*	8*	8*
Ternstroemia gymnanthera	-	4	-	8	8	2	15	-	-	-	-
Trachelospermum jasminoides	-	4	-	8	8	2	15	-	-	-	-
Vinca major	0.5*	2*	2*	4*	8*	2*	16*	-	-	4*	8*
Vinca minor	0.5*	2*	2*	4*	8*	4*	4*	8*	2*†	8*	8*
Xylosma congestum	0.5	4	-	8	8	2	15	-	-	-	-

[1] Plants established from liners in gallon containers; a minimum of 3 weeks.

[2] Planted as unrooted cuttings.

* Newly planted rooted liners.

S Sensitive.

† Injury occured at lowest rate applied.

\- Sufficient data not available.

Table 6. Control of *Oxalis corniculatus* With Four Herbicides in Container Grown Ornamentals

Herbicide	Rate lb a.i./A	Weed Control[a]	*Pyracantha* sp. Growth Indices[b]	Top Weight (gms)[c]
trifluralin	4.0	9.1	97.9	101.8 a
oryzalin	2.0	10.0	84.2	98.7 a
oryzalin	4.0	10.0	66.2	93.7 a
oryzalin	8.0	10.0	108.8	97.4 a
linuron	1.0	9.2	100.6	80.8 abc
simazine	2.0	4.2	84.6	98.4 a
simazine	4.0	9.1	77.5	100.8 a
simazine + charcoal	4.0	5.1	103.5	68.3 c
linuron + charcoal	1.0	8.0	118.7	82.3 abc
charcoal	-	9.7	104.1	72.4 bc
weeded	-	2.8	72.0	94.9 a
non-weeded	-	1.9	68.2	90.8 ab

[a]0 = no effect; 10 = complete control

[b]$\frac{\text{Height in cm x diameter in cm}}{2}$

[c]Any mean followed by the same letter is not significantly different at the 0.05 level

Further research is being conducted on several aspects of the control of weeds, including application methods of sub-surface blading for control of *Convolvulus arvensis* (field bindweed), microwave irradiation of seeds as preplant treatments, as well as determining safety and use of new and established herbicides. The future is bright for methods to combat weeds in our environment.

MODERATOR RAUCH: Thank you, Clyde. I would now like to turn the program back to George Oki.

GEORGE OKI: For the second half of this morning's session Tok Furuta will act as moderator.

TOK FURUTA: We will now resume the program with a discussion by Howard Brown on his experiences in visiting some nurseries in England.

A DAY AT EXBURY

HOWARD C. BROWN

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During the spring quarter this year I had a sabbatical leave from my teaching assignment at Cal Poly. My wife and I made a horticultural tour of the Southern United States and spent an enjoyable six weeks in Great Britain.

When we started planning the British junket over a year ago we contacted Richard Martyr, a member of IPPS, G.B. & I. Region, and Director of the Horticulture College in Pershore. Richard was most helpful in setting up a tour of British horticulture.

Two of our most worthwhile and interesting experiences in Britain were the IPPS Day at Exbury Estate and the Chelsea Flower Show. I want to tell you today about Exbury.

This famous estate, the home of the Rothschilds, is located a short distance from Southampton in Southern England. Our visit was on May 9 and we were hosted by the IPPS Region of Great Britain and Ireland. The estate consists of over a thousand acres. In addition to the home grounds there is an arboretum of over 250 acres devoted to rhododendrons and other exotic species, a game bird farm, a wholesale nursery, and a retail garden centre. The grounds are open to the public and during the spring are visited by many thousands of people. Attendance is especially high on weekends.

We had a guided tour of the nursery operation and found a variety of crops being propagated in the glasshouses and cold frames. In addition to rhododendrons and azaleas there were camellias, Japanese maples and conifers in profusion.

All the soil is purchased from an aggregate company and instead of being the traditional John Innes compost it is a U.C. type mix. Osmocote is incorporated in the blending operation at the rate of five pounds per yard.

The glasshouse structures were particularly interesting and I said to myself, "They don't build 'em like that today." Constructed in 1925 of teak wood, they are still in excellent condition. While they were built as show houses or hobby houses, they lend themselves reasonably well to commercial production. During the spring they are double-decked with newly-propagated plants.

Most cuttings are potted into clay pots in a light soil mix. When established, they are set onto level benches or plastic-lined ground beds with a layer of sand and watered by capillary action. This appears to work well in the climate of Southern England.

Exbury is most famous for the Exbury azalea, many cultivars of which have been introduced to the nursery trade. We were told that one of the Rothschilds had introduced over 1000 cultivars.

One of the most impressive crops now being grown is the "Exbury Extra Heavy Standard Tree." Bare root two-year old trees are purchased from British or Dutch nurseries and lined out on 8' x 8' spacing. They are staked with sturdy poles and allowed to grow for 3 to 4 years at which time they are semi-balled for sale. This makes a tree of approximately 3-inch diameter with a height of from 12 to 15 feet. Most of these are sold to "local authority" (city or county agencies) and they produce a quick effect as street trees and shade trees. Drip irrigation was used experimentally and proved so effective that many acres of it are being installed.

While British nurseries are generally small by American standards, the Exbury tree program is not. By the end of this year they will have over 400 acres of these trees — approximately 50 percent of them in the Exbury area and the remainder at several other locations in Britain.

I brought home one strong impression of the British as a businessman.Whatever he does, he does with great pride. He wants to be the best in his class.

TOK FURUTA: Our next speaker is again not a stranger to those of us in California. Carl Zangger is vice-president of Perry's Plants, headquartered in La Puente, California, but they have growing grounds in several other places as well. Carl is a past president of the California Association of Nurserymen. I would now like to present Carl Zangger who will talk on greenhouse coverings. Carl:

GREENHOUSE COVERS — POLYETHYLENE, FIBERGLASS, OR GLASS?

CARL ZANGGER

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When I was asked to speak on this subject, 'Polyethylene, Fiberglass or Glass — Which Would I Prefer', I had never seriously considered whether I really had any deep preferences. Probably like most growers we had gone along solving problems as they came up in the most suitable manner, dictated by economic necessities. I think it is safe to say there are a far greater number of growers in the United States today who have had to consider the necessities of economics in this decision than those fortunate enough to have ample funds available so that the decision could be one of a purely technical or scientific decision. Not being a student or a researcher I am not going to attempt to delve into all the various considerations of depreciation, taxes, investment costs, etc. that should be considered as I am sure that each one of us is going to have to make these decisions for himself depending upon his local situation with regard to taxes and building codes and his own requirements for climate control.

Let us consider the various advantages and disadvantages of each:

Polyethylene;

Advantages: Low initial cost for supporting structure.
High light transmission — good diffusion.
Tight and weather proof.
Heat Saving — By using double layer with air space one can save approximately 40% in heating costs.
Versatility of use of structure.
Good humidity retention — less watering.
Because of lower capital investment — lower taxes.

Disadvantages: Short life — generally six months to one year, depending upon type of polyethylene
Easily damaged — vulnerable to storms.
Condensation and drip problems.

Fiberglass:

Advantages: Economy — less expensive than glass.
Ease of construction. Lightweight. Rigid.
Diffused light.
Semi-permanence; good for several years.
High humidity retention.
Tight and weatherproof.

Disadvantages: Not as permanent as glass.
Light transmission deterioration. Expense of treatment.
Taxes higher for more permanent type structure.

Glass:

Advantages: Excellent light transmission.
Permanent.
No condensation problems.

Disadvantages: High initial cost.
More heat requirement — not as weathertight.
Higher maintenance.
Taxes higher for permanent structure.

These are the most obvious advantages and disadvantages of each. We could more than likely get into some lively discussion about the quality and type of light rays transmitted, etc., but in my requirements these more technical aspects were not major considerations.

We are growers of bedding plants and ground cover plants, grown in flats. We have a high seasonal requirement for a great deal of greenhouse space during winter and spring. We have a high requirement for shade house spacing summer and early fall. Initially in the construction of our nursery we erected several conventional glasshouses. We like these very much and I would not want to give them up. We use them for production of our seedlings principally, and for other of our most vulnerable crops. I like the feeling of security we have on a windy day or night that our hundreds of flats of seedlings in various stages are not going to lose their protection.

We also have several acres of poly houses with which I am very pleased. As I mentioned we have a very large requirement for greenhouse space in spring. Poly gives us this space. We have experimented with many types of poly structures through the years and now have several with which I am very pleased. They offer reasonable security to storms and, with good equipment for climate control, are as good as or even better than glass for production of our type of crops. Also, we can remove the poly covers in summer and cover with saran shade cloth to give us additional shade houses for production of our summer crops.

We have, as I mentioned, several types of structures. We are now adapting all of these with the relatively new method of fastening poly down by clamping it between two pieces of extruded aluminum which are made specifically for this purpose. This is a great time and labor saver in the annual job of replacing the poly covers and provides a very secure method of fastening. We are also now covering most of our poly houses with two layers of poly and blowing air from within the houses between the two layers to separate them and provide air space which acts as an insulating barrier, resulting in a great reduction in heating costs. Another benefit of the air inflation is that we have less flapping of the poly which extends the life by several weeks or months.

We also find that we have far less vulnerability to wind damage with the inflated poly covers. One other advantage is the tremendous reduction in condensation within the house.

We have one fiberglass house which does a good job for us. However, I am not as fond of it personally as I am with either our glasshouses or our newer poly houses. I will admit that our fiberglass house was an economy model. We used a light-weight fiberglass that was not coated, consequently I can see considerable deterioration in light transmission. We have not, in all fairness, given the maintenance to the fiberglass that it should have. In last winter's severe wind in our area several panels were blown off the roof so there is some vulnerability. But considering the cost of the structure it was a good investment for us and fills a need we have for production of several of our crops. I have seen several very fine ranges of fiberglass houses of which the owners were very proud and producing some top quality materials.

In conclusion, I would say that we have a need in our operation for all three. Sure we could do with any one of them and do an excellent job but, if I had my druthers, I would do just as we are. I think they all have their place and we need each one.

SOME LITTLE KNOWN METHODS OF VEGETATIVE PROPAGATION OF SELECTED PLANTS

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VEGETATIVE PROPAGATION USING *IN VITRO* CULTURE TECHNIQUES

When the main objective is the rapid multiplication of a selected individual, *in vitro* culture techniques may prove to be the answer. Ever since Morel showed that thousands of potential plants could be produced from one meristem of a *Cymbidium* in a year, it has been the dream of tissue culture workers to repeat 'meristem culture of orchids' with other plants. Plant breeders are particularly interested, as years may elapse between hybridizing and obtaining flowers. When selections are made, selected individuals must be bulked up as rapidly as possible into clones so that cultivar trials may then be carried out. Although plant breeders are only too aware that genetical variation may occur in culture and that precautions must be taken, nevertheless Eucarpia, the European Plant Breeding Association, spent much of its five-day conference, in Leeds, in July, 1973, discussing aseptic methods of vegetative propagation.

The range of material which responds to *in vitro* culture techniques is increasing rapidly. Recently, John Innes Institute has been successful with a number of flower bulbs and corms, including hyacinths, lilies, muscari, narcissi, freesias and gladioli, but so far have failed with tulips. Because 10 years, at least, generally elapse between hybridizing and the commercial introduction of a new bulb selection, attempts to reduce the long period of time are to be welcomed.

Virologists are also keenly interested in aseptic methods of vegetative propagation. Returning to Morel's orchids, it will be remembered that his technique for rapid multiplication followed a chance observation when he was culturing meristems with the aim of obtaining healthy plants from them, because the original plants had cymbidium mosaic. If meristem culture samples, from a flask of young orchid plantlets prove, on testing, to be free of certain viruses then it may be assumed that the remaining plantlets are likewise free. (Should the sample show the presence of these viruses then all plantlets would be destroyed). This is now the aim — to clean up infested plants and at the same time multiply *in vitro*. Much time and labour is saved as testing plants for the presence of viruses may be a long process. Davies (2) at John Innes has developed a technique for rapid multiplication of freesias, which he propagates from thin slices of the stem of the inflorescence, and hopes to render infected plants virus-free at the same time. Adams (1) at East Malling Research Station obtained virtually unlimited numbers of healthy strawberries from virus-infected ones, using a meristem culture technique. Greater progress will doubtless be made when we know more about the behaviour of plant viruses in tissue culture. Walkey (5) studied this problem and among other plants was able to free virus-infected cauliflowers from virus by culturing minute portions of the curd.

Is there any place for *in vitro* propagation in the commercial production of plants? For high value plants such as orchids it has already been shown that there is. For difficult-to-propagate plants where, at present, there is no feasible method of vegetative propagation, there well may be. A great deal of research work has already gone into attempts to produce plants of the coconut and oil palm but, so far, woody plants are proving to be exceedingly difficult and few have responded. This summer, there was a T.V. programme about aseptic culture techniques at present being used by a large commercial laboratory in England. This may be the forerunner of specialist concerns which propagate, on factory-lines, high value crops, for sale to nurseries in flasks for growing-on, as if they were young seedlings.

General principles are evolving, although modifications have to be made for different species and even for different cultivars. Plant propagators will be glad to know that tissue culture workers are beginning to realise that the history of the plant, and the plant material selected for propagation, may be important! It is also becoming clear that it is worth studying the plant which one wishes to propagate!

I am now going to describe how we have propagated a few plants by rather unusual methods. I will start with asparagus.

VEGETATIVE PROPAGATION OF ASPARAGUS BY AERIAL SHOOT CLUSTERS

Plants of asparagus (*Asparagus officinalis* L.) are normally produced from seed, but the quantity and quality of edible spears per plant varies considerably. Plant breeding programmes have been handicapped because male and female flowers arise on different plants and there has been no reliable method of vegetative propagation of selected individuals. Division of a plant into several pieces is cumbersome and gives a low rate of multiplication; shoot and root cuttings fail to regenerate.

During the last decade research workers in a number of countries have succeeded in producing plants in vitro, but their subsequent establishment and further growth after transferring to compost and a normal environment created problems associated with the character of the plantlets and not with lack of green fingers. John S. Aynsley, a research worker at Nottingham, had been doing anatomical studies on such plantlets and had been comparing their growth with that of seedlings. In the course of his work he noticed that sometimes a main shoot of a young seedling carried a small cluster of shoots. Subsequently, he observed that clusters of shoots may develop on shoots of field-grown plants at the end of the season. These clusters are like the aerial part of an asparagus plant; shoots develop one after the other and small buds develop at their base so that a crown is built up. Hence, if these shoot clusters could be induced to produce roots there would be a means of vegetative propagation without resource to aseptic culture techniques.

Quite independently, Yang and Clore (6) of the Washington State University have also observed aerial crown formation and have described the subsequent development of these crowns into apparently normal plants.

Aynsley failed to root the shoot clusters using conventional propagation techniques, bud did so *in vitro* when he used a nutrient medium supplemented with sugars. However, his propagational material was thin and spindly and attempts were then made to induce shoot clusters on asparagus plants grown in pots in a glasshouse and in a growth room. By removing the crown buds of an established plant but retaining some good growing shoots, small shoot clusters did develop on the proximal part of these shoots. Roots formed *in situ* — good rooting was obtained when the plants were laid on their side and the bases of the shoot clusters lightly covered with compost — and so the parent plant looked as if a number of seedlings had been attached to it!

The challenge is now to find a quicker means of inducing the formation of shoot clusters. We would also like to develop a technique for treating clusters like cuttings so that they could be removed from the plant at an early stage.

There should be no risk of genetic variation when asparagus is propagated by shoot clusters, a risk that has to be considered when certain aseptic techniques are used. But whether or not the shoot cluster/aerial crown technique ever becomes an economic proposition, we have a good example of how plant behaviour may be modified by physical manipulation.

PROPAGATION OF HYACINTHS BY SCALING

Since at least the 17th century, the Dutch have propagated hyacinths by "scooping" and by "scoring". Commercially, an artificial propagation method is essential since a hyacinth bulb only produces about one small offset per year. Present commercial practice entails the critical control of both temperature and of humidity in specially designed bulb chambers. These two techniques are quite unsuitable for use in a plant breeding programme where there is only one bulb available, asscooping and scoring both destroy the parent bulb and the plant breeder has to gamble on ending up with either dozens of small bulbs or none at all!

It is possible, however, to remove a few of the scale leaves which completely surround the bulb, dust the remaining core of the bulb with a fungicide and replant it (4). The bulb suffers a check, but recovers. To facilitate removal of the scale leaves, a circular cut should be made immediately above the basal plate, to a depth of two or three scale leaves depending on the size of the bulb. By then making 4 to 6 cuts of the same depth from the nose of the bulb to the circular cut, a number of "scale pieces" result, in fact they resemble lily scales. The bulb should be left to dry for about an hour before gently teasing off the scale pieces. We have good results by dusting with captan (15% dust) and laying them horizontally in a peat/grit mixture (1:1 by volume). Although the environment is not critical an initial period of some weeks in a warm house (minimum temperature around 16°C) resulted in slightly larger bulbs the first year.

Small bulbs develop, as on lily scales, at the proximal cut surface and within a few months may produce thin and onion-like leaves. When the foliage has died down the original scale piece will be found to have disintegrated, but one or two bulbs should have developed. From then on the small bulbs are treated as if they had been produced by scooping or scoring.

A somewhat modified technique could be used for any of the commercial cultivars where there is no need to retain the parent bulb. The base of the bulb may be sliced off and the remaining upper part quartered. All but the smallest, i.e. innermost, scale pieces are likely to produce one or more small bulbs. The scale pieces may be kept in a cool house which is heated sufficiently to keep out frost. Although fewer bulbs may result than in the conventional techniques of scooping and scoring, the method is quick and does not require any special facilities.

The basal plate should also be inserted as it also may produce a few bulbs!

PROPAGATION OF ROSES BY ROOT CUTTINGS

Over the last few years we have built up a collection of about 40 rose cultivars on their own roots. These have mainly been propagated by one-node cuttings, each consisting of a short piece of stem, one leaf, and its axillary bud (3). This collection has given us an opportunity to find out whether rose cultivars could be propagated by using root cuttings.

Our first attempt was in January, 1972 with the hybrid tea cultivar 'Fragrant Cloud'. Plants *were* obtained and their flowers proved to be true to type. (Cultivars raised by normal methods of plant breeding should come true, but those arising as 'sports' might not — mutations which are periclinal chimeras are generally not reproduced by root cuttings.) These plants of 'Fragrant Cloud' were grown on in pots. Within months a number of shoots arose from the base of the plant. At first sight this seems to be a good characteristic, but only time will tell whether or not sucker-like shoots subsequently develop from the roots. There is always the possibility that such shoots could be as much of a nuisance as suckers from roses which are budded onto rootstocks.

This last winter we did a small exploratory experiment with 'Prima Ballerina' (H.T.). Root cuttings were inserted in late December 1972, because plants produced early in the new year would then have ahead the whole of a growing season. (Experience with propagation by one-node shoot cuttings has indicated that young shoots may rosette in autumn, unless supplementary light is given, and such checked plants are liable to succumb to attacks of botrytis and mildew.) A number of other cultivars were also propagated in December and in April. Under our conditions much better results were obtained from the earlier date. However, until batches of root cuttings are inserted regularly throughout the year, in a number of different environments, it will not be possible to state whether there is a definite ON/OFF cycle as with root cuttings of red raspberry (*Rubus idaeus* L.).

Many modifications could be made to the techniques which we have tried. Our root cuttings were 5 cm long. All thicknesses from about 3 mm to 15 mm diameter were included, but were not kept separate. Most of the thinnest cuttings did not regenerate, whilst some thick cuttings developed shoots ahead of new roots and many of these shoots withered and died. Our observations suggest that an adventitious shoot develops near to, but not at, the proximal end of the root cutting and the first new adventitious roots develop near to, but not at, the distal end.

In our preliminary work, a greater proportion of root cuttings have regenerated when inserted horizontally than when inserted vertically. Although fewer cuttings may be inserted horizontally than vertically in a given area, a shallower depth of compost is required. It is also quicker to chop a length of root into pieces for horizontal insertion than for vertical insertion, as there is no need to indicate the distal end with a slanting cut.

A technique which is used with raspberry root cuttings and which is worth further investigation with roses is to remove the developing shoots when a few centimetres long and insert these as shoot cuttings. With the rose cultivars which we have tried such cuttings inserted under mist and given bottom heat rooted readily. The original root cutting if left undisturbed may produce further shoots. If it is the intention to try this modification, root cuttings should be inserted horizontally, as it is much easier to remove shoots from horizontally orientated root cuttings than from vertical ones.

Our root cuttings were inserted in a peat/grit mixture. No growth substances have been tried, but a greater percentage of root cuttings regenerated when they were lightly coated with captan (15% dust) by shaking gently in a polythene bag. The environment does not seem to be critical. In a warm house (minimum temperature around 16°C) those root cuttings given bottom heat at around 20°C regenerated more quickly than those without. Root cuttings in a cool glasshouse which received enough heat to keep out frosts eventually regenerated, but not until a number of months had elapsed. Overall, the percentage of 'Prima Ballerina' root cuttings, made in December 1972, which regenerated in each environment was about 50%, but thick and thin cuttings had been included. When root cuttings of a number of cultivars were inserted in late April their performance was erratic; eight cultivars gave some regeneration whilst 6 failed completely.

Flowering of plants produced from root cuttings inserted in winter is unexpectedly quick. Pot-bound plants in 8.4 cm diameter pots may flower within several months but, although the colour of the flowers may be true, there may be few petals, thus giving the appearance of wild roses. It is probably best to keep plants growing steadily and to remove flower buds and not allow them to flower until late summer.

Experimental work in the future depends on having a supply of roses on their own roots. One great disadvantage in using root cuttings is that the parent plant may be severelychecked— if not destroyed. Nevertheless, if rose bushes from root cuttings prove to be of an acceptable quality, stock plants might be grown specifically for this purpose. Root cuttings could help in year-round production of roses and could provide an indoor winter job requiring relatively unskilled labour. However, this is looking into the future. I must emphasise that this account of propagating roses by root cuttings is based on observational work and that statistical analyses have not been done.

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DISCUSSION

In reply to a question posed by the President, Harold Tukey agreed that in the eastern United States the trend is to the development of specialised commercial laboratories operating on contract for growers rather than individual nurseries attempting to carry out their own work.

Mehlquist enquired as to the effects of nutrition on aerial shoot production but the reply indicated that little was known in this field, asparagus tending to produce its aerial shoots when nutritional and/or environmental conditions were unsatisfactory.

Jim Wells was interested in the comparative performance of roses produced by the different methods of propagation, but the work was at too early a stage to make any reasonable observations. In answer to an enquiry as to why propagate from roots at all the speaker replied — 'Curiosity.' The President asked about cultivar response in the rooting of rose varieties. Dr. Marston, in reply, indicated that although they had not failed with any cultivars there had been a varying response according to cultivar. As to why single leaf bud cuttings had been used, she intimated that usage of plant material did not then exceed that required for budding. Referring to plant development of roses on a rootstock as compared with roses from cuttings she indicated that habit was often different — viz. 'Iceberg' (a white floribunda) was more compact on its own roots.

ROOT-SOIL RELATIONSHIPS

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I think most people would agree that root studies have been relatively neglected in the past. The internal anatomy of roots has been studied often, but the study of their distribution and function in soil has suffered from the simple fact that they are concealed. Excavating roots is a tedious matter, and even successful excavation destroys the experimental material. Nevertheless, studies on roots seem to be increasing rapidly, and they received a large impetus from the 15th Easter School at Nottingham University in 1968 which dealt with root growth. Further, the development of the Agricultural Research Councils Letcombe Laboratory has led to some exciting work.

I cannot summarise all recent work in one paper but for convenience we can classify such studies under these headings:

1. Root detection and measurement.
2. Root system morphology and distribution.
3. Root system function in nutrient uptake.
4. Root system function in water uptake.
5. Roots and soil biology.

I want to discuss some recent work in groups 2, 3 and 5.

Root Distribution. The basic question is how much root a plant needs to supply itself with sufficient water and nutrients. It has been suggested, mainly from root pruning experiments, that crop plants have much more root than they now need, because they evolved in competitive situations where this large amount was needed. When cultivated, the plants might manage with less. I think that such generalisations may be dangerous — the amount of root which a plant needs depends upon the soil and climate, as well as the degree of competition and growth.

It is well known that the root/shoot ratio is small in conditions where nutrients and water are in good supply, and vice versa. Adding nutrients, particularly nitrogen, will increase the root proportionately less than the shoot, and if sufficient is applied, the total root mass may actually be decreased. Individual parts of the root system also respond to local soil conditions and either nutrient concentrations or soil compaction or, even the presence of other roots. Thus roots react to a small localised application of P or N by branching and proliferating in that area, though the growth rate of the primary root apex may be greatly diminished. Thus, root systems in poor or dry soils tend to be sparse, thin and widespreading, whereas root systems in fertile and well-watered soils are dense, compact and heavily branched. If too much fertiliser is added, salinity problems are encountered which may reduce growth of roots, and of tops, drastically. Some of the results of Thiessen and Carolus (3) are quoted in Table 1, to indicate how large the effects may be.

Table 1. Main root elongation in 2 days for tomatoes, growing with various additions of 10-52-17 fertiliser in 6 inch pots with sandy loam soil.

Fertiliser rate g	Osmotic pressure of soil extract, bars	Root elongation cm
0	0.11	0.39
2	0.17	0.85
4	0.18	0.65
8	0.24	0.21

The stimulating effects of small doses of fertiliser, and the detrimental effects of too much soluble salts, are evident. In general, damage can be correlated with the osmotic pressure of the solution, and 1-2 bars seems to be a danger limit, but this depends greatly upon the nature of the salts, and the plant species. It has been known for a long time in general terms that plants react in these ways, but if you ask what the mechanisms are which cause it, or exactly how large the effects are, I cannot give any precise reply.

Root system efficiency. It is laboring the obvious to say that a plant only takes up nutrients because it is growing. It is the speed, or *rate*, of nutrient uptake we should be interested in, not total amounts. If we know the growth rate of the plant, the percentage of a nutrient in it, and the quantity of root, we can calculate the uptake rate per unit length or weight of root. Quite a lot of information on mean uptake rates is becoming available now (2), and it is quite surprising that this average rate, for young, healthy plants is not too dissimilar among different species. Roughly, it seems that 1 gram of plant root needs to supply the plant with about 1.5 mg/day N, 0.2 mg/day P and 3 mg/day K to keep it growing at full speed. The whole question of plant nutrition is whether it can maintain this rate. If the root is to absorb at this rate, it must get the nutrients from the soil around it, and we ask now whether the soil can supply nurrients at the required rate. Obviously, the soil close to the root becomes depleted, and the supply of nutrients to the root depends upon the process of diffusion of ions in this depleted zone.

A lot of effort has been expended on studying the movement of nutrients in this thin layer of soil close up to the root, since this determines the rate at which ions arrive at the root surface. We have had to simplify, because the real state of soil near the root is exceedingly complicated, heterogeneous and variable. Our aim has been to identify those soil properties which determine the rate at which ions arrive at the root surface. Gradually, we build up a mental picture of what is taking place in the soil exploited by a root system, and if we can put this into mathematical form, we call it a 'mathematical model'. One relatively simple one is as follows (1):

$$M_t/M = 1 - \exp\left[\frac{-2\pi \alpha a L t}{b\left(1 - \frac{1}{2}\frac{\alpha a}{b D} + \frac{\alpha a}{D b} \ln \frac{x}{a}\right)} \right]$$

Here M_t is the amount of a nutrient taken out of a unit soil volume by roots up to time t; M is the total amount present in that volume; α is a coefficient which indicates the root absorbing power, a is the root radius, L the length of root in unit volume of soil, b is the buffer power for the nutrient, which measures the reserve supply, D the diffusion coefficient for the nutrient in that soil, and x the average half-way distance between two roots. I cannot pretend to discuss it in the time available, but it will show those soil and root factors which we consider to be important to the nutrition of plants. We have made tests of this equation with plants growing in simple, uniform conditions, and found that it predicts the uptake of potassium and nitrogen well.

You may enquire what good this is in practice. At present it is of no direct use, but I think that because of this work we can see our way forward more clearly. Our test shows that we now understand the soil system fairly well. With this knowledge, we can (cautiously) predict the effects of changes in root systems. In particular, we can aim to determine how large a root system ought to be for a defined environment and plant system. Perhaps we can design root systems for maximum efficiency. Plant breeders now consider the effect of shape and structure of a plant on light interception; we may expect them to consider the efficiency of the root system in the same way in the future.

I think this sort of work could well have interest in situations where root systems are artificially reduced below normal levels. This occurs with root disease, with transplants and with newly rooted cuttings. In this case the selection of fertiliser rate and type to ensure the most rapid root growth often is critical. There is a limit to the uptake rate of a given piece of root, and too much fertiliser causes salt problems. Such situations should repay a careful and quantitative study of how much effective root is left on the plant, whether this restricts nutrient and water uptake, and how it can most rapidly be increased.

Root and Soil Biology. I now want to pass on to some questions of soil biology which we are interested in. I must leave out discussion of disease organisms, and I do not intend to say much about bacteria on roots. They certainly exist there, in large numbers, but exactly what they do to or for the plant is still a subject of extreme disagreement.

There is much less doubt about the soil fungi which form mycorrhizal symbiosis with plants. All of us will know the ectotrophic mycorrhizas on trees such as beech and pine, but it is now becoming evident that a different group, the endotrophic arbuscular-vesicular mycorrhizas may have enormously greater importance.

These mycorrhizas are formed by fungi of the genus Endogene; and they are found on the great majority of cultivated and wild plants. Table 2 lists some common species which have been investigated.They are virtually ubiquitous, being found in every type of soil and climate. We have found the spores in practically every soil sample we have tested, and it is my guess that they are in all your nurseries, unless the soil has been sterilised.

Table 2. Some species which have been found to be infected with vesicular-arbuscular mycorrhizas.

Maize	Rice	Tomato	Strawberry
Barley	Clover	Apple	Coffee
Strawberry	Tobacco		Rubber
Onion			Cotton
Liquidambar			Maple

The fungal hyphae ramify inside the plant root cortex after initial infection by a spore germ tube. The host plant supplies carbohydrate, and the hyphae increase both inside and outside the root. The external mycelium moves down the root, re-infecting it at intervals. Eventually, there is a network of hyphae outside the root, extending at least 1 cm. out into the soil.

Inside the root the hyphae form a network too, and small highly-branched structures called arbuscules extend into the cell interior. We have pretty good evidence that the interchange between host and fungus takes place in those arbuscules. It is certainly an exchange; the fungus get carbon compounds, but in return the plant gets nutrients. We know for certain that the fungus supplies phosphorus, and it may supply trace elements also.

These are precisely the elements which move slowly in the soil, and which may, therefore, not reach the root easily in sufficient quantity.

The phosphate supplying effect can be dramatic. We have had 100% response to simple infection with this fungus, on phosphate-poor soils. Obviously we do not expect responses with well-developed root systems in fertile soils, and the infection is in fact much less when the plant is well supplied with phosphorus. If the plant does not need more phosphorus, it is possible that the fungus acts as a parasite, and may decrease the plants' rate of growth.

Research on this subject is still in its initial stages. We really know nothing yet of the effects of these mycorrhizas in practice — simply that they are virtually always present in most wild and cultivated plants. It occurs to me that there may be interesting possibilities in getting rapid growth of transplants with poor root systems, by ensuring that the roots are already mycorrhizal. This point is well known in silviculture, with the ectotrophic mycorrhizae. The endotrophic mycorrhizas may prove equally important — on more species — if we look for them.

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DISCUSSION

Referring to the shape and size of containers and their effect on root development Prof. Tinker said that growing roots close together does not pose a problem as roots rarely compete for space and, therefore, from a physical limitation aspect, container-growing was not deleterious. However, what does cause trouble is the restriction in volume, which may induce problems of salinity and maintenance of the adequate water status, hence the volume must be big enough to provide a sufficient buffer in relation to the rate of uptake.

Bill Flemer was concerned about the mechanical restrictions imposed by the container and the 'pot bound' effect; the speaker did not deem it deleterious at this stage provided reasonable precautions were taken on planting. In relation to this latter factor he also indicated the importance of the presence of mycorrhiza for quick establishment and the quick development of a good root system.

The confirmation of the necessity for mycorrhizal presence was implied by one speaker who cited the problems associated with methyl bromide sterilisation of citrus orchards in California and good subsequent establishment of citrus was only achieved when the soil had been re-inoculated with chopped citrus roots.

THE RAPID PRODUCTION OF ERICAS, CALLUNAS AND DABOECIAS

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Trends and developments. There is a modern tendency to use ground-cover plants for areas where low maintenance costs are necessary. As a result, the mass market for such subjects is rapidly increasing and the nurseryman had the opportunity of filling this need by growing large numbers of ground-cover plants, reasonably priced. The especially suitable growth habit of these plants and the sensible use of modern herbicides will reduce maintenance to a minimum.

Heaths and heathers are examples of subjects being more commonly used for such purposes, and whilst generally in good supply are often too expensive to be considered for this role on a large scale. The costs and system of production dictate the selling prices and, as a result, these aspects were investigated at Kinsealy to ascertain how best to produce saleable plants that: (a) require the minimum handling during the various stages of production, and (b) spend the shortest time in the nursery after propagation.

Production systems. The following production system should quite easily fit into the nurseryman's propagation year. The system aims at cutting handling costs to a minimum. Cuttings of *Erica*, *Calluna* and *Daboecia* species are inserted in moss peat in a glasshouse bench, with a base temperature of 21°C. The cuttings are covered with 80 gauge polythene film. The bench is ventilated at intervals of ten days and after one month (*Calluna*, *Daboecia*) and two months (*Erica*) the plastic film is pierced in a number of places to allow air to circulate freely amongst the plantlets and thereby reduce gradually the humidity under the plastic. After some more days during which the hardening off process is completed, planting can commence in a 4 in. layer of moss peat in simply constructed wooden frames at a spacing of 3-4 in. between and within the rows. After the plants are watered in, the frames are covered with shaded Dutch lights or white opaque polythene.

The feeding programme can commence some days later. A 1% solution of a liquid feed containing 9% N, 9% P and 7% K together with trace elements is applied as a drench. When the plants are firmly established and growing (May) the lights are removed. The liquid feeding is repeated at fortnightly intervals until early September. It is necessary to trim the leading shoots of the

APPENDIX 1 — DETAILS OF PRODUCTION

October/November. Mother Crop — During the autumn period 5000 mother plants are purchased and planted into prepared ground at a spacing of 9 in. x 9 in. These will occupy 0.1 acres.

COSTS			*Resources*	
Land Preparation			Land	0.1 acres
(rotovation, fertilising)		£13.00	Labour	53 hours
Purchase of mother stock		£750.00		
Planting 53 hours		£40.00		

February. Mother Crop — Cuttings to be taken this month.

Crop 1 — 25,000 cuttings are taken from the mother plants. It is not necessary to treat these cuttings with hormone. The cuttings are immersed in a 10% solution of captan prior to being inserted in a moss peat medium in a warm bench, temperature 21°C. The glasshouse temperature is maintained at not less than 15°C. The cuttings are covered with a layer of 80 gauge polythene which gives them a warm, humid micro-climate. Distance apart 1½ in. The cuttings are inspected each week and ventilated for thirty minutes. Using this method about 80% of the cuttings will root.

COSTS			*Resources*	
Bench preparation 35 hours		£26.00	Frames	Nil
Collection and insertion of cuttings, laying polythene (100 hours - 2000/man/day)		£75.00	Glasshouse	450 sq. ft. bench space
Plastic		£1.00	Land	Nil
Heat		£50.00	Labour	135 hours
Peat	(25 bales)	£25.00		
		£177.00		

April/May. Mother Crop — The plants are top-dressed with fertilisers and pesticides are applied where necessary. Some handweeding may be required also.

COSTS			*Resources*	
Herbicides		£ 4.00	Land	0.1 acres
2.7 hours		£ 2.00	Labour	13.4 hours
Fungicides		£ 4.00		
2.7 hours		£ 2.00		
Handweeding	5.3 hours	£ 4.00		
Fertilisers		£ 8.00		
2.7 hours		£ 2.00		
		£ 26.00		

Crop 1 — The 25,000 cuttings are lifted and those rooted after an appropriate hardening-off period are planted into cold frames. The frames may be cheap temporary structures. They will contain a 4 in. deep layer of moss peat. The plantlets are spaced at about 10 per sq. ft. After being watered-in, the plants should be covered by placing Dutch lights over the frames or by stretching 500 gauge white polythene over the frames, fixing it with battens. After a few days the first liquid feed should be applied and thereafter at fortnightly intervals until early September. At the end of May the Dutch lights/plastic should be removed.

COSTS			Resources	
Frame preparation			Land	0.1 acres
80 hours		£60.00	Labour	13.4 hours
Moss Peat	(40 bales)	£40.00		
Lifting cuttings and planting into frames 120 hours		£90.00		
Watering and covering frames	10 hours	£8.00		
Watering when required and feeding each fortnight				
22 hours		£16.00		
		£214.00		

June/July. Mother Crop — These plants should be trimmed to produce suitable shoots for the following years cuttings. About half the plants will be excess to requirements and trimming will produce bushiness prior to sale in the autumn.

Spot treatment with herbicides and also handweeding will take place.

COSTS			Resources	
Herbicides		£2.00	Land	0.1 acres
1.3 hours		£1.00	Labour	8 hours
Fungicides		£2.00		
1.3 hours		£1.00		
Handweeding	5.3 hours	£4.00		
		£10.00		

Crop 1 — The plants remain in the frame throughout the summer. They are watered when necessary and feeding continues once fortnightly. A fungicide spray can be applied if necessary. Plants are lightly trimmed to produce bushiness.

COSTS			Resources	
Watering and feeding			Frames	2250 sq. ft.
22 hours		£16.00	Glasshouse	Nil
Fungicides		£2.00	Land	Nil
1.3 hours		£1.00	Labour	43 hours
Handweeding	5 hours	£3.00		
Trimming	15 hours	£12.00		
		£34.00		

August/September. Mother Crop — Spot treatments with herbicides are carried out, and handweeding where necessary.

COSTS			Resources	
Fungicides		£4.00	Land	0.1 acres
2.7 hours		£2.00	Labour	7.7 hours
Handweeding	5 hours	£3.00		
		£9.00		

Crop 1. — Watering, feeding, herbicide and handweeding operations continue. The plants should be trimmed for the second time, for stocky development.

COSTS		*Resources*	
Watering and feeding		Frames	2250 sq. ft.
22 hours	£16.00	Glasshouse	Nil
Fungicides	£2.00	Land	Nil
1.3 hours	£1.00	Labour	21.3 hours
Handweeding 5 hours	£3.00		
Trimming 15 hours	£12.00		
	£34.00		

October/November. Mother Crop — Due to increase in bulk, the mother plants will provide at least twice as many cuttings as one year ago. Therefore, half the original stock can be lifted and sold off for $500.

COSTS		*Resources*	
Lifting, sorting, labelling, wrapping, packing 2500 plants		Land	0.1 acres
40 hours	£30.00	Labour	40 hours
Materials	£18.00		
	£48.00		

Crop 1 — Of the 20,000 plants originally planted into the frames, 90% will have survived. Of these, 75% will be sufficiently large to be sold off to retail nurseries, i.e. would be suitably sized for planting into their final quarters. Thus all young plants will be lifted from the frame, 13,500 will be sold and 4,500 planted into prepared ground for a further years growing-on.

COSTS		*Resources*	
a(Plants being lifted and sold (13,500)		Frames	2250 sq. ft. (until harvest)
Lifting, sorting, labelling, wrapping, packing		Glasshouse	Nil
plants 200 hours	£150.00	Land	0.1 acres
Materials	£ 67.00	Labour	245 hours
	£ 217 00		
b(Plants being lifted and replanted (4,500)			
Land preparation	£13.00		
Lifting and transplanting 4.500 plants 45 hours	£34.00		
	£47.00		
Total =	£264.00		

April/May. Mother Crop — The plants are top-dressed with fertilisers and pesticides are applied. Some handweeding may be necessary.

COSTS			*Resources*	
Herbicides		£4.00	Frames	Nil
2.7 hours		£2.00	Glasshouse	Nil
Fungicides		£4.00	Land	0.05 acres
2.7 hours		£2.00	Labour	13.4 hours
Handweeding	5.3 hours	£4.00		
Fertilizers		£8.00		
2.7 hours		£2.00		
		£26.00		

Crop 1 — Continue to care for growing-on crop. These plants should be lightly trimmed and should be treated with pesticides where necessary. Handweeding must also be done.

COSTS			*Resources*	
Trim once	6.7 hours	£5.00	Frames	Nil
Herbicides		£4.00	Glasshouse	Nil
2.7 hours		£2.00	Land	0.1 acres
Fungicides		£4.00	Labour	17.4 hours
2.7 hours		£2.00		
Handweeding	5.3 hours	£4.00		
		£21.00		

October/November. Mother Crop — The remaining 2,500 mother plants are reduced by 100, which are lifted and sold. The 1,500 plants now left in situ will be ample for providing 25,000 cuttings per annum.

COSTS		*Resources*	
Lifting, sorting, labelling, wrapping and packing 100 plants		Land	0.03 acres
15 hours	£11.00	Labour	15 hours
Materials	£6.00		
	£17.00		

Crop 1 — The 4,500 planted into open ground from the frames one year ago, are now lifted and sold.

COSTS			*Resources*	
Lifting, sorting, labelling, wrapping and packing 4,500			Land	Nil
plants	45 hours	£34.00	Labour	45 hours
Materials		£16.00		
		£50.00		

APPENDIX 2. CASH FLOW OF PRODUCTION SYSTEM OVER 3 YEARS

		YEAR 0					YEAR 1					YEAR 2					
		Oct./Nov.	Feb.	April/May	June/July	Aug./Sept.	Oct./Nov.	Feb.	April/May	June/July	Aug./Sept.	Oct./Nov.	Feb.	April/May	June/July	Aug./Sept.	Oct./Nov.
Mother Plants	Costs	803		26	10	9	48	-	26	10	9	17	-	26	10	9	-
	Returns						500					200					
Crop 1	Costs		177	214	34	34	264	-	21	-	-	50					
	Returns						1,350					540					
Crop 2	Costs						675	177	214	34	34	264	-	21	-	-	50
	Returns						-	-	-	-	-	1,350	-	-	-	-	540
Crop 3	Costs												177	214	34	34	264
	Returns												-	-	-	-	1,350
Cash Flow	Costs	803	177	240	44	43	312	177	261	44	43	331	177	261	44	43	314
	Returns						1,850					2,090					1,890
Net Cash Flow		-803	-980	-1,120	-1,264	-1,309	+231	+54	-207	-251	-294	+1,465	+1,288	+1,029	983	940	2,516

APPENDIX 3. RESOURCE REQUIREMENTS OF PRODUCTION SYSTEM OVER 3 YEARS

	YEAR 0						YEAR 1					YEAR 2				
	Oct./Nov.	Feb	April/May	June/July	Aug./Sept.	Oct./Nov	Feb	April/May	June/July	Aug./Sept	Oct./Nov	Feb.	April/May	June/July	Aug./Sept	Oct./Nov.
Mother Crop																
Land (acres)	0 1	0 1	0.1	0 1	0.1	0 1	0.5	0.5	0.5	0.5	0 5	0 3	0.3	0.3	0.3	0 3
Labour (hours)	53	-	13	8	8	40	-	13	8	8	15	-	13	8	8	-
Crop 1																
Bench space (sq.ft)		450	-	-	-	-	-	-	-	-	-					
Frames (sq ft)		-	2250	2250	2250	2250	-	-	-	-	-					
Land (acres)	-	-	-	-	-	0.1	0.1	0.1	0 $	0 1	0.1					
Labour (hours)		135	232	43	21	245	-	17	-	-	45					
Crop 2																
Bench space (sq ft)							450	-	-	-	-	-	-	-	-	
Frames (sq ft.)							-	2250	2250	2250	2250	-	-	-	-	-
Land (acres)							-	-	-	-	0 1	0 1	0.1	0.1	0 1	0 1
Labour (hours)							135	232	43	21	245	-	17	-	-	45
												450	-	-	-	-
												-	2250	2250	2250	2250
												-	-	-	-	0.1
												135	232	43	21	245
All Erica Crops																
Bench space	-	450	-	-	-	-	450	-	-	-	-	450	-	-	-	-
Frames	-	-	2250	2250	2250	2250	-	2250	2250	2250	2250	-	2250	2250	2250	2250
Land	0 1	0 1	0.1	0 1	0 1	0 2	0 15	0 15	0 15	0 15	0 15	0 25	0.13	0.13	0 13	0.13
Labour	53	135	245	51	29	285	135	262	51	29	305	135	262	51	29	290

plants twice during the growing season, as this results in more stocky growth.

By October/November the plants have reached a suitable size for sale (top growth 4-6 in. diameter). Cutting through the layers of peat between plants from the front of the frame to the back and along its length enables the plants to be removed with a substantial root block. At this point they can be:

(1) planted directly into their permanent quarters,

(2) stood out and loosely bedded by shaking peat through them. (In this condition, whilst on display, they can be easily lifted and bagged at sale), or

(3) containerised for standing out in garden centres.

Economics. The costs of production and cash flow for the system are shown in Appendices 1, 2, and 3. It is being assumed that the strike of rooted cuttings is 80 per cent. Therefore, although 25,000 cuttings are taken, the costs after propagation relate to the handling of 20,000 plants. The number eventually sold is 18,000 The costings take no account of management, capital investment or of rent, overheads, etc. It will be appreciated that no nursery will have exactly these costs and returns, but suitable adjustments can be made for individual circumstances.

SUMMARY

It can be seen that this system involves taking cuttings earlier than usual. The cuttings, although of hardwood, take only slightly longer to root than those propagated in July or August. Having plantlets available for planting into frames in April ensures maximum use of the growing season. The harvesting and sale of the majority of one-season-old plants in October means no over-wintering on the nursery, and releases resources (i.e. frames) for the autumn operations of planting up or of propagating other genera.

There is no potting carried out on these plants. The manner of their harvesting and the cohesiveness of the peat root-ball will enable the plant to pack and travel well and removes the painstaking operation of de-potting the subject, particularly if this task has to be done on a large scale.

No figure has been included for transport costs of the crop. This will vary between nurseries and according to the bulk of orders etc. In many cases the purchaser will pay for these, but when large numbers of plants are required for ground cover (and it is for this mass market the system is principally designed) then transport costs could be a consideration.

If the value of stock plants is not considered, a profit of approximately £200 (Appendix 2) is shown after year one, and of

£1465 in year two. The selling price of 10 to 12p, depending on the age of the plant, has been applied. At this price the purchase of stock for mass ground cover purposes would be attractive for municipal authorities and industrial site planting and may indeed rival the grassing of areas in view of the high maintenance costs of the latter.

THE BUDDING OF HAMAMELIS

G. V. PURCELL

L. R. Russell Ltd., Windlesham, Surrey

The successful budding of quality plants like *Hamamelis* is naturally more important to me as a Specialist Propagator, than the routine budding of standard nursery stock like roses and other main varieties. From a commercial aspect it should also be very important to all nursery owners.

Everyone knows the quotation that, "big oaks from little acorns grow." May I therefore suggest that "big profits from little *Hamamelis* could grow." By this method of production you can obtain a good saleable end product in the same time it takes to produce a rose. The main difference being that you can sell the *Hamamelis* at 6 to 10 times the price which you could obtain for the rose (currently *Hamamelis* sells for approximately £3.00 to £5.50 and the rose for around 50p).

I should emphasise that the budding itself is not a new way of producing these plants, as I understand it was done in the pre-war period. I will now endeavour to explain the whole operation with the aid of slides to illustrate the sequence of events.

First, we have to find the appropriate understock — in this case we use *Hamamelis virginiana*, the north American species. Although it was first introduced into this country around 1736, it is now virtually impossible to obtain here — or in Europe either, in the quantities required by the trade. We, therefore, have to rely on our American friends to produce the understock for us, in our case Gulf Stream Nursery, Inc. I should, however, mention here that in 1972 I did carry out experiments with de-budding onto *Distylium racemosum* an evergreen member of the *Hamamelidacae*, as an alternative understock Results were promising at first but subsequent scion growth was very slow. However I intend to continue experimenting to resolve the growth problem of this particular understock.

When the *H. virginiana* stocks arrive they are usually very thin and often do not improve as much as one would like in order to make the budding operation as easy as possible.

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When the *H. virginiana* stocks arrive they are usually very thin and often do not improve as much as one would like in order to make the budding operation as easy as possible.

SLIDE NO. 1 Here we see the stock; note how thin it is and how low down one has to make the "T" cut. I should, however, point out that the thickness of the stock will not affect the result of the take. It may try the patience of the best of us, but a dedicated propagator, with the skill of a surgeon, will soon overcome this problem.

SLIDE NO. 2. Here is an ideal piece of material from which we can obtain 3 good buds. This is about the maximum you will be able to find as the fourth one is usually soft. When collecting material from old stock plants, generally you will only obtain two good eyes — unless they have been well fed. With young maiden plants, however, you will obtain similar material to that shown on the slide. This incidentally is *H. mollis* 'Pallida', which is fast becoming the most popular cultivar.

SLIDE NO. 3. The next step is to sever the bud from the piece of material selected. This is done in the orthodox manner by starting from the top of the material. The thin sliver of wood is removed from the back of the bud to reveal a good plump eye base.

SLIDE NO. 4. In most cases you will find that the thin sliver of wood will not come cleanly away in one piece, it will have to be worked on from both ends of the bud as shown on this slide. This may take time but when one becomes accustomed to the material, the operation becomes easier for the experienced operator.

SLIDE NO. 5. Now here is probably the most important part of the operation, the insertion of the bud into the stock. It is more difficult to get the bud inserted correctly, to be held firmly and squarely, than it is to provide the bud.

To secure the bud in the stock I use German Fleischhauer R.20 rose ties, using two per bud. The lower half of the bud is secured first, and when this tie is firm, the second tie is fixed making absolutely sure that it overlaps the lower one to prevent any moisture entering the "T" cut. When attempting to secure with the R.20 ties it is essential that they are stretched to their full capacity before making contact with the stock and bud. The only pressure which is brought to bear on the bud, before the pins are pushed home, is a direct force pushing the bud firmly against the stock leaving no room for sideways movement of the bud. I assure you that the bud will tilt to one side or the other if these steps are not followed.

One might ask "Why not use raffia?" but this would require the subsequent operation of cutting the tie and possibly risk cutting the stock — extra work is also unprofitable. It is possible that rubber tie strips could be used, but not having used this material I would hesitate to recommend them.

SLIDE NO. 6. This shows a small batch of *H. m.* 'Pallida'; the leader is 4 feet high. These were budded in August 1970 and the best were sold in autumn 1971. All had good leaders and four or five strong growth points to make fine quality plants. Commercially they retailed as follows: 1½ to 2 ft. at £2.75, 2 to 2½ ft. at £3.25, and up to £5 or £5.50 for the very best large plants.

SLIDE NO. 7. Leader growth here has reached 4 ft. 5 ins. on a variety we call 'New Red' which was obtained by Mr. John Russell in his travels. It starts off deep red and eventually changes to an orange-brown. As yet we do not market this one, but it is very free flowering and a good strong grower, somewhat similar to *H. m.* 'Carmine Red' with larger flowers and good autumn foliage. Also included in this batch is *H. m.* 'Coombe Wood' which is a delightful form of the species with larger flowers than the type but still sweetly scented. *H x intermedia* 'Jelena' showed the most vigor and at the time the slides were taken had reached 4 ft. 8 ins. in height.

The previous two slides have shown some well-grown witch hazels which obtained 3 to 4 ft. in height as maiden plants. Of course, they did not do this naturally but were encouraged with extra feeding which at the moment I cannot disclose, as experiments are still continuing to ascertain the best results. I must, however, point out that only one feed was necessary in late May, 1971, to produce 4 ft. plants. They were not given any extra feed of any kind in 1972.

To sum up therefore:

(a) Provide the best available understock.
(b) Retrieve only good quality buds.
(c) Operator's skill in trimming to reveal the eye-base.
(d) Form the T-cut carefully and low down on thin stock.
(e) Insert the bud squarely and secure firmly to the stock.
(f) Try to encourage extra growth by selective feeding.

This spells; PROFIT

DISCUSSION

In reply to a question regarding the success of the technique, Gerry Purcell indicated that out of 250 in the first year of operation only 12 failed and in the subsequent year only 10 out of 150 failed. Latterly failures had been due to trials with the Fleischauer budding tie which had not proved successful.

Editorial Note: Subsequent slides demonstrated maiden growth early in the year and the way in which growth developed. Certain comparisons of the rate of growth of various cultivars was also demonstrated.

Jim Wells and Ron Dool indicated that hamamelis could be successfully propagated from cuttings if treated in the same way as deciduous azaleas; i.e. achieve growth before the winter and store at 33° - 35° F. (Pete Vermuelen)

NARCISSUS PROPAGATION

H. J. EATON

Ministry of Agriculture, Fisheries, and Food
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Rosewarne Experimental Horticulture Station
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Abstract. The "twin scale" method of narcissus propagation is described and the results of a number of experiments dealing with different sizes of segments, cultivars, and storage temperatures are reported, with details of the number and weight of bulbs obtained by natural increase and by twin scaling after two growing seasons.

REVIEW OF LITERATURE

Bulb propagation by various methods of cutting or sectioning the bulb has been studied for many years at a number of centres. The early work dealt largely with hyacinths but more recently various methods of sectioning have been used successfully with narcissus and other bulbs. During the past two years, following earlier work by Alkema at Jaarverslag Laboratorium voor Bloembollenonderzoek, Holland, and by Brunt at GCRI, England, we have tried out the "twin scale" method of narcissus propagation on a number of cultivars, using various segment sizes and storage temperatures to find the most satisfactory method for large scale propagation of new seedlings.

MATERIALS AND METHOD

Bulbs for dissection must be free from pests and disease and not bruised or damaged by lifting. "Round" or "double-nosed" are the easiest to dissect but any type can be used. Dissection should be carried out in July or August; later dissections will survive but make poorer growth.

Selected bulbs are first washed in a solution of 0.5% formaldehyde (40%) to remove soil and give surface sterilizing. The nose of the bulb is then cut off about ¼ to ⅓ from the tip and the body of the bulbs dissected downwards into 8 to 16 segments shaped like the segments of an orange and each held together by a portion of the basal plate. The basal plate of each segment is

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RESULTS

Varietal Response. We have tried a limited range of cultivars. *Narcissus tazetta* 'Grand Soleil d'Or' and *N.* 'Carlton' propagate freely, the former even when dissected in September. *Narcissus*, 'Golden Harvest', 'Magnificence' and 'King Alfred', all yellow trumpet varieties, produced fewer bulbs, while *N.*, 'Fortune' was intermediate.

Size of Segments. With the smallest size of twin-scaled segments only half or less of the small bulbs formed produced foliage the first year and many were very small when lifted at two years old. For example, with *N.* 'Fortune' cut into 16 segments and twin-scaled, 12 twin scales produced foliage the first year and 51 the second. The very small bulbs produced at the end of two years will probably require another two years to reach flowering size, while larger bulbs produced by cutting the original bulb into a smaller number of larger segments will probably reach flowering size with one more year's growth. This year we have cut the bulbs into 8 segments and then twin-scaled each segment to try and produce a high number of bulbs, most of which will be sufficiently large to produce leaves the first year and small flowering size bulbs in three years.

Rate of Multiplication. Table 1 shows the rate of multiplication obtained from one round bulb for a number of cultivars in two growing seasons when grown naturally and when twin-scaled. While twin scaling has always given a reduced total weight it has given a greatly increased number of small bulbs and these are expected to increase in weight more rapidly than the few large bulbs over the next two years. In another two years it is hoped that reasonably full-sized bulbs will develop from all the bulbs produced by twin scaling, while the large bulbs will continue to produce 150% to 200% increase in weight and number of bulbs.

Table 1. Narcissus propagation, 1973 Mean product of 1 round bulb in two growing seasons

	Propagation method	No of shoots in first season	No. of bulbs produced	Harvested weight as % of planted weight
'Grand Soleil d'Or'	Whole bulb	1 0	2 8	220
	Twin scaled*	30.0	61.6	215
'Carlton'	Whole bulb	1.0	2.4	366
	Twin scaled*	24.6	59 0	289
'Fortune'	Whole bulb	1.0	2.0	236
	Twin scaled*	12.0	47.8	173
'King Alfred'	Whole bulb	1.0	3.1	273
	Twin scaled*	5.9	23.9	69
'Golden Harvest'	Whole bulb	1.0	2 1	306
	Twin scaled*	9.8	21 0	95

* 16 segments per bulb twin-scaled and stored 8 weeks 23°C + 4 weeks 17°C.

Application of "Twin scaling". In Holland this technique is being developed for the propagation of virus-free stocks, selected clones, and new cultivars. In this country the Glasshouse Crops Research Institute is using bulb dissection for the multiplication of virus-free clones produced at the Institute for distribution through the Nuclear Stock Association, and at Rosewarne we have just commenced using twin scaling for the propagation of selected seedlings from our breeding programme after two years of preliminary work with commercial cultivars.

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EXPERIENCES WITH THE USE OF THE "NISULA ROLL"

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With the continuing shortage of labour new techniques in producing forest trees had to be found. In May, 1970, I did an extensive tour of Finland to study nursery techniques. I looked firstly at the Japanese paper pot system, which is now widely used there. The main species to be reproduced by this method are Scots pine and birch, but this method has a good future for many species; most important I think is Corsican pine. Transportation to the forest will be a problem as the pots would have to be transported in trays.

At Rovaniemi Nursery, which is a State Nursery in the Arctic Circle, I was told that several million Scots pine had been produced by the paper pot system, and that field results were very encouraging. On closer questioning I learned that in Finland only three main tree species are used in the forest, namely Scots pine, Norway spruce and birch. The manager at Rovaniemi told me that although Scots pine are successful in paper pots he was not able to produce a large enough Norway spruce plant in one season. He had therefore tried a Finnish technique known as the "Nisula" System. The name Nisula comes from the inventor, a scientist, Pentti Nisula, of the Forest Research Institute of Finland. The system is simply producing seedlings in a roll of peat, fertilizer and polythene.

First trials were carried out in 1965; a length of polythene film 12" wide, 100 gauge, was laid on a bench, on this film fertilized peat was spread, seedlings were then placed on the peat on each side of the film, roots to the centre of the roll. The polythene, peat and seedlings were then rolled up like a Swiss roll and the end of the roll secured with Bostick. The roll was then cut into two with a hand saw. making two rolls 9" dia. by 6" in depth, and the rolls were then stood on a hard surface and allowed to stay in this position until taken to the forest for planting.

The machine consists of a conveyor belt on to which the polythene film is introduced at the conveyor end; fertilizer is then fed on to the film by a lawn fertilizer spreader, followed by peat; a reciprocating blade then spaces the peat into small heaps 9" apart; seedlings are placed on to these heaps by four men or women feeding the seedlings on to the peat from each side of the belt. To start the roll then proceeds towards the end of the conveyor. At this end are two rotating dimpled rubber rollers; the started roll is held between these rotating rollers and rolled under pressure to correct size. The last man on the belt places a smear of Bostick across the film which joins the roll. The man operating the rollers releases the roll which is taken off the conveyor and placed on a cutting machine which has been produced in our own workshops. It consists of a power saw electrically operated and a spring-loaded cradle into which the roll is placed. The weight of the roll takes it through the saw, and the cut roll is then taken by conveyor to be placed on a specially designed trailer. This trailer was designed and produced in our own workshops. This consists of moving floor pivoted at the point of balance on to a trailer chassis: when loaded the moving floor is locked in position and is controlled by a handle. Rolls are placed on the end of the trailer and progressively wound forward until the trailer is loaded. The trailer is then taken on to the nursery by tractor; the moving floor is tipped and as one man winds the handle the tractor moves forward and the rolls are pushed off the trailer. This means that the rolls need only be handled once.

The method of feeding peat to the Nisula machine is by a converted Meal Mixing Machine which not only breaks up the peat but also enables lime to be added. Water is sprayed on to the peat and the whole thing is then mixed; it is then transferred to another mixer and from there to a conveyor and then on to the Nisula Machine.

The advantages of the Nisula Method are:

1. Approximately 3,000,000 seedlings can be produced on one acre against 4-500,000 by conventional methods.
2. No need to lift, grade, tie or heel-in plants.
3. Transplanting can be put on a factory basis, which means that it can go on no matter what the weather conditions. Seedlings to maintain the machine can be held in cold store.
4. Substantial reductions in costs as large quantities of fertilizer, spent hops and cultivations are not required and less land area needed.
5. The Finns claim a production of up to 120,000 seedlings per day for 12 operators. We have only managed to obtain 70-80,000 up to date. We hope to improve on this in the coming year.
6. In the forest it is no longer necessary to heel-in plants.
7. Planting can be carried on over a longer period.
8. A higher survival rate in the forest as the tree has its own plate of peat on the roots, which gives an almost root-balled plant.

The machine and the method is patented in 18 countries, which includes Great Britain, and royalties have to be paid to Finland for plants produced by this method.

We produced 200,000 plants by this method in 1971 using a variety of species, Scots pine, Lodgepole pine, *Thuya*, *Abies procera* [*A nobilis*], *Abies grandis*, Sitka spruce and Corsican pine.

As we were the first nursery to use this system outside Finland we have run into quite a number of problems, some we have overcome, while others have still to be solved.

Some of the improvements already carried out are as follows:

1. We have reduced the number needed to operate the machine from 12 to 9. This has been made possible by placing a knife at the beginning of the conveyor to cut the polythene through the centre instead of having to cut the rolls as a final operation.
2. By incorporating a bell that rings when 50 seedlings have been placed on the conveyor. In conjunction with the bell there is also a counter to record the number of rolls per day.
3. By removing the rear roller from the machine and placing a conveyor belt in its place to transport rolls direct to trailer. We have also improved on the spacing device; the object of this is to divide one seedling from the next to avoid root damage and loss of peat.

A major problem has been that the trees grew too fast; to overcome this we are holding the seedlings in cold store and rolling in April, May and June. By doing this we are hoping to reduce the plants' growing season.

Weed attached to roots and foliage of seedlings is another problem which we are hoping to overcome by using sterilized seedbeds.

We have had some good results with ornamental seedlings. Species tried include *Berberis*, *Araucaria*, *Quercus cerris*, *Thuya plicata*, *Chamaecyparis lawsoniana*, and *Acer*.

NUTRITION OF CUTTINGS UNDER MIST

J. L. W. DEEN

Glasshouse Crops Research Institute
Littlehampton, Sussex, England

There is considerable evidence that nutrients are leached from cuttings under mist (1) and that cuttings deteriorate during propagation due to the dilution of existing nutrients in the cutting when new growth occurs on the propagation bench. Various

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There is considerable evidence that nutrients are leached from cuttings under mist (1) and that cuttings deteriorate during propagation due to the dilution of existing nutrients in the cutting when new growth occurs on the propagation bench. Various methods of replacing lost nutrients and maintaining the nutrient supply for new growth have been investigated. The use of nutrient mist is reported by John Wott in this volume (p. 000) and elsewhere (3). McGuire and Bunce have reported on an alternative method using slow release fertilizers incorporated into the rooting medium (2). It is this aspect that has been the subject of trials at G.C.R.I. using the slow release fertiliser, Osmocote.

For these trials a mist unit under glass was used with mist application controlled by an "electronic leaf". Base temperature was controlled at 20°C and the cuttings were rooted in small trays using a basic rooting medium of 50% peat, 50% grit.

Trial 1. 1972 Cuttings 12 cm long of *Cotoneaster dammeri* 'Skogholm' ['Skogsholmen'] and *Symphoricarpos orbiculatus* were taken in early August. The basic rooting medium was used with and without the addition of 4 oz/bushel of 18-6-12 Osmocote. Batches of cuttings were lifted from the propagation bench after 3, 5 and 7 weeks and their rooting performance assessed. In both the trials reported here all the cuttings rooted with all the treatments; the differences where they occurred were in the number of roots and the type of root system which developed. After 3 weeks there was little difference between treatments but after 5 weeks under mist it was noted that the cuttings with Osmocote were taller and had developed side shoot growth (Fig. 1). Those without fertiliser had made virtually no new growth during

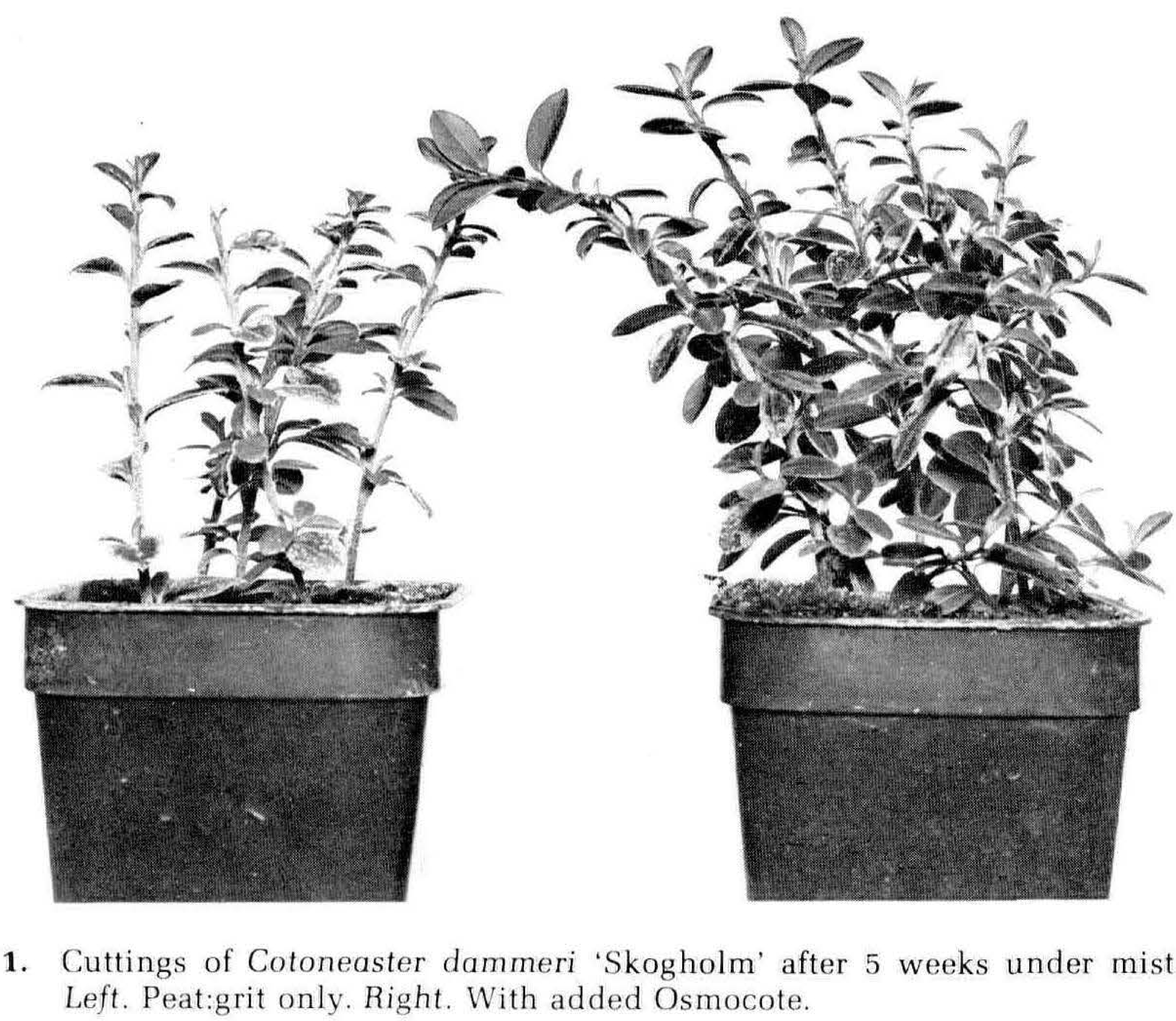

Fig. 1. Cuttings of *Cotoneaster dammeri* 'Skogholm' after 5 weeks under mist. *Left.* Peat:grit only. *Right.* With added Osmocote.

propagation. After 7 weeks these differences between treatments were even more marked. In addition, the root systems of those cuttings with Osmocote were whiter and more succulent than the browner and more fibrous roots of those without fertiliser (Fig. 2).

All the cuttings were potted into a standard 75:25 peat/sand compost with complete nutrients added. At the end of the season plant height and spread was measured. Those lifted after 3 weeks showed no difference between treatments; those rooted with Osmocote and lifted after 5 and 7 weeks were, on the average, 25% larger than those rooted without fertiliser.

Fig. 2. Cuttings of *Cotoneaster dammeri* 'Skogholm' after 5 weeks under mist. *Left*. With Osmocote added. *Right*. Peat:grit only.

Trial 2. 1973. Cuttings of the same two subjects were taken in mid-June. There was an additional treatment of 4 oz/bushel of 14-14-14 Osmocote. After 5 weeks under mist a marked improvement of shoot growth was again noted with both types of Osmocote.

Some cuttings were potted off as before into a standard potting compost; others were retained for more detailed analysis. They were partitioned into roots, original stem and leaves, and new stem and leaf growth. The separate parts were dried and weighed to get a more accurate measurement of the influence of Osmocote on the distribution of growth in the rooted cuttings (Fig. 3). As expected there was little effect on the weight of original stem but the weight of new stem and leaves was considerably increased by Osmocote with slightly more favourable results with 14-14-14 Osmocote. There was not, however, a corresponding increase in the weight of roots and in the case of *Symphoricarpos*, some evidence of a reduction with Osmocote. It is probably that this imbalance in the distribution of growth between roots and shoots may limit the development of these rooted cuttings after potting off. The dramatic differences in growth seen at this stage from this earlier propatation may not be so evident by the end of a long growing season. Further dry weight measurements of plants in this trial are to be taken to verify this point.

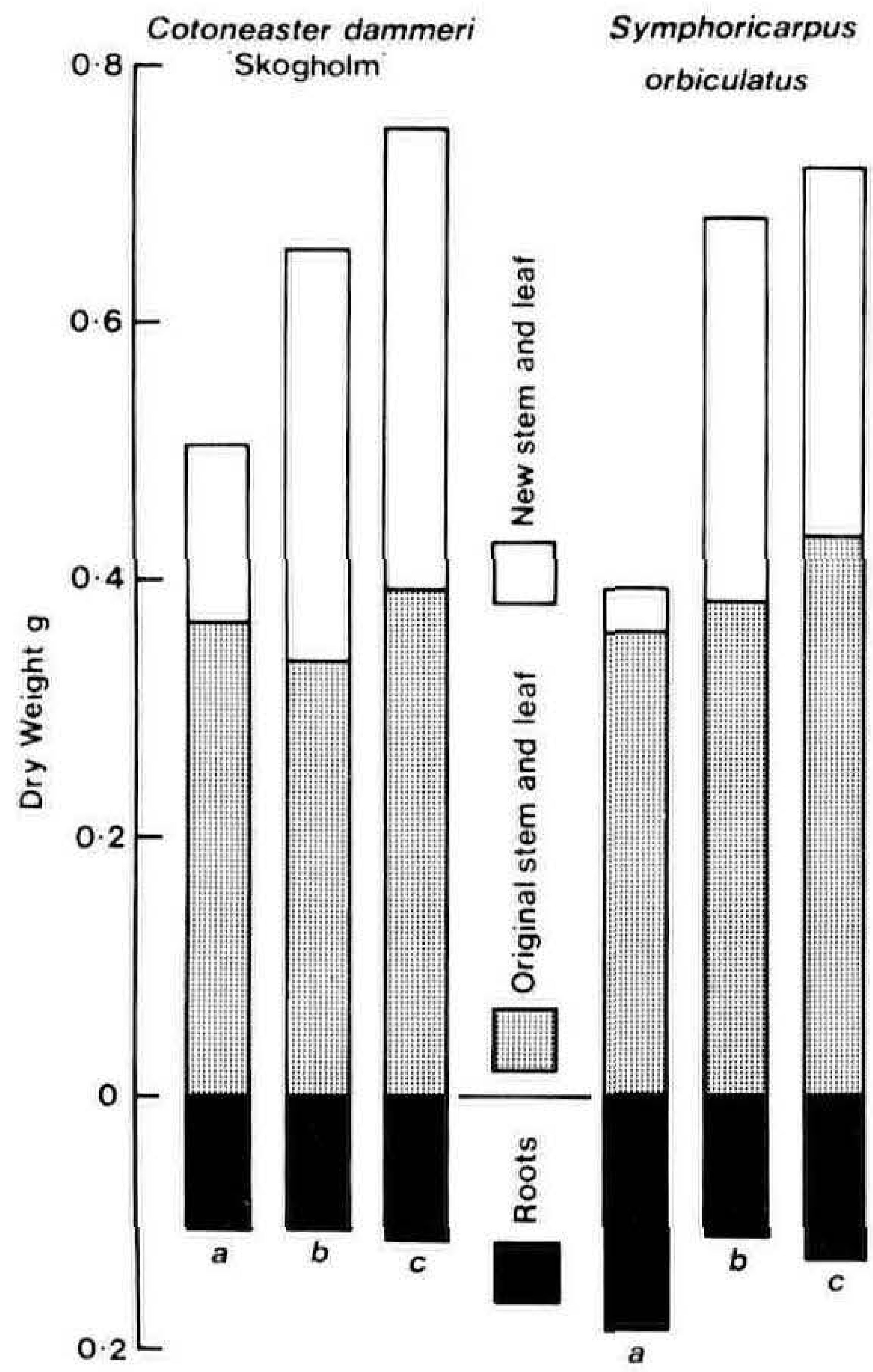

Fig. 3. Dry weight of cuttings after 5 weeks under mist. (a). Peat:grit only. (b). With 18-6-12 Osmocote added. (c). With 14-14-14 Osmocote added.

A range of other subjects were screened at the same time as Trial 2 for their response to Osmocote. In most cases increased shoot growth was noted where Osmocote was used.

It would appear that the incorporation of Osmocote into the rooting medium may have a useful part to play in propagation practices particularly for quick rooting subjects taken late in the season when enhancement of shoot growth on the propagation bench may help to produce a larger, stronger plant for overwintering.

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DISCUSSION

In reply to questions, Jim Deen indicated that he had not used fritted trace elements and the analysis of the Osmocote additives were 18:6.12 and 14:14.14, both used at 4 oz./bushel.

THE ABSORPTION OF NUTRIENT MIST INTO CUTTINGS

JOHN A. WOTT[1] and H. B. TUKEY, JR.[2]

Abstract. Cuttings, especially softwood and herbaceous, grew tremendously in new roots, shoots, and leaves during propagation Those propagated under nutrient mist had a higher N, P, and K content than those propagated under water mist Cuttings of *Chrysanthemum morifolium*, Ram rooted in special containers showed that almost all of the P absorbed by the cuttings during propagation was absorbed by the stems and foliage from the nutrient mist and either utilized in new growth or translocated into the developing roots.

INTRODUCTION

Symptoms characteristic of nutrient deficiencies have been reported in cuttings propagated under mist (1, 3). These symptoms may be due to leaching of nutrients or the growth of the

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cuttings causing a dilution of the nutrients within the cuttings. Nutrients applied to cuttings through the rooting medium have shown erratic results (2,7).

MATERIALS AND METHODS

Softwood, hardwood and herbaceous cuttings of more than forty cultivars and varieties of plants were propagated under two mist systems (4). One set of cuttings was propagated under ordinary tap water and the other supplied with a nutrient mist of (Ra-Pid-Gro, analysis 23-9-17) at the rate of 4 oz./100 gal. of water (5).

The nutrients were premixed and injected directly into the mist line by a Goulds Balanced Flow Shallow Well Pump. When a high percentage of each species had rooted, they were harvested and root evaluations conducted. After drying in a forced air oven, the cuttings were analyzed for N by the modified Kjeldahl Method, P by colormetric methods and K by a flame spectrophotometer (5). Growth records were also kept on representatives which were potted and grown for further observation.

RESULTS AND DISCUSSION

Softwood cuttings of many woody species increased tremendously in dry weight and nutrient content during the propagation period.

For example, softwood cuttings of *Philadelphus coronarius* (Table 1) originally had a dry weight of 515 mg/cutting when placed in the propagation benches. After six weeks, those propagated under the water mist system had increased to 845 mg/cutting, an increase of over 50%. Those propagated under nutrient mist increased even more in dry weight, (75%). This indicated growth of the cuttings.

Table 1 Influence of nutrient mist on the total dry weight, nutrient content, and root development of softwood cuttings of *Philadelphus coronarius*

	Before rooting	After rooting	
		Water	Nutrient
	(mg/cutting)		
Dry Wt	515	847	928
N	17 94	12 26	53 92
P	2 17	2 14	7 68
K	14 98	9 86	22 23
% Rooting		54 2	86 2
Root Quality Index		1 67	2 80

The N content of the water mist cuttings decreased during propagation from 17.94 mg/cutting to 12.26 mg/cutting, indicating leaching. However, those under nutrient mist showed a 3-fold increase. The P content showed a similar change whereas K, the most leachable nutrient, also showed an increase.

The rooting percentage and root quality also was better in those cuttings propagated under nutrient mist.

Nutrient mist affected the lateral bud growth of some species of cuttings after propagation. For example, softwood cuttings of *Pachysandra terminalis* propagated under nutrient mist averaged 3.2 more breaks per plant than the water mist propagated plants when counted 3 months after removal from the propagation benches.

Nutrient mist also affected the linear growth of many softwood cuttings after propagation. The results of 4 representative species are given in Table 2. For example, the water mist propagated plants of *Euonymus fortunei* averaged 47 cm in height whereas those grown under nutrient mist averaged 68 cm per cutting.

Table 2. Influence of nutrient mist during rooting on linear shoot growth of selected softwood cuttings after propagation

Species	Days	Increase in Stem Length	
		Water mist	Nutrient mist
	(cm cutting)		
Eyonymus fortunei	114	47	68
Forsythia suspensa	101	73	126
Philadelphus coronarius	106	65	91
Lonicera morrowii	111	66	77

Thus cuttings, especially softwoods, increased tremendously in dry weight and had large amounts of nutrient uptake during the propagation period. Also these cuttings made large increases in linear growth and in lateral bud growth after propagation.

In order to study the effect of nutrient mist on rooting, two cultivars of *Chrysanthemum morifolium* were propagated so that nutrient mist was applied during different times of the propagation period. Results showed that fast rooting cultivars (those which rooted in 7-10 days) were beneficially affected by applications of nutrient mist. For example, cuttings of *C m*. 'Giant Betsy Ross' had a higher number of roots when nutrient mist was applied, but the time of nutrient application, whether early or late in the propagation period, had no effect In contrast, a slower rooting cultivar, *C m* 'Yellow Columbia' showed a definite increase of root number when the period of nutrient application was also increased.

Nutrient mist also affected root quality. For example, *C m.* 'Yellow Sceptor' cuttings propagated under nutrient mist, had a thicker type of root system which also had more lateral roots. Those propagated under water mist had thinner, and sometimes longer roots. Similar findings were found in softwood cuttings of *Forsythia intermedia*, *Pachysandra terminalis* and *Salix purpurea*.

It was also of interest to determine whether the large increase in nutrient content was due to absorption by the foliar stems and leaves or through the cut stem bases. Thus an experiment involving the use of radioactive phosphorus was conducted.

Four hundred *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' cuttings were inserted through the lids of Freezete polyethylene containers (20 cuttings/container) 4 cm into a rooting medium of quartz sand (6). The aerial portions were misted with nutrient mist. The rooting portion was supplied with an identical nutrient solution only labeled with radioactive P to a specific activity.

The radioactive solution was contained in large 5-gallon plastic carboys suspended above the cuttings. Then by a series of spigots, the labeled solution was allowed to drain, by gravity, through polyethylene tubing to the inside of the rooting containers where by means of a sprinkling system, the medium was thoroughly watered. The solution drained out of the containers and was collected for disposal.

Thus by using ^{32}P, it was possible to propagate plants with a different environment to the aerial (above ground) and basal (below ground) portions of the plant.

Starting on the second day after insertion into the propagation containers and every second day thereafter, 40 cuttings were harvested, divided into aerial and basal portions and assayed for total P content by colorimetric methods. The total amount of P contained in the cuttings at the beginning of the experiment, also determined colorimetrically on control plants, was subtracted to give the total increase of the P content of the cuttings (Table 3).

Table 3. Method for Phosphorus Determination.

	Total P content at harvest time	(colorimetric)
—	Total P at experiment beginning	(colorimetric)
	Increase in P content	
—	Basal Uptake	(radioactive)
	Foliar Uptake	

The cuttings were also assayed for total radioactivity in the aerial and basal portions, as counted on a Nuclear-Chicago Gas Flow Detector. This was a direct measure to the amount of P absorbed by the cuttings from the labeled solution being applied to the rooting medium. Then the amount absorbed from the basal portion was subtracted from the total increase in P content, to give the total amount absorbed from the unlabeled nutrient solution applied through the mist.

The results showed that the P content of the entire cutting changed from 772 micrograms/cutting to 3196 micrograms/cutting during the 20-day propagation period (Table 4).

Table 4. Absorption of phosphorus by cuttings of *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' propagated under nutrient mist.

Days of propagation	Total P content	P uptake during propagation				
		Total	Basal	Foliar	Foliar	Rooting
		(micrograms per cutting)			(%)	(%)
0	772					
2	823	51	0	51	100	0
4	1071	299	2	297	99	0
6	1174	402	4	398	99	0
8	1379	607	11	596	98	0
10	1487	715	32	683	95	5
12	1547	775	49	726	94	15
14	1636	864	38	826	95	55
16	1887	1115	43	1072	96	68
18	2495	1723	93	1630	95	83
20	3196	2424	371	2053	82	100

During the first 2 days of the propagation period, the cuttings absorbed 51 micrograms/cutting, all of which was absorbed by the aerial portion from the nutrient mist. This trend continued throughout the propagation period. However, there was a larger increase noted on the twentieth day when root growth was quite extensive.

Also the pattern of translocation of the P, once-absorbed, should be noted. Of the 2053 micrograms of P which were foliarly absorbed by the cuttings, 1674 micrograms were retained in the foliar portion and only 379 were translocated into the basal portions and new roots. During the first 8 days of propagation, foliar absorption, accumulation in the foliage, and basal translocation were considerable After root initiation this diminished, but again increased markedly from the 14th to 20th day when roots were elongating.

The percent of the P absorbed by the cut stem bases and foliage was very small. For example, during the entire propagation period, the percent of the P absorbed from the radioactive nutrient solution rose from 0 to 18.1% of the new P absorbed (Table 5). Analyses of the separate foliar portions showed an increase up to 14.6%, whereas the basal portions increased to 18.3%. This meant that 80% of the total new P absorbed by the cuttings during the propagation period was absorbed through the foliar stems and leaves. Even on day 18 when most of the cuttings had rooted, 95% of the P absorbed by the cuttings had been foliarly absorbed from the mist.

Thus, throughout the propagation period, almost all of the P absorbed by the cuttings was absorbed through the stems and foliage. This indicates that nutrients are more efficiently absorbed by chrysanthemum cuttings from nutrient mist than from the rooting medium. Thus nutrient mist would appear to be more effective in applying nutrients to cuttings during propagation than by adding nutrients only to the rooting medium.

Table 5. Percent of total phosphorus absorbed through basal portions of *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' cuttings.

Days	Total Cutting	Aerial Portion	Basal Portion
2	0 0	0.0	0 0
4	0 7	0.5	1 0
8	1.8	0 8	6 1
10	4 5	2.4	15.3
14	4 4	2.2	24 4
18	5 4	3 6	13 6
20	18.1	14 6	18.3

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DISCUSSION

In reply to questions, John Wott gave the following information: The nutrient misting compound had an analysis of 23:19:17 and was used at a rate of 4 oz./100 gallons of misting water. It was used continuously in a timed misting regime of 12 sec. burst every 2½ minutes. Because of the likelihood of run-off, they had assessed the effect of nutrients to the medium but had found foliar application to be superior.

SIMPLIFIED METHOD FOR THE PROPAGATION OF PLUM HARDWOOD CUTTINGS IN SYRIA[1]

N. NAHLAWI

Central Research Station
Damascus, Syria

Treatments known to influence the rooting of plum rootstock hardwood cuttings when propagated in heated cutting bins in England have been shown to influence the rooting of two local plum cultivars, Ajami Janirek, and Tephahi janirek (*P cerasifera*), when planted directly into the soil in Syria.

For the greatest level of success, 60 cm long cuttings should be prepared from the proximal portion of the shoot, treated with indolyl butyric acid at 5000 ppm in 50% alcohol to the basal cut surface avoiding, where possible, contact with the epidermis and planted during the months of November, December and January. For a summary of results see Tables 1, 2, 3 and 4.

[1] **Editor's Note**· As Nazir Nahlawi was not able to be present because of his recent appointment to a position with F A O , Brian Howard summarised the paper It was not possible to reprint this paper as it was not properly finalised for submission as a scientific contribution and, because of the recent problems in the Middle East, he was unable to obtain data from Damascus to complete the paper Hence the paper is presented as summarised

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Table 1. Final plant size as related to IBA concentration

IBA concentration ppm	Percent establishments Ang.	Total shoot length per plant, cm	Weight per plant, gm
	'Ajami'		
2500	71	332	169
5000	74	440	210
Mean	72	386	189
	'Tephahi'		
2500	59	312	147
5000	64	410	196
Mean	61	361	171

Table 2. Percentage established (angular transformation) related to cutting position and IBA application in 'Tephahi'

Cutting position on the shoot	Area treated within the proximal 2 5 cm zone			Mean
	Cut end only	Cut end plus epidermis	50% ethanol control	
Proximal	67.2	48 5	16 2	43 9
Median	55 8	31.2	17 9	34.9
Distal	38 1	25 5	10 5	24 7
Mean	53 7	35.0	14.8	34 5

SE of means within body of the table ±2 23, comparison between cutting position P<0 05, comparison between position of IBA application P<0.01; Interaction P-0 001

Table 3. Establishment as related to position of IBA application (percentage, angular transformation)

Cultivars	Area treated within the proximal 2.5 cm zone			Mean
	Cut end only	Cut end plus epidermis	50% ethanol control	
Ajami janirek	68.8	49 9	27.6	48.7
Tephahi janirek	65.6	45 7	22 4	44.5
Mean	67 2	47 8	25 0	46 6

SE of means within body of the table ± 2 30; comparison between IBA treatment P<0 001,
comparison between cultivars P<0.01, interaction P<0.001.

Table 4. Establishment (per cent) as related to season of planting for 'Janirek' cuttings

Collection day within each month	Sept	Oct.	Nov	Dec.	Jan.	Feb	Mar.
10th	—	0	40	53	61	35	0
20th	0	12	59	65	66	42	0
30th	0	33	62	63	58	20	0
Mean	0	15	53	60	61	32	0

Discussion

In reply to Bill Flemer, Brian Howard emphasised that cuttings should be planted 7"-8" deep and not shallowly. The following points were made in reply to questions posed by Donald Cook: (i) that a high concentration of hormone for a short dipping time produced the same effect as a low concentration for a long period dip; (ii) that uptake was affected by the moisture status of the cutting, significantly greater uptake being achieved when moisture tension of the cutting was high (i.e. the cutting had been allowed to dry out slightly) . . . . fresh cuttings needed a higher concentration of hormone than partially dried cuttings; and, (iii) that cuttings should be left to dry partially after treatment so that uptake through the base is enhanced.

Jim Wells enquired about the use of powders. Brian Howard intimated that East Malling has always used liquid formations because of the precision with which they could be used. He had a series of powders under observation but different factors were involved, one of the chief problems being in the cell penetration of the hormone; this could be affected by the use of wetting agents (e.g. alcohol, water, D.M.S.O., etc.) but was also related to the grade of the powder.

PLANNING A PRODUCTION FLOWLINE

JOHN EDMONDS

Bransford Nurseries
Worcester

Each nursery produces a different product mix. For any particular plant there are several ways of propagation and any one of them can be correct within the disciplines that the layout, resources and skills impose on a particular nursery. So today you are not going to get definite solutions to your own problems —

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rather I hope to stimulate thought and discussion which may help you with your own particular problems.

There is talk within the industry in the U.K. of over-production in some items. There is truth in this for some particular plants. Thus it becomes vital to produce plants which can be sold. Remember that if you produce 100 plants and you are expecting to make 15% profit you will only cover your costs when you have sold 85 of those plants all the profit lies in selling the last 15.

So our first requirement in planning our propagation is an accurate sales record. At Bransford we only have 3 years records but already it is beginning to show trends. We are selling proportionally less of the cheaper lines and more of the more difficult and more expensive items. Accordingly, we are adjusting our propagation programme.

You will note that at this point I have said nothing about the way in which the numbers wanted of a particular plant are to be produced. At home we produce a list with the required numbers of each variety and we then divide it into field and indoor propagation. Dealing with the indoor list — this is again divided into 1st and 2nd priority. A plant will go into 1st priority on two grounds.

1. It is an item where timing of propagation is vital.

2. Unsatisfied demand, or rather, a demand in excess of expectations.

A variety in the 2nd priority list can be one where there are alternative ways of propagation; e.g., if we miss propagation under mist in the summer then we can catch up with hardwood cuttings in the winter.

When deciding on a propagation programme, there are a number of very obvious limitations which must always be borne in mind. It must fit into the available propagation space. It must fit into the available labour. It must not produce more plants than there is room to grow on, but with the qualification that the aim should be to produce 110% - 125% of the plants required and to dump the poorer plants at some time. I am convinced that this is a correct way of doing it. It is never worth while trying to produce a good plant from a poor rooted cutting. Finally, there must be sufficient material of the correct type available.

So now we come to the provision of the propagation material. At Bransford, up until now, many of our cuttings come from stock beds planted out both to provide such material and as display areas — or from saleable plants. I am sure this is wrong. So what should we be doing; or rather, what are we now aiming to do?

We are in the process of clearing a fair-sized area close to our propagation block by fallowing for a full twelve months to remove all the perennial weeds. This is then due to be planted out with the best forms of each particular plant in rows. This should enable us to collect much more propagation material than we need, quickly. By cutting all the plants — shearing hard — we should be able to produce cuttings which are at the correct stage of juvenility and growth when we want them. And by putting fair numbers of plants out — more than are wanted — to produce the number of cuttings we require now we have, as it were, a deposit of cutting material to enable us to switch our programme quickly if our sales record tells us it is correct to do that. This area will be kept clean without the use of any residual weed-killers.

Again, you will note that there are built into what I have said, some qualifications. Such a regime will not suit all plants and we have to make provision in the correct way for these. I can think of azaleas, magnolias, rhododendrons, etc. which would obviously require shade, as an example; other limitations will no doubt occur to you.

Such a stock area has other advantages in that it should become easier to control pests and diseases because the plants are closer together. Also by rigorous selection it should be possible to maintain superior plants. I am sure that as an industry we pay far too little attention to the latent effects of virus diseases in the plants we produce. If we can maintain virus-free stocks of a plant, there will be very considerable benefits to be gained in growth rates, propagation percentages, and general livability.

It is also easier to control the feeding of a group of similar plants — to produce the right sort of cutting material — with the correct balance between nitrogen and other food elements.

Other things being equal we have, for the purposes of this talk, provided ourselves with a plentiful supply of the type of cuttings we want in the varieties needed and we come to the problem of putting on the so-very-necessary roots. Whilst we, like so many nurserymen, use mist for our propagation, I am becoming increasingly aware that plants have very differing water requirements over the period of propagation. We have found with the more difficult-to-root subjects that a lot of water at the beginning followed by a very considerable reduction in the later stages is of great benefit. To this end, an adjustable control unit is of much value and we shall be converting some of our older control units.

Within a range of plants there are large differences in temperature requirements for the undersoil heating. With this in mind, I think that there are advantages in small units perhaps of only 3 or 4 sq. yards, each with its own control for heat and mist.

Whilst the design of the bench is a matter for the individual nursery, there are obviously certain basic factors to be considered. Firstly, let me put in a plea for flexibility.

1. Root cuttings directly into a rooting medium straight on top of the heat source.
2. Root cuttings in boxes or trays, over-winter in trays.
3. Root cuttings in individual pots.
4. Be converted easily and quickly to other purposes — such as a grafting case.

Such a bench must also provide drainage for water and air. Air circulation is far too often neglected and contributes to a large number of disease problems.

With cuttings in a bench in conditions of high humidity, disease is always close at hand and a regular programme of prevention is better than attempts at control.

The media to be used and the rooting hormones used are subjects which are obviously vital but I don't propose to do more than mention them. Other people closer to actual propagation are much more skilled than I in talking about them.

The handling of rooted cuttings is an area where I do feel more qualified. Firstly, at home we have been doing too much potting. Increasingly we are tending to put plants directly from the rooting bed into a container in which they can be sold. To do this there are certain very definite requirements in the compost. It must be sufficiently loose that relatively small, immature roots can penetrate it quickly and easily. It must be free draining to stop water accumulating whilst the container fills with root. And perhaps most importantly, it must have a very low salinity.

Some of the work which Arthur Carter and his people have been doing have shown that certain well known composts and fertiliser mixes can give large numbers of deaths during this establishment period. Over the last few weeks, we have potted some 7-8,000 conifers rooted last winter into 5" polythene bags. There are perhaps 20 deaths in all. In fact, there are less losses here than in a batch which were in small pots for a year to develop a root-ball before potting on. You can only do this with a compost which has a very low salinity. If there are soluble salts in the compost, there will be deaths. So I would say either use Osmocote or a similar slow-release fertiliser, which does not begin to release feed for 3 weeks or so, or use liquid feed, giving the plants a period without feeding to establish themselves. One word of warning with Osmocote and rooted cuttings; we have had considerable losses when we have mixed and stored the soil for a period before use, so allowing salinity levels to build up.

I am less catagoric about the container which should be used for rooted cuttings except to say that it could, with advantage, be considerably larger than is commonly employed — always with the proviso that there is sufficient growing-on room to take a larger pot. Try as far as possible not to mix types of containers. One of the worst mixes is clay and plastic pots, which need totally different water regimes

As far as possible, handle your rooted cuttings in bulk loads. Using 2½" pot as an example, one person can pick up 6 or perhaps 8 pots in his hands — 15 in a seed tray, but he is perfectly capable of lifting 30 plus if the correct sort of carrying tray is available.

The overall layout of the propagation area is important and at Bransford we have, after a period of developing like Topsy who just grew and grew, settled on a plan to which we can add for future expansion. It is important to be able to increase the overall size of a unit without too great a disturbance.

We have our propagation facilities at one end then follow this with a 64 x 20 glasshouse fitted with wooden sides. Each side will have 4 polythene tunnels running off at right angles. One side will contain plants which have to go towards the potting shed and the other will hold those plants which don't need to go through it for one reason or another. The main glasshouse contains a work area — flexible in position so that it can be moved round to any place wanted. It also has heaters for the polythene tunnels; most of the area is shaded with white polythene to enable us to wean plants from mist properly before moving them into polythene tunnels.

Eventually, the whole area will have concrete paths and we shall be moving plants around on trays on a close equivalent to a dinner trolley.

With this sort of lay-out, expansion of propagation space in one direction can be coupled up with the correct increase in growing area in the other direction.

Time obviously limits me but in consideration of a Flow Line, thought should also be given to the following items.

Compost mixing
Liquid feed systems
Cyclic lighting
Potting Machines
Cold Storage

In conclusion, I want to introduce six words which were drummed into me some years ago in a work study course. They are — "THERE IS ALWAYS A BETTER WAY." So don't be complacent. In these days of rapidly escallating costs it is vital that we keep on searching for ways of producing plants more cheaply.

RECENT DEVELOPMENTS IN THE PROPAGATION OF RHODODENDRONS AT BOSKOOP

ir. B. C. M. VAN ELK

Proefstation voor de Boomkwekerij
Boskoop, The Netherlands

Abstract Briefly, the propagation of rhododendron cuttings in Boskoop is described A soil temperature of 20°C (68°F) proved to be the best When the pH of the cutting medium, pure blond peat, is too low this can be raised by adding 1-3 g/1 of a chalky compound With only small losses one can make cuttings at the beginning of October The best time proved to be the second half of November or the beginning of December

After quick-dip treatment of 2,500 to 30,000 ppm, rooting was poor in comparison to the rooting of cuttings treated with a powder of 8% IBA + captan (83% spray material)

INTRODUCTION

Altering the words of a famous saying, I should like to say "What is in a rhododendron cutting". We, in fact, do not know so much about it. By concluding and deciding, people all over the world try to solve problems; we also do so at the Proofstation voor de Boomkwekerij in Boskoop. With the aid of ideas gathered in literature and the conclusions of our own trials, still existing problems must be solved. Working with living plant material, growing each year in totally different circumstances, it has been seen in several experiments that repeats of the same propagation experiment in one year often produce almost identical rooting percentages.

Because it sounds less scientific, statistical analysis of one experiment for one year does not convince a Dutch nurseryman. The importance of a certain method must be proved over the years. For that reason we try to develop repetition over the years by making cuttings of as many cultivars as can be obtained in the same trial, sometimes the details are altered but the trial will be repeated till the regularity of the results has been proved. This means that every trial will be repeated at least three years in succession, for the second year's results could have been reached by chance.

Briefly, I will speak about the normal way of rhododendron propagation and mention some of the trials and the results obare — "THERE IS ALWAYS A BETTER WAY." So don't be complacent. In these days of rapidly escallating costs it is vital that we keep on searching for ways of producing plants more cheaply.

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Briefly, I will speak about the normal way of rhododendron propagation and mention some of the trials and the results obtained with the temperature of the cutting compost, raising the pH of the peat, time of making the cuttings, shallowly or deeply wounding of the cuttings and the use of quick-dip solutions.

For a long time easy-to-root *Rhododendron* cultivars like *R. catawbiense* selections or hybrids, *R* 'Cunningham's White' and *R* 'Pink Pearl' have been propagated from cuttings during summer, just after the first flush of growth, normally in mid-July under double-glass in a cold frame. Although results were different from year to year, due to the growing season and the weather conditions after the cuttings had been stuck, rooting percentages were very different.

Because of the shortage of rootstocks of *Rhododendron ponticum* seedlings at the Proefstation, cuttings were made of the tops of these rootstocks in the beginning of December and the rooting percentages were sufficiently interesting. This was the start for the propagation of *Rhododendron* cultivars from cuttings by the growers.

I will exclude *R impeditum*, *R. praecox* and the cultivars of *R repens* and *R. williamsianum*, for these can be propagated rather easily from forced cuttings early in spring, from summer cuttings, and also better from late autumn or winter cuttings.

With the hybrids or cultivars, best rooting was reached when cuttings were made in the second half of November and the first weeks of December. One should ask; "Why not later in the season?" One never can predict the weather conditions during this time of the year. When the cuttings had received sufficient cold, differing from cultivar to cultivar, they started producing shoots instead of rooting. When, however, cuttings start growing, rooting can be improved by taking away the newly formed shoots, but this costs very much labour and what is also of importance, these cuttings, which have been stuck with care, are not sufficiently fixed in the medium, so rooting is diminished.

The cutting medium is pure brown peat. In experiments in which a mixture of 9 parts brown peat and one part sand was compared with brown peat only the rooting percentages, even from R. 'Catawbiense Boursault', dropped from 90 in peat to 10 in the other mixture. This difference is more extreme than in the experiments of Kelly (1), but more experiments have been made with about the same results, also under a mist system at the research station and, therefore, only peat has been used in further experiments. Mr. Wells states, during the same conference with Kelly, that liming could be of interest: I believe he overlooks the fact that he raises pH by adding 50% of coarse river sand to his cutting medium, while he places his cuttings under a mist system where the water-air ratio of the cutting medium is very important.

In Boskoop, propagators try to take thin cuttings without a flower bud from the lower, more or less shaded, part of the plant. Rhododendron cuttings grown in a half-shaded woody area, root better, as has been outlined by Vanderbilt (3) but in the flat area of Boskoop this type of cutting cannot be found. In the early experiments there was a remarkable difference in rooting between cuttings treated with 1% and 2% IBA in favour of 2%. When van Doesburg started his experiments with equal mixtures of captan and IBA, he mixed the same quantities of 4% IBA and captan dust to be certain of 2% of the active ingredient for the cuttings. In further experiments, captan spray material (83%) proved to be of more value than captan dust material (10%). Also when the cuttings of the difficult-to-root hybrids were treated with 4% IBA + captan spray material (83%), with which nowadays the difficult-to-root hybrids (cultivars) are treated before sticking in the medium of pure brown peat. Actually the cuttings receive 4% IBA plus the captan protection.

For a long time cuttings have been really pushed into the medium and not placed in preshaped holes because the stated stripping of the growth hormone (2) was of no influence on the rooting percentages, as has been proved in several experiments in Boskoop.

EXPERIMENTATION

Soil temperature. In several publications temperature for rooting rhododendron cuttings is discussed (5,7).

In Boskoop the practical side of propagation must be kept in mind too. In general, the number of cuttings of just one cultivar is limited because of the great number of cultivars grown at one nursery. So the best average temperature had to be found.

During the first experiments — making cuttings between mid-November and mid-December — the temperature was held between 18° and 20°C (64° to 68°F) and, although there were differences, the more easy-to-root cultivars reacted very well to this temperature.

In America, however, 70° to 75°F was favoured. In one of the experiments, therefore, part of the cuttings was placed at a soil temperature of 23°C (73.5°F) and the rooting was rather bad. In the following experiments, about 4 weeks of 20°C was given til callus formation had started and, after that, the temperature was raised to 23°C, until the cuttings were rooted. Temperature was maintained by hot water running through plastic tubes spaced one foot at a depth of one foot below the base of the cuttings.

Table 1 Rooting percentages of rhododendron cuttings[1] placed in a ground level bench and a raised bench in a glasshouse on different soil temperatures

Cultivar	Ground Level Bench 20°C, later 23°C	Ground Level Bench 20°C	Raised Bench 18-20°C
'Catawbiense Boursault'	100	99	94
'Madame de Bruin'	96	98	90
'Professor J H Zaayer'	88	86	77
'Professor Hugo de Vries'	94	92	94
'Souvenir de Dr. S. Endtz'	99	99	98

[1] At least 50 cuttings per treatment

Sometimes the rooting percentages in the raised benches were a little bit better. In general, no advantages have been seen in raising the soil temperature after callusing had started. Conclusion: why should we raise the soil temperature to about 20°C, when the rooting percentages are hardly influenced, while heating costs will be much higher.

Raising the pH of the medium. In Oldenburg (Germany) the nurserymen use freshly ground peat from their own fields. In this material the rooting was rather poor. After a mistake of using too much captan dust against *Rhizoctonia solani*, rooting of a bench of cuttings was very good. Nowadays 3 g/1 of a chalky compound is added to the peat to neutralize the decomposed (?) or unsaturated (?) fresh humic acids and the rooting is good.

The pH of peat which can be bought in the Netherlands is lowering. Sometimes the pH-water measured is only 2.9 to 3.1. To see the influence of raising the pH, 1.2 and 4 g/1 of a chalky compound were added to the peat and cuttings were placed under the same regime of temperature and water. The results can be seen in table 2.

Table 2. Rooting percentages of rhododendron cultivar cuttings[1] as influenced by different acidities of the rooting medium (pH-water)

chalk added	0	1	2	4	g/l
pH beginning	3,6	4,7	5,5	5,9	
pH end	3,7	'4,4	5,6	6,6	
r 'Catawbiense Boursault'	91	90	93	81	
r 'Edward S Rand'	91	94	90	85	
R 'Louis Pasteur'	58	61	47	55	
R Madame de Bruin'	100	90	95	93	
R 'Professor J. H. Zaayer'	95	99	84	94	
R 'Van Wilgen's Ruby'	99	90	99	98	

[1] at least 50 cuttings per treatment

In the first experiment some positive influence of raising the pH was observed. In the above mentioned table the rooting diminished at the higher calcium rate. I have to say that the pH of the blond peat was not so low as it should have been, because this material had been stored for one year. In practice, when the pH is low, 1 to 3 g/1 chalk is added without any harmful effect on the rooting of the cuttings. In the future this probably will become of more importance when younger peats with unripened or unsaturated humic acids must be accepted.

Timing of making cuttings and wounding. The propagator in Boskop is limited in time and space on his small nursery. He has to follow a very strict scheme of propagation. For about the last 7 years rhododendron cuttings have been made in mid-November, but at that time there is much other work to be done too. You can imagine that people will take a chance to spread the time of making cuttings. According to Wells (5) and others, September is a good time to make cuttings of rhododendron. Others liked to do it earlier and others later.

In Boskoop, experiments were set up with cuttings taken at about the beginning of October, November and December.

Normally only a thin slice of the bark was cut off. In these trials a part of the cuttings was also wounded heavily; that means part of the wood had been taken away over a length of 2-3 cm. This has also been done to convince growers that wounding is important, but that it is not so accurate (almost scrupulous) a job as thought. In his research, Wells (5, 6) has proved that deeply wounded cuttings very often root as well, or even better, than shallowly wounded ones. As can be seen, the results of the timing experiments differ too much to justify a conclusion at this moment.

Some cultivars can be made over the whole period. Some root better when made early; most do better when made rather late in the season. When a propagator asks for advice at the moment, he will be told to make the cuttings during November or the beginning of December. When he is restricted in his possibilities during this time he can make them in October, although we cannot forecast for him optimal results. This subject is still under research.

When a choice has to be made between the types of wounding, shallow wounding is preferable in almost all cases, for the occasional figures which are smaller in comparison to the deeply wounded ones, I believe, must be seen as exceptions, confirming the rule. More research needs to be done on this subject. In my opinion, this is less a case of roughening of our profession but more a case of dismantling the mysteriousness around propagation.

Table 3. Rooting percentages of normally and deeply wounded cuttings[1] of rhododendron cultivars made on three different dates.

Season 1970-1971	Wounded Normally			Wounded Deeply		
Cultivar	Oct. 2	Oct 29	Dec 1	Oct 2	Oct 29	Dec 1
'Direcktor E Hjelm'	74	76	84	44	52	84
'Dr H C Dresselhuys'	28	36	50	50	28	58
'Hollandia'	24	20	22	28	34	14
'Mrs. Lindsay Smith'	16	28	64	52	54	90
'Pink Pearl'	96	86	84	96	84	92
'Professor J. H. Zaayer'	84	90	100	82	94	100
Season 1971-1972	**Wounded Normally**			**Wounded Deeply**		
Cultivar	Oct 4	Nov 8	Dec. 7	Oct. 4	Nov 8	Dec. 7
'Britannia'	44	32	50	62	10	50
'Direcktor E. Hjelm'	68	70	58	34	46	72
'Doncaster'	56	42	64	70	60	56
'Dr H C Dresselhuys'	18	14	44	32	60	44
'Hollandia'	42	28	48	52	16	16
'Mrs Lindsay Smith'	18	6	6	58	70	12
'Pink Pearl'	90	96	70	90	96	84
'Queen Mary'	58	34	80	84	52	84

[1] at least 50 cuttings per treatment

Quick-dip solutions. A new idea for our research was born in 1969 after personal communication with Dr. Howard and Mr. Humphries, our first president.

Of course, the experiments in the U.S.A. (3, 4) were known, but 2, 4, 5 - TP never was a success in the series of experiments with this product carried out by my predecessor, van Doesburg, and myself. The solutions for the IBA quick-dip treatments to the base of the cuttings were prepared according to the advice of Dr. Howard. The check cuttings were treated with 8% IBA plus captan spray material (83%).

The check cuttings were wounded slightly; the others were cut as horizontally as possible and only treated at the base. One group was wounded in the normal way.

Table 4. Rooting percentages of rhododendron cultivar cuttings [1] after a quick-dip treatment, as compared with the controls

Treatment	'Britannia'	'Doncaster'	'Edward S. Rand'	'Nova Zembla'	'Pink Pearl'	'Van Weerden Poelman'
8% IBA + captan spray	46	88	66	98	93	80
2500 ppm IBA	2	4	4	30	58	20
5000 ppm IBA	10	8	24	55	56	15
10,000 ppm IBA	12	24	16	73	58	28
10,000 ppm IBA, normally wounded	—	—	44	—	90	49
30,000 ppm IBA	—	—	28	—	76	30

[1]at least 50 per treatment

In this table it can be seen that the treatment with the normally used powders is far the best. Remarkable are the results with the normally wounded cuttings treated with 10,000 ppm IBA. This underlines the importance of wounding of the cuttings.

Perhaps there has been made a fault in one or other way during the treatment or after the plants have been stuck, but on the basis of these results a treatment with quick-dip solutions cannot be advised to the Dutch propagator.

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Yearbooks of the Proefstation voor de Boomkwekerij at Boskoop 1967-1973

Discussion

An enquiry from Peter Brazier on the availability of information regarding rhododendron species elicited the response that the Experimental Station had included some species in their trials and results could be obtained by a written request to the Director.

Discussion also revealed that it was the practice to take cuttings from both flushes of growth during the season without any apparent differences in response.

Although considerable discussion revolved around the concentrations of IBA employed and its placement, no conclusion was determined.

THE ROLE OF THE PLANT PROPAGATOR IN THE AMERICAN MAIL-ORDER COMMUNITY

RALPH SHUGERT

Spring Hill Nurseries Co
Tipp City, Ohio 44371

The topic at hand is a fascinating one and I suppose plant propagators do not vary in their daily activities a great deal in most of the nursery community enterprises. Mail-order is somewhat different in that most mail-order propagators are requested to supply a range of plant material from houseplants through all the woody ornamentals indigenous either to their geographic location, or to a profit and loss statement in a mail-order catalog. Mail-order, be it nursery stock or any other commodity, is a game of arithmetic. The only interest is, of course, complete customer satisfaction, which is the only way you can obtain a reasonable profit on a fantastic advertising investment. There are nursery mail-order concerns throughout the world whose advertising percentage costs will range from 30 to 55% of their sales dollar. Those of us in a wholesale growing operation, or a garden center endeavor could, of course, not live with this horrendous advertising cost.

I will have to limit my remarks primarily to my own company — Spring Hill Nurseries, Tipp City, Ohio because, naturally, this

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I will have to limit my remarks primarily to my own company — Spring Hill Nurseries, Tipp City, Ohio because, naturally, this is the company with which I am most familiar. My remarks will not pertain to the propagator growing a specialty crop, be it roses, herbs, etc., but rather a propagator who is growing a wide range of plant material, dictated entirely by those items that are going to be featured in the present or upcoming mail-order promotions. A propagator in such an enterprise must be well-versed in virtually all phases of propagation, which we will touch on a bit later and, probably equally as important, he must be a very astute businessman. In most cases, he is operating on a rather rigid budget and he must be able to utilize the fullest effort from his labor market. He also must be a very careful buyer pertaining to supplies and knowing when, and how many, to buy is equally as important as growing a good crop.

In regard to the various facets of propagation, in our particular case seedling propagation is probably more important than the other types of propagation. In our nursery we are seeding directly into plant pots on benches, as well as drilling seed in field seed beds. There is also a modest amount of broadcast sowing in seed beds which are, of course, maintained entirely by hand. The direct sowing into pots is relatively new, and certainly has been a panacea in the production of plants difficult to transplant. Another factor which enters into direct sowing is the statement I alluded to earlier in customer satisfaction. Perennials across the board from Allysum to Yucca are a very important segment of our sales dollar. We are endeavoring to strive for 100% perennial production in pots so that we can ship in late February to our southern customers a green-topped perennial which will give much more satisfaction than a dormant division or clump. We have also found that direct sowing, from a cost standpoint, is much more economical in most cases than drilling in seed rows. The factor that enters into this is, of course, weeding and other field cultural techniques. We can also turn a sales dollar faster with a direct-sown perennial than a field-grown seedling. In addition to perennial sowing, most of the woody ornamentals which we seed propagate, are also handled as the field-drilled prennials — drilled with a Planet Junior Seeder then grown two years prior to transplanting. The propagator, then, must be well-versed in seed dormancy, techniques of seed stratification, and must, of course, have a reliable, dependable seed source. In our case, we are purchasing seed not only in the United States, but from several seedsmen in Europe and one or two in Asia. We also maintain seed rows on the nursery of particular species. This indeed is very handy and neat, particularly in the case of some Viburnum cultivars, where the seeds can be picked half-ripe and sown the same day they are picked thus eliminating stratification or maintaining the seed bed an extra year. Two days before we left the States I sowed *Viburnum plicatum* 'Maresii' (*V. tomentosum* 'Maresii'' and, if past results run true, we should have seed germinating by next spring.

In discussing asexual propagation, softwood cuttings, in our particular company, would be the second most important propagation technique. Our softwood cuttings are propagated under intermittent mist and have been for quite a few years. There is nothing unique about our particular mist propagation facilities, but we are doing a reasonably good job in coming up with good stands and being able to over-winter the plants. At present our softwood cutting program consists of about a ½ million cuttings taken from early May and terminating in mid-August. Over the years we have learned that cuttings of some species are easily rooted, but it's quite difficult, if not almost impossible, to over-winter them. We are presently trying to consolidate those difficult to over-winter varieties in one series of beds, so that we can place the hoops over the beds and cover them with polyethylene for winter protection. We have also been pleasantly surprised with lilac cultivars left two years in the mist bed and sold as a 9-12 inch well-rooted cutting in the mail-order catalog. Of course, in most cases, the majority of mist cuttings are rooted in the summer, over-wintered, and then transplanted the following spring directly into the field with the typical nursery transplanter. The winter hardwood program consists primarily of conifers. We have a production of about 180,000 conifer cuttings in one greenhouse.

In our nursery, all of the propagating work is not handled by our propagator, Mr. Andrew Brumbaugh. Although he is in complete charge of the greenhouses and maintains a staff of approximately 30 people year-round, there are other propagating activities which are assigned to other members of the nursery. For example, Mr. Phillips, our storage foreman, handles all of the summer budding we do in the field, which incidentally is all on piece-work, and Mr. Powell, our balling foreman, is in charge of apple and lilac bench grafting in the winter. I have the responsibility of all field seeding through drilling and a modest amount of direct broadcast sowing of new plant cultivars we are experimenting with — primarily for the purpose of evaluation. The reason I mention this is that I think it is extremely important in a company of our size to have close liaison among staff members of the entire nursery. This has worked out quite well for us with no "jealousy" or petty bickering; the cooperation among all concerned is admirable. In discussing grafting, we do a very modest amount of spruce grafting of some of the species, and this is under the direction of Mr. Brumbaugh.

The present era has been labeled by some as the age of the computer, and I would most certainly concur with this philosophy of thinking. The computer at our nursery has been of great assistance to most of us and certainly is beneficial to our plant propagator. By looking at the weekly sales analysis reports, he is able to evaluate the projected sales of any given plant in the catalog, and can immediately check back against last year's sales, as well as the inventory on hand. All of this data, plus other information, is on one sheet of paper which gives him great assistance in planning and programming. Planning and programming of plant propagation is equally important, in my opinion, to the production and the actual growing of the crop.

I should like to direct a few remarks to the Junior Members of the I.P.P.S. I note with great interest and delight that 18% of the GB & I Region consists of Junior Membership. To those Junior Members in the audience, as you move through the nursery community in your life span, you will probably make one or several job changes. I personally see nothing wrong with this since one's ambition in life is to reward your talents with enthusiasm and, of course, the remuneration is part of the overall package. If you would permit some advice, as you interview for a job change, I think there are several salient points that should be discussed with your prospective employer. First and foremost, is of course, the business of philosophy of the company to which you are applying. This is extremely important from a plant propagator's standpoint since you must know what type of plant material you are going to be asked to produce and the existent philosophy of the company naturally goes hand-in-hand with your production. At the same time, I think it would be wise to explore the possibility of a conceivable change in business philosophy in the immediate future. For example, if you are interviewing with a prospective employer who presently is doing the bulk of his business through garden center and landscape endeavors, you will be producing an altogether different plant than a mail-order nursery. This is an item that is very rarely discussed and the questions that you ask in this broad area deserve an answer. Secondly, it is expected of you, and you are entitled to know, the profit and loss statements for the existent year and perhaps a year or two back. There may be some reluctance to disclose figures, but if you have applied for a position and are seriously considering joining a management staff, you should be entitled to see this information, and at the same time, be a gentleman to consider it privileged information in that it should not leave the room with you. And lastly, of course, the facilities in which you will be working and the problem, if you will, of existent employees who will be under your direction Sometimes this can present a major problem, and it is not unusual for some friction and, in isolated cases, the dismissal of an employee who absolutely will not cooperate with your own idealogies and concepts of work performance. In my experience, this has been quite overrated, and I do believe that anyone joining a new company can perhaps adapt and, if the situation is intolerable with an isolated person or two, then it is to the betterment of all to dismiss the problem. The reason I mention this in this presentation is that we very rarely discuss job opportunities or the problems and situations that do arise when one wishes to move to a new company I think quite often both management and the prospective employee act too hastily and we do not deliberate over the aspects of many things that will make life much more tolerable for all concerned I personally delight in companies who are strongly departmentalized and allowing the various department heads some responsibility as far as hiring employees, purchasing, etc The challenge is much greater and most well-knit companies who operate in this tenor also have well-scheduled staff meetings so that each department is working cohesively with the adjacent department and therefore, we have harmony rather than discord

The nursery community, whether it be in Great Britain or the United States, is a fascinating and challenging industry.

Someone said once that nothing comes easy, and I suppose this is true, but I do believe that the challenges that a propagator encounters in a mail-order endeavor are perhaps larger than in any other facet of the nursery community. As I mentioned earlier, rather than the mere production of a wide range of plants, one factor that certainly keeps an active mind more active, is, of course, diversification. Believe me, if you consider propagating for a mail-order nursery, you will encounter this attractive stimulating activity.

The closest that the United States has ever come to a poet laureate was a gentleman by the name of Robert Frost. Mr. Frost, along with Mr. Thoreau and several other gentlemen are favorites of mine, and I think of all the words that Frost wrote — the one verse that sticks firmly in my mind goes as follows:

> "The woods are lovely, dark and deep,
> And I have promises to keep,
> And miles to go before I sleep,
> And miles to go before I sleep."

I think that we could paraphrase Mr. Frost's words to that of a propagator, *per se*: We all have miles to go before we experience the same activity twice and before we can actually assure ourselves that we have solved a knotty problem that might arise. I think many of us have been in the situation that I found myself in. After spending five years in the nursery community, I knew all the answers to all the questions! Now after 26 years in the community, I become more impressed each day with my own ignorance. We are in the most challenging, the most dynamic, the most gratifying profession that anyone could be engaged. Each of us has an obligation to ourselves to contribute to this quite honourable profession. When we are sowing seed — taking cuttings — grafting — we are doing just that! I have made the comment that I would not trade my profession with any nuclear physicist or any other profession in the world, and I mean that. I am pleased, honoured, and proud to be an integral part of the nursery community. The International Plant Propagators' Society is the cohesiveness that we as propagators need, and this is why we revere our Society as we do. My last word . . . much success, much happiness, much peace. May God walk at your right hand today — tomorrow — forever.

CERTAIN ASPECTS OF PROPAGATION IN HOLLAND AND GERMANY

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The following is based on horticultural experiences gained when I worked in Holland and Germany during the period 1970 to 1972. I was initially employed by a Boskoop export nursery — William de Jong & Sons, and worked there during the despatch and packing season. I then worked with a specialist propagator for one year — Mr. Leo van Lint. I was then engaged by Firma Wilhelm Eberts, in Schleswig-Holstein, Germany. Mr: Eberts' nursery specialized in the production of pot liners of a wide range of evergreen and deciduous shrubs and conifers.

In many ways I was luckier than most British students because I became involved with the growers who supply the better known Export Nurseries. I was, therefore, able to understand the business functions and dealings reciprocating between nurserymen and exporters alike. Although cultural methods are different in Holland as compared to those in Germany, the business methods used in both countries are very similar and, in turn, quite different to our present methods in Britain.

Most exporters and dealers on the Continent are also growers although they do not propagate vast quantities themselves. Propagation is usually contracted out, or plants are bought as liners from specialist nurseries such as the firms of van Lint and Eberts.

I think it is fairly obvious to all of us that propagation is a specialized job. The equipment and labour necessary for successful commercial propagation is expensive compared to other key jobs involved in growing. To fully utilize this labour and equipment vast amounts of plants have to be produced intensively. The annual turnover of plants for such a unit is usually too large for even very large firms to grow on to saleable sizes.

As propagation timings often coincide with other cultural timings such as planting, containerising, staking and tying, or lifting and packing, it seems logical that propagation should be carried out by specialists. This streamlined system is universal throughout Holland and Germany. I feel that British nurserymen will very shortly need to be thinking on similar lines, especially when the market becomes even more competitive and the need for maximum utilization of labour and equipment becomes essential. One of the first things I noticed on the Continent was the production of stock plants! I am pleased to see that the British nurseryman is becoming more and more aware of the need for porperly grown stock plants. Successful propagation can only be achieved if mother plants are pruned and fed to give maximum production of cutting or scion material. The hedge system of growing mother plants ensures that the plants are cut hard back every year, and therefore reproduce vigorous young material for harvesting the following season. This system of hard pruning and forcing can be used with most plants, with only few exceptions such as *Cotinus coggygria* 'Royal Purple'. I find *Cotinus* cuttings root very well when the young growing shoots from large unpruned plants which have just formed their terminal buds are taken as cuttings.

The German and Dutch nurseries have extensive areas of well kept mother plants. The Dutch also force deciduous azalea mother plants under glass or polythene structures. They were originally forced in order to produce cutting material earlier than from open ground grown plants, but it was very quickly noticed that the percentage take was also much higher using indoor material. I have since proved this with other crops whilst working in Germany and South England. I would imagine that mother plants grown under artificial lighting in conjunction with glass or polythene would produce still better strike rates. I feel this would be particularly so in crops such as Japanese maples, magnolias, Japanese and deciduous azaleas, *Prunus*, *Exochorda*, and even difficult subjects such as *Kalmia*, *Daphne x. burkwoodii* and *Acer griseum*.

Mist propagation is very rarely used in Boskoop. Instead, polythene film is used to cover cuttings and grafts in cold frames as well as in heated glasshouses. The clear polythene film is only 0.015 mm thick — heavier gauge polythene film does not give acceptable propagation results. I have since used polythene film in Germany and England, with excellent results. Cuttings rooted by this method included clematis, Japanese maples, *Chaenomeles*, evergreen and deciduous azaleas, rhododendrons, etc. The technique is very simple basically — after the cuttings are watered in, the polythene film is laid on top of the cuttings. The edges of the polythene are tucked in, so sealing the cutting bed. It is, of course, important to shade the cutting frames adequately. I have found that 250 gauge dense white (milk-white) polythene is the ideal material for this job. After about ten days, the cuttings are aired for an hour or two and, if necessary, are sprayed with captan if fungal attack is at all suspected The cutting bed is then sealed up again and opened at weekly intervals until the crop is rooted. It is important, especially in high summer, to harden-off a crop by removing the polythene film gradually (i.e. opening the cutting bed up daily for about one or two hours for at least three days before finally removing the polythene film). If the film is simply taken off at the first signs of rooting, severe scorching and possibly collapse can occur. Nevertheless, I was very impressed with the way the Dutch used this cheap method of propagation to best advantage, proving that sophisticated heated mist units are not the only means of propagating commercially.

Firma Wilhelm Eberts in Holstein-Germany did, however, have extensive misting houses. Firma Eberts is a firm which is geared up to production of pot-liners only and, it could be said, is run on factory lines. One third of the nursery area is taken up by stock plants which are planted in the hedge system. Briefly, cuttings are rooted in summer, autumn and early winter. The cuttings are stuck in boxes, rooted in the mist units, then weaned and kept under cold glass until they are potted off and graded in the following spring. All the cuttings are liquid fed after they are weaned off.

The bulk of the potting at Eberts was done on a Meyer potting machine. Square pots were used throughout the nursery, ranging from 7 cm. to 11 cm. The majority of the potliners were, however, in 7 or 8 cm. pots. Square pots are much easier to handle than round pots because a block of up to twenty-one pots can be lifted in one movement, whereas no more than six round pots can be moved at any one time.

Pallets were used throughout the nursery for taking plants from the potting machine to the frames. The Datsun-Nissan pallet truck could be operated on gas or petrol so it could be used safely in the glasshouses and sheds.

The potted cuttings were stood in 9' (approx.) wide beds which were covered with dense white polythene for winter protection. It was interesting to see that conifers over-wintered under glass were of inferior quality and colour when compared to those overwintered under polythene tunnels. The plants in the polythene tunnels were also quite moist throughout, and no signs of frost damage could be noticed even though the temperature had often remained below freezing for periods of four days or more at a time. The glass-covered frames, on the other hand, did have a number of frost-damaged and dry plants in them.

Secateurs were used whenever possible for making cuttings. Tina, 18 cm. long, were found to be easiest type of secateur for cutting making. *Symphoricarpos*, *Potentilla*, *Cotoneaster* and similar shrubs were bunched up and cut into sections about three inches long. Seradix No. 2, mixed with captan, was the only hormone used at Eberts.

The bulk of the nursery's labour force was made up of Spaniards who worked from April until early December every year. During winter and the early part of the year, only a skeleton staff of regular workers were employed.

Although the bulk of Mr. Eberts' production consisted of cuttings, a wide range of plants were also grafted. Miniature roses were grafted in December using dormant buds. The understock used was 8/12 mm. *Rosa multiflora*. A "T" incision was made at the top of the stock, and a single-eyed scion was then inserted in the same way as in summer budding. The grafts were not tied, and were plunged into beds of moist peat which was heated to 65°F. The bed was covered with a polythene tent and after about six weeks the young shoots produced from the dormant eyes were used for 'green-leaf' scions; so the process was repeated. The first batch of grafts were potted into 9 x9 cm. square pots making saleable plants within fifteen weeks. A production line was set up when we grafted the roses, in which one man collected and cut the scions and two others made the incisions and inserted the scions into the stocks. *Cedrus*, *Hammamelis*, *Picea*, *Pinus*, *Syringa* and *Parthenocisus tricuspidata* 'Veitchii' were also grafted. I was interested to note that two, three and five-needled pines were *all* grafted onto the common rootstock, *Pinus montana* (syn. *P montana mugo*) (i.e. reverse)

I hope in this very general paper to have summarised the highlights of the time I spent working on the Continent. I felt, as is usual in similar cases that the time spent on the Continent was all too short but the memories and horticultural experience gained will always be of value to me.

It is encouraging to know that our products are in great demand throughout Europe, and I see great futures for progressive companies within the now enlarged Common Market.

INITIATING A PROPAGATION PROGRAMME AT KINSEALY

J. G. D. LAMB

The Agricultural Institute
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The considerations that prompted the initiation of a research programme on hardy nursery stock at Kinsealy in 1967 included a rising import bill, the possibility of building up an export trade, and consideration of the very favourable conditions of soil and climatic factors as evidenced by the existence of famous gardens in all parts of the island. These gardens are of international repute for the extent of their collections and for the size and luxuriance of growth of many of the trees and shrubs cultivated in them. Another positive factor was the comparative freedom from

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Yet despite this obviously favourable background Irish nurseries are mostly small scale family businesses, catering for a local trade; few are large enough to become companies. Here then was an identifiable opportunity to encourage growth from a small base with, in the short term, a home market and further ahead, a large export potential.

The immediate question was the type of research to be undertaken at the start of the programme. One possibility was to undertake fundamental investigations into such problems as the identification and manipulation of factors of the environment which control rooting in cuttings with a view to a better understanding and hence to improvement in techniques. Other fundamental studies such as photoperiodic responses of various species, nutritional requirements and so on were considered. It was recognised that such studies are highly desirable, indeed essential, but they were deferred in favour of questions of more immediate urgency as judged by the criteria of national need and likelihood of results that would quickly stimulate expansion of the nursery industry.

Visits to nurseries, and a survey carried out in 1968 with the co-operation of the advisory services of the Department of Agriculture, showed that while garden centres were multiplying near the larger areas of population, these centres depended to a large degree on greater imports to meet the demand for trees and shrubs which was growing yearly with the increasing number of new houses, parks and factories. The existing nurseries were not geared to rapid expansion of production and there was little realisation on the newer techniques of plant propagation. A few nurseries had installed mist units, but there were no data tested under conditions in Ireland and little information was available on which to organise a planned production programme.

The basic problem, therefore, was one of the improvement of existing practices, especially the introduction and testing of newer techniques. During the first six years of our programme the work has been along three main lines:

A) The propagation requirements of individual species and cultivars, including vegetative propagation and production from seed

B) The testing of new systems of propagation

C) The synthesis of (A) and (B) into production programmes for the nurseryman

A] The propagation requirements of individual species and cultivars

i) **Influence of cultivar.** It is well known that with many genera, some cultivars are more easily rooted from cuttings than are others. However, such knowledge is generally acquired on a trial and error basis by individual propagators and is not recorded for the benefit of a wider public. Experience at Kinsealy with *Chamaecyparis* cultivars has been quoted in the Proceedings of this Society (1). Other examples which could be given include *Acer palmatum* where the cvs. Atropurpureum, Osakazuki and Vitifolium have, over several seasons proved relatively easy to root and to grow on. Others, like A p. 'Dissectum Paucum' and A *japonicum* 'Aureum' have proved either more difficult to root or to grow on afterwards. The Exbury azaleas 'Gibralter', 'Gold Dust' and 'Kathleen' are among those found relatively easy to root. Examples of more difficult cultivars include 'Golden Girl', 'Ballerina', and 'Cecile'. Similarly the rhododendrons, 'Pink Pearl', 'Purple Splendour' and 'Gomer Waterer' root readily at Kinsealy, but 'Britannia', 'Doncaster' and 'Cynthia' are more exacting.

ii) **Timing.** The date at which the cuttings are taken can be important in several contexts. At the species level, *Betula lutea* has rooted well from cuttings taken at intervals from May to July, whereas those of *B. jacquemontii* only rooted from mid-August on. Cherries, too, can be divided into two groups, those which come readily from softwood cuttings in spring, (e.g. *Prunus incisa*, *P subhirtella* 'Autumnalis') in contrast to the Japanese cherries which have rooted better from late summer cuttings. At Kinsealy a few junipers have rooted as well from October cuttings as from April cuttings but, in general, better and quicker rooting has resulted from the latter, using the cold frame and plastic method.

The influence of timing over a period of two months on rooting and the effect on subsequent development has been described for *Chamaecyparis* (1). Another aspect of this question is whether cuttings taken early, rooted quickly, and then grown on surpass in subsequent development those allowed to grow to a larger size before being removed from the parent plant. Two contrasting examples are *Prunus incisa* and *Pyracantha coccinea*. With the former, May cuttings not only rooted in higher percentage but were larger plants by autumn than those taken in July. With *Pyracantha*, to the contrary, May cuttings never caught up with larger cuttings struck in September. Furthermore, the May cuttings did not flower the following season, whereas the September cuttings could be sold as berried specimens one year later.

With some trees and shrubs, e.g. Japanese maples and deciduous azaleas, while rooting is feasible over a period of weeks, only early struck cuttings will give plants which will survive their first winter without heavy losses. This has led to the development of techniques for the production of early cuttings, as will be described presently.

iii) **Time taken to root.** In planning a production programme it is necessary to know which species and cultivars can be grouped together to vacate propagating space simultaneously. While speed of rooting is usually associated with ease of rooting, the propagator will frequently wish to know, in addition, which species, often quite unrelated, require the same rooting time. For example, when filling frames with soft cuttings in June, subsequent operations are much simplified if it is known that *Viburnum tinus, Weigela, Ulex, Lavandula, Kolkwitzia, Escallonia* and many others can be rooted in 3 weeks, whereas *Senecio compactus, Skimmia, Ligustrum ovalifolium* 'Aureum', *Cotoneaster adpressus* and others require 5-8 weeks under conditions at Kinsealy.

iv) **Type of cutting.** Taking cuttings with a heel of older wood is a long established practice amongst propagators. Trials at Kinsealy with four cultivars of *Chamaecyparis lawsoniana* (2) and with five species and eight cultivars of *Juniperus* (2) gave better results from cuttings of the current year's shoots clipped off with a secateurs than from prepared heeled cuttings. With *Chamaecyparis* the results from the heeled cuttings were at least as good or substantially better whether propagated under mist, in a cold frame with double glass, or by the cold frame and plastic method. With *Juniperus* also, the stem cuttings were, in almost all instances, superior in numbers rooted and size of root system.

'Mallet' cuttings are side shoots taken with a short section of the parent shoot attached. In a trial at Kinsealy with *Berberis x lologensis* such cuttings gave 65% rooted as compared with 35% for basal cuttings (i.e. cut through the swollen base of the shoot just above the parent branch) and 15% for the nodal type. Material for nodal cuttings is not, however, abundant in this barberry, so pruning trials to investigate the possibility of increasing side shoot production would be desirable. With the more readily propagated *B. verruculosa* no significant differences resulted in a trial comparing mallet, basal and nodal cuttings.

v) **Use of root promoting substances.** The usefulness of root promoting substances was, in the absence of published information based on trials under local conditions, regarded as a matter for trial and error for the 'individual nurseryman, resulting in opinion rather than documented information. Experience at Kinsealy has shown that even easily-rooted subjects, e.g. *Euonymus, Hebe* and *Cytisus* can react positively to treatment (Table 1). Examples of genera rather more difficult to root which have also given improved results with IBA are *Magnolia, Hamamelis* and *Viburnum* (Table 1). Species and cultivars which did not give a marked response included some of the Exbury azalea cultivars, *Caryopteris* x *clandonensis*, *Ceratostigma wilmottianum*, *Cotoneaster congestus* and others. Just because a species or cultivar shows a definite response to root promoting substances when propagated one way, it does not follow that it will do so when propagated under an alternative system.

With leaf-bud cuttings, e.g Camellia and *Mahonia japonica*, the use of IBA is not recommended owing to the delay in bud break that follows application of this substance so close to a single bud.

Table 1. Response of some easy and some difficult rooting species to IBA

Species and cultivar	Treatment	Percentage rooted
Euonymus radicans	0 4% IBA	98%
" 'Silver Queen'	Control	11%
Hebe pinquifolia 'Pagei (*H pageana*)	08% IBA	60%
"	Control	40%
Hebe 'Simon Delaux'	08% IBA	90%
"	Control	55%
Cytisus scoparius 'Dragonfly'	.08% IBA	70%
"	Control	35%
Magnolia stellata	08% IBA	90%
"	Control	63%
Hammamelis mollis	08% IBA	100%
"	Control	75%
Viburnum carlesii	08% IBA	95%
"	Control	67%
V x *carlcephalum*	08% IBA	85%
"	Control	30%

vi) **Wounding.** is often an aid to better rooting. Apart from participation in the IPPS experiment reported by Howard (2) in most cases wounding of the cutting has been carried out on cuttings of subjects for which it has been recommended by various authorities. In general, it has been observed to be beneficial, but more experimental work is needed in this field.

vii) **Medium for rooting.** For most subjects we use 2 parts granitic sand to 1 part moss peat. Trials on a limited scale and wider experience indicate that generally this mixture gives better results than peat only, sand only, or 2 parts sand to 1 of peat. Where there is little difference in rooting, we favour the mixture containing the greater proportion of peat, since this material is obtainable as a standardised product. Current investigations at Kinsealy indicate that the origin and grade of sand will have to be considered in relation to the subject being propagated. For *Ericaceae* we recommend peat only.

B) **Systems of Propagation.** Since mist propagation was already practised in nurseries, our initial work on the requirements of individual species and cultivars was carried out in a mist unit. Though considerable information has since been built up under cheaper alternative techniques, where the nurseryman has a mist system already installed it is essential for him to have the information to enable efficient utilisation of the system. Hence the information that has been compiled on date of insertion, time taken to root, and the other details described above will enable him to plan maximum throughput. Systems involving plastic sheeting in the place of mist are being recommended for more and more species in the light of further experience. Nevertheless, it is useful to know which species are quick and easy to root under mist, so that they can be utilised as catch crops should there be vacant space on the bench.

This substitution of thin (80-100) gauge, clear plastic sheeting for the mist to provide the necessary humidity is the first step in simplification. Successive steps are the cold frame and plastic system, and then the low tunnel of white plastic out-of-doors. These latter systems are well adapted to the mass production of quickly-rooted subjects such as *Ribes*, *Deutzia*, *Philadelphus* and many others. To complete the range of systems, the plain cold frame and open ground rooting of cuttings are included in our tests.

C) **Production Programme.** Our experience at Kinsealy on the individual treatments of different species and cultivars and the results from different systems have been tabulated in our publication 'Propagation of Trees and Shrubs at Kinsealy' (3). A sample page is quoted below:

WARM BENCH AND PLASTIC

The results in Table 2 (below) refer to the method whereby light plastic sheeting (100 gauge) is placed closely over the cuttings and sealed down at the edges. This plastic sheet is lifted every 10 days for 10 minutes, any fallen or unhealthy leaves being removed before replacing the sheet.

Undoubtedly, many more species than are listed can be propagated by this method. Those included merely represent results to date at Kinsealy.

This information enables the propagator to consider the alternative means of propagating the plants in which he is interested, to decide what equipment he needs, and to plan his throughput to a degree to which would have been impossible without these guidelines before him. It is not claimed that these are final recommendations, but are to be improved on or modified in the light of further experience.

Table 2 Warm bench and plastic. results from work at Kinsealy

Species, cultivar	Percentage rooted	Period	Wound + No wound -	Hormone	Medium
February					
Calluna vulgaris cvs.	92-100	3 weeks	—	None	P
Daboecia cantabrica 'Alba'	96	9 weeks	—	"	P
Erica carnea cvs.	85-100	6 weeks	—	"	P
Erica ciliaris 'Wych'	68	6 weeks	—	"	P
Erica stricta	92	6 weeks	—	"	P
Erica vagans 'Lyonesse'	48	6 weeks	—	"	P
Rhododendron 'Blue Tit'	88	8 weeks	+	Seradix 3	P
Rhododendron campylogynum	78	8 weeks	—	"	P
Rhododendron fastigiatum	44	8 weeks	—	"	P
Rhododendron hanceanum	100	8 weeks	+	"	P
Rhododendron macrostemon	90	8 weeks	+	"	P
Rhododendron mucronatum	77	8 weeks	+	"	P
April					
Azalea — Exbury (forced under plastic)					
'Gold Dust'	98	10 weeks		None	P
'Balzac'	95	9 weeks	—	"	P
'Hotspur'	85	12 weeks	—	Seradix 3	P
'Marconi'	100	12 weeks	—	"	P
'Strawberry Ice'	75	10 weeks	—	None	P
July					
Azalea — Evergreen hybrids					
'Armada'	100	5 weeks	—	Seradix 3	P
'Buccaneer'	80	5 weeks	—	"	P
'Hino-crimson'	80	5 weeks	—	"	P

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1. Lamb, J. G. D. 1970. Trials on propagation of *Chamaecyparis* at Kinsealy. *Proc Inter Plant Prop Soc* 20:334-338.
2. Howard, B.H. 1971. Nursery experiment report: The response of cuttings to basal wounding in relation to time of auxin treatment. *Proc Inter Plant Prop. Soc* 21:267-274.
3. Lamb, J. G D , Propagation of Trees and Shrubs at Kinsealy, 5th ed

Discussion

In answer to a request from John Gaggini, Dr. Lamb supplied the following details concerning the rooting of cherries from stem cuttings:

Group 1 — (*Prunus incisa*, *P. subhirtella* and cvs., *P. 'Accolade'*, *P x hilleri* 'Spire' etc.) were taken in spring as softwood cuttings when large enough to handle, treated with Seradix 3 and placed under intermittent mist, in 2 peat/1 sand mixture with a bottom heat of 70°-75°fi. These rooted well and made good growth in the first year

Group 2 — (Japanese cherries 'Kanzan, 'Tai-Haku-Zakura', etc.) — taken in July as semi-ripe cuttings; the cuttings were wounded, treated with Seradix 3 and inserted as above. Rooting was good but extension growth didn't occur until the following year.

Andy Leiser asked why cuttings were used rather than budding, to which the speaker replied that in Ireland there was no expertise for tree budding, it saved purchasing stocks and, in practice, the time scale to tree production was no greater. Dr. Lamb also indicated that he had not yet worked with virus-free material.

Peter Vermeulen observed that he had taken *P.* 'Kanzan' cuttings in June, used the Propacon system and achieved 18-21" plants by the end of the season.

PRODUCTION OF GARRYA ELLIPTICA

DAVID RIDGWAY

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Hadlow, Kent

With increasing demand for this plant within the trade, it was decided to adjust our production programme so that a saleable plant of acceptable size could be produced in one season instead of the traditional time of 18 months. To do this, we analysed the plant from the first principles; its propagation, subsequent production, and growth behaviours.

PROPAGATION

There seems to be no difficulty in rooting this subject if normal procedures and precautions are taken.

Preparation of Cuttings. Cuttings are collected, prepared and inserted from late summer through November. Tip nodal cuttings, 3-4 inches long, or strong side shoots with a heel are used, ensuring, with both types, that the terminal bud has developed. Avoid thick, vigorous "water shoots." Wounding is optional; if carried out then a light wound should be made, 1 inch long. Deep wounding will often result in loss of the cutting due to fungal infection. Seradix No. 3 (0.8% I.B.A.) is applied to the base of the cuttings. Bottom heat (68°F - 70°F) was given and within six to eight weeks rooting should take place.

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Compost. This should be very well drained; we would suggest 60% peat, 40% ¼ inch crushed grit (sharp angled grit, *not* pea grit). Sand will fill in the pores of the peat, making it poorly drained.

Conditions Under Mist. Reduce the incidence of mist to a minimum; i.e. turn off at night and manually operate during dull, overcast days. Keep cuttings from the direct rays of the sun as they easily scorch; therefore shade that part of the mist unit.

Excellent results have been obtained in rooting by just applying bottom heat and covering the cuttings with 100 gauge polythene film.

Apply a systemic insecticide to overcome sclerid fly larvae infection, if necessary; the regular use of a fungicide is also desirable.

PRODUCTION

Systems preventing root disturbance. The greatest problem with producing this plant is that it reacts unfavourably to root disturbance and it is to this point that special care and attention is required.

We have tried a number of methods to lessen root disturbance during the propagation stage. Jiffy 7's and 2" Jiffy pots have been used, each of these having the disadvantage of being costly and reducing the number of cuttings per square foot of propagation area. Jiffy 7's gave poor rooting results, which we think was due to their poor drainage qualities.

The BLOXER SYSTEM still gives us the best results. This is a system using a jig which weaves a 2" polythene strip into a honeycomb design which fits into a standard seed tray, giving 40 or 60 separate compartments per tray. These compartments also add to the drainage of the compost.

Over Wintering. Once rooted, remove trays from propagation area and stand down in a cool house with a minimum night temperature of 40°F, keeping them as dry as possible. *Garrya* adapts itself to drought conditions very well. If kept wet and cold the rooted cuttings will damp off very quickly.

Potting Off. Wait until the rooted cuttings finish their first spring growth flush. This first extension growth should be limited to a minimum, therefore water sparingly and the young growth will soon harden up, developing a terminal bud. To pot off during "full flush" is not recommended. The whole plant is under stress; it is physically in a very vulnerable condition and the roots are fully active supplying water to the extension growth to maintain turgidity. To disturb the plant at this stage is to damage the extremely brittle roots resulting in the young growth collapsing, turning black and dying. Very rarely does the plant recover from this shock.

To succeed at this stage, it is vital that one only handle the rooted cutting when the demand on the root system by the leaves is at a minimum.

At this stage the rooted cutting can be roughly handled without undue harm and can, with confidence, be potted directly into its final container, i.e. 6¼ inch. During this operation, we pinch out the terminal bud, ensuring a well-balanced plant with 2-4 shoots. At the end of the growing season plants are at a saleable size of 2 feet and also well-branched.

Growing on. Once potted, the plants are placed pot thick in a 14' x 60' polythene structure. The day temperature is allowed to get quite high before ventilating, keeping the humidity high. The plants respond well to this treatment. The polythene is taken off in July allowing sufficient time to harden up. No liquid feed is given as it did not seem necessary.

Potting Compost. Naturally *Garrya* will thrive in poor sandy soil. It is a plant that does not need high levels of nutrition and as long as it is supplied with sufficient water it will produce strong vigorous growth.

Potting compost used was:
70% peat, 20% loam, 10% ¼" crushed grit
5 lb. John Innes Base fertiliser per cubic yard.
3 lb. crushed limestone per cubic yard.

Garrya will suffer from root scorch if the compost contains a high level of fertilizer — in particular readily-available nitrogen.

CONCLUSION

To be successful in producing *Garrya* plants one has to treat it with respect and as an individual Its needs must be fully understood. It is a plant that will not tolerate standard production techniques which a wide range of shrubs will, i.e standard propagating and potting composts, propagation procedures, potting off times and hard handling, etc.

Garrya elliptica will tolerate:

Arid conditions — low fertility.
Well-drained sandy soil.
Drought conditions.
A wide range of soil pH.

It will not tolerate:

Root disturbance when actively growing
High fertility, which causes root scorch and death

Once the plant is established it will then grow away with vigour, if supplied with water and warmth. By carrying out the procedures described in this paper, a profitably saleable plant can be produced, with minimum losses, within 10 months.

Discussion

John Gaggini inquired as to the effects of pinching *Garrya* plants when growth was still soft rather than awaiting the end of a growth flush. Arthur Carter indicated that only about 50% of the shoots broke, the remainder produced only a continuing leader shoot. Bernard Van Elk explained that they had a similar problem with hibiscus in Boskoop.

PRELIMINARY TRIALS WITH PULVERISED PINE BARK AS A ROOTING MEDIUM

ARTHUR TURNER

The Royal Horticultural Society's Garden
Wisley, Surrey

INTRODUCTION

In September, 1970, Mr. J. R. Aaron of the Forestry Commission visited Wisley and asked if we could use pulverised pine bark experimentally for various purposes around the garden and offered a generous consignment of the material to enable us to assess its merits. Some of the uses were fairly obvious and these included mulching, plunging material and inclusion in growing composts for orchids and bromeliads; its use as a rooting medium was less obvious although it has the physical properties needed in cutting composts. It is capable of retaining moisture, although absorbing somewhat less than peat, and it drains off any surplus water rapidly, thus remaining well aerated.

Pine bark is available in large quantities from felled timber and not many years ago was regarded as a waste product not easily disposed of; now, in its pulverised state, it is proving a very useful commodity in horticulture. It lacks any readily available plant food and can create nitrogen deficiency if mixed in the raw state with soil. This food shortage is not an important factor whilst cuttings are rooting and can be corrected by applications of liquid feed or compensated for by foliar feeding when this is necessary. Although the pH of the material is not specifically stated in Forestry Commission literature, a sample tested at Wisley gave a reading of pH 5.5, nicely on the acid side and very suitable

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Pine bark is available in large quantities from felled timber and not many years ago was regarded as a waste product not easily disposed of; now, in its pulverised state, it is proving a very useful commodity in horticulture. It lacks any readily available plant food and can create nitrogen deficiency if mixed in the raw state with soil. This food shortage is not an important factor whilst cuttings are rooting and can be corrected by applications of liquid feed or compensated for by foliar feeding when this is necessary. Although the pH of the material is not specifically stated in Forestry Commission literature, a sample tested at Wisley gave a reading of pH 5.5, nicely on the acid side and very suitable for ericaceous plants Perhaps it should be pointed out at this juncture that bark ammoniated by the forestry commission in early experiments jumped to what is for many plants an unacceptably alkaline reading quoted by Aaron (1) as about pH 8.0.

MATERIALS AND METHODS

The pine bark used in our initial trial had been stacked and weathered for a year. Experience gained since then indicates that there is no inhibition of rooting or other ill effect when new material is used. No sand, grit or other drainage material was added and on a subsequent occasion when 1 part polyolefin granules were added to 3 parts of pulverised pine bark, no significant advantage was noticed.

Cuttings were taken over the period October, November and December, 1972, were lined out in the bark in plastic seed trays and then placed under intermittent mist with bottom heat thermostatically controlled at 75°F in the bench sand bed. Air temperature in the glasshouse was maintained within the range 50-55°F. Woody subjects were wounded with a ½" slice wound and dipped in I.B.A. powder at a strength of 0.5%.

A wide range of plants were used and these included rhododendrons, camellias, ericas, cassiopes, X *Cupressocyparis leylandii* and *Ilex aquifolium* 'Golden King'. Sundry glasshouse plants needed in our routine replacement programme were also rooted in the pine bark.

RESULTS

Results in most instances were extremely good. Early inspections showed that most of the cuttings from woody plants were forming roots in about four weeks, softer cuttings naturally rooted much more rapidly.

Twenty-two species or hybrids of rhododendrons were inserted and these gave us between 90% and 100% potted with extremely good root systems within 8 weeks of insertion, with the exception of *Rhododendron* 'Emerald Isle' (50%), *R* 'Jalisco' (60%), and *R oreotrephes* (30%). *R. oreotrephes* is inclined to be partly deciduous and may have given better results if taken earlier. The poor percentage of R '*Emerald Isle*' can probably be accounted for by its constitution, its health has never matched the beauty of its bloom.

The worst response was from X *Cupressocyparis leylandii*, surplus material of clone 11 received for the I.P.P.S. experiment and given the treatments prescribed for the experiment, except that pine bark rooting medium was used. At the same time of assessment none was rooted satisfactorily although they had formed callus and were still alive. A repeat trial under the same conditions in 1973, although giving better results, only produced 30% cuttings satisfactorily rooted by the time they were lifted, compared with 69% from the sand and peat mix.

Ilex 'Golden King' gave 80% rooted for potting in 6 weeks, *Cupressus* 'Cost of Living' 100%. As anticipated the heathers, cassiopes, hebes, euonymus and sundry other hardy plants rooted rapidly and with virtually no losses, as did all of the glasshouse plants.

None of the rooted cuttings showed any inhibition of growth by the move from bark to our normal potting composts; the particles of bark adhered well to the roots and the young plants quickly grew away.

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Discussion

In general it can be said that whilst most rooting percentages were no better or worse than one would expect if using an orthodox peat and sand mixture, rooting commenced earlier than anticipated and most of the root systems were particularly good. The behaviour of X *Cupressocyparis leylandii* was somewhat inexplicable and I can only assume that the poor result was due to the lightness and extreme aeration of the bark.

No overall system of controls was used as there was no intention of carrying out a formal experiment. We were asked to try the bark as a rooting medium; we did and found it, in most respects, a good medium. The trial was carried out whilst handling our normal throughput of plants. Perhaps those better placed to do so will explore in depth.

In answer to various questions the following information was given

The pulverised bark was of ¼"-3/8" grade and was very consistent; it had been stacked in the open in approximately 10 ton lots and had received no additives. Hardwood bark had not been used About 10 cuttings of some 22 different plants had been used in the observations.

SYNTHETIC PROPAGATION BLOCKS

R. J. HARES

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During the past three years, we, at the Pershore College of Horticulture, have been evaluating various types of commercially available synthetic propagation blocks for the rooting of cuttings exposed to intermittent mist. To date all the types we have tested suffer from serious limitations. Most of the commercially available blocks have since been withdrawn from the market.

Many propagators feel that the principle of using synthetic blocks is a sound one, and it is my intention to try and assess what we have learned during our investigations, and with our knowledge of the known variables, to attempt to predict where we should go from here.

Perhaps the main advantage of using propagation blocks lies in the ability to pot up plants without root disturbance and therefore growth checks. In practically every trial we have undertaken, establishment using the blocks was better, and plants were often larger and more well established at the end of the growing season. A few plants were planted out directly from the mist bench into the open ground with no apparent check. For example *Rubus tricolor* and *Lamium galeobdolon* 'Variegatum', rooted in the prototype block SILVA-FOAM, were inserted in the blocks in the 7th July this year, planted on the 17th July and are now, on the 20th August, growing away strongly. This was only a small scale trial, but the method does seem promising.

Synthetic blocks are sterile, light in weight, and can be transferred from one place to another. Because they are manufactured articles they are reproducible in their physical and chemical characteristics. Their use avoids the need to prepare composts

Donald Cook at the last G.B. & I. Regional I.P.P.S. Conference, held at Myerscough Hall, reviewed — using slides — the development and properties of synthetic blocks. I summarise the information given.

Three main types of materials have been used·

1. Blocks which are based on foamed polyurethane.

   One of the first examples is "Nutri-foam" which was developed by Dow Chemicals and marketed by the Nutri-foam Corporation. These blocks were based on flexible foams which, because of their pore characteristics, tended to suffer from surface water drainage, and saturation at the base of the blocks. The cell wall membranes were also difficult to penetrate by the roots.

"Baystraat" is also included in this group. Root penetration was good but these blocks suffered from excessive surface water drainage, leaving the tops of the blocks dry, and the base too wet. Cuttings of quite a number of species rooted well in "Baystraat", including *Prunus incisa* and many of the quick-rooting species, such as the *Hebe*.

"Rack Substraat", again developed in Germany, is based on shredded polyurethane admixed with peat and then annealed into sheets of flexible foam resembling the Nisula-type rolls about 4 cms. wide.

This material has a high density and is difficult to wet. Leaf wilt occurred rapidly.

2. An interesting product known as "BR-8" was developed by the American Can Company of America. It consisted of cellulose pulp fibres held together by synthetic adhesives. These blocks are characterised by rapid water uptake leading to near saturation of the block. The basic problem with such blocks is that it can only be used with plants requiring near saturation conditions for propagation. In common with many other types of blocks it has been withdrawn from the market.
3. A third group is based on mineral wool which is manufactured from a fused mixture of sand, carbon and chalk. The fibres are held together by a binding agent such as the phenolic resins.

The best known commercially available type was developed in Denmark and is called "Grodan". In our opinion this product has no particular advantage over sphagnum peat except that it is easier to use These blocks absorb large volumes of water and, when wetted, approach near saturation. The blocks have a low wet strength and, to retain the integrity of the block, they are frequently enclosed in a skin of polyethylene Unless so coated, delamination of the fibres can present a problem. Moss grows readily on the surface of the blocks.

In the past the manufacturers, have tended to produce a foam which will absorb water rapidly and can be penetrated by the stem of the cutting, or have pre-made holes for the insertion of the cutting. Because of the high rate and level of water absorption the blocks tend to suffer from near saturation. The manufacturers have ignored the findings of the propagators that, as a generalisation, there is no one compost system which is suitable for all plants, and for successful propagation there is a need to vary the peat-grit or peat-perlite ratios according to the water-air requirements of the plant. Because of this the manufacturers have tended to overclaim the advantages of their products and brought the principle of using blocks under suspicion. Just as variable grit-peat mixtures are required for different plants, so if propagation blocks are to be adopted as standard practice by the propagator, the blocks should be so manufactured as to be made available having different water-air ratios. For example many propagators root certain plants such as *Daphne cneorum* in pure grit having a low water and a high air content. This plant will just not propagate successfully in a block maintained at near saturation by intermittent mist. Some conifers need more air available to their developing roots than most cotoneasters and so on. One of the problems therefore in developing propagation blocks, which has not been recognised by most manufacturers, is the development of blocks having a higher air-water ratio without making the pore-spaces too large. With large voids the base of the cutting or the root hairs may be suspended in air.

Another important factor is good root penetration. We have found that a cutting is less likely to succeed in tough-membraned blocks if, as in the potentillas and some ericaceous subjects, the very fine root systems have to force their way through the membranes. On the other hand, *Viburnum* x *bodantense* with its strong, vigorous rooting system can often succeed in blocks because it can break through the membrane.

The pH is, of course, important with some species. A good wet strength is also important, and the block should keep its integrity when wet. It is an advantage if the block can contain root activators and nutrients as it is not always convenient to liquid feed at the correct time

The blocks should obviously be porous and readily wetted by capillary or by mist and they should be able to retain the moisture to the plant requirements.

The blocks with which we have had the most success to date is the pehnolic foam type known as 'Silva-Foam', under development by Silva-Development Ltd. of Pontefract, Yorkshire. I understand that these blocks are to be developed further before they are marketed. The object behind the development of these blocks is to try and tailor-make the blocks according to the requirements of the plant. I understand from Donald Cook that this could involve 5 moisture ranges and 2 pH variables making 10 types of blocks, covering as far as it is possible the water-air and pH requirements of the plants. Consideration is also being given to the inclusion of root activators and nutrients in the blocks. This may take longer to produce propagation systems which are sufficiently advanced to market with confidence.

We have examined three prototypes of "Silva-Foam" having varying water-holding capacities from 550, 620 and 690 kg./cu. m. and having an adjusted pH of about 7.0. In further trials, the blocks will be adjusted to pH ranges of 4.0-4.5 and 5.5-6.5. The disadvantage of using blocks of pH 7 at Pershore is due to the hard water we have to irrigate our plants. This can quite clearly exaggerate the pH effect on rooting to the detriment of the test. It should be emphasised that the blocks we have tested were prototypes to establish whether or not the make up of the blocks could cause phytotoxity to the plants. The water-holding capacities, even of the coarse blocks, were known to be considerably higher than those of the grit-peat composts we normally use for propagation, or use in our controls when evaluating new systems. Sphagnum peat, by way of example, has a water holding capacity under intermittent mist of about 620 kg./cu. m. A 50:50 grit-peat compost has a water holding capacity of about 340, and grit of about 70 kg./cu. m., when exposed to intermittent mist.

In one trial using *Garrya elliptica* and *Viburnum tinus*, good results comparable with the controls were achieved. The Garryas propagated in the compost died after potting, as no special after care was given.Those propagated in the blocks established well. *Chamaecyparis lawsoniana* 'Stardust' did not show as good a rooting response in the blocks when compared with that achieved in the compost but the cuttings which rooted in the blocks developed better plants, when potted on, than the controls. *Viburnum* x *bodnantense* rooted 100% in all treatments, whereas *Betula nigra* and *Daphne cneorum* failed to root in the blocks. These failures were probably due to the known excessively high water content of the blocks; the rooting responses in the controls were about 90%

We have established that many plants will propagate successfully and pot on well when rooted in synthetic blocks. Other plants will not do as well or fail. This does not condemn the principle of using blocks to propagate; it does mean, however, that failures assume significant importance because, from these failures, we can assist in the development of blocks which will eventually cover the whole spectrum of propagation from cuttings.

SEARCHING FOR DWARFING ROOTSTOCKS FOR SWEET CHERRIES

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PRODUCTION DECLINE IN CHERRIES AND ITS CAUSES

Throughout the world fewer and fewer sweet cherries are being grown. Only a few countries are more or less maintaining their output, notably Germany, Italy, and the United States; the rest produce far less than they did. In ten years, English production has declined some 50 per cent — the Netherlands even more. Yet the demand for dessert sweet cherries remains high and is, apparently, insatiable. Then, why is not production not only maintained but increased? There are two main reasons, depredation by birds and high cost of picking. There are other contributing factors, such as delayed onset of cropping, diseases and pests; e.g. bacterial canker in cool climates and cherry fruit fly in others, splitting of fruit due to rain, and short storage life of the fruit. However, these contributory factors, whilst important, are all present subjects for research and may eventually prove solvable.

PROBLEMS OF TREE GROWTH

Hitherto, sweet cherries have been grown as large or very large forest-like trees, either on mazzard (*Prunus avium*) rootstocks or upon the St. Lucie cherry (*P mahaleb*), the former succeeds well on the deeper moisture-holding soils and the latter on stony or rocky soils in warm and rather drier areas. Any marked reduction in vigour of sweet cherries on *P. mahaleb* is usually due to soil conditions, or so-called delayed incompatibility. Large trees are not only costly to pick but almost impossible to protect from birds, and this has stimulated a keen interest throughout the world in the production of much smaller trees both for orchards and gardens.

ROOTSTOCK CONTROL

When, in 1925, East Malling Research Station (6) reported upon the behaviour of selected mazzard rootstock clones, they were able to show considerable differences in vigour of growth among unworked mazzard trees and it was then hoped that such differences would be passed to the scion, as they had been in apples, but such hopes were largely disappointing. There is, indeed, considerable evidence of scion dominance by sweet cherry over a wide range of cherry species, some of the dwarf shrubby species and hybrids producing large trees when worked with scions of the sweet cultivars, at least in the early years (4).

But selections from certain of the species have exerted a considerable dwarfing effect on the scion, notably *P fruticosa* (1, 2, 8), *P dropmoreana* (4), *P canescens* and *P. mugus* (5). A number of clonal selections from *P. incisa* (3) are in field trials in the Netherlands and have yet to be reported upon.

Having in mind the good anchorage and erect habit of the mazzard rootstock, also the dwarf nature and ready propagation of certain shrubby species, Tydeman of East Malling raised a number of hybrids (9). Some of these hybrids, notably *P avium* x *P pseudocerasus*, of which he obtained fifty or so, exhibited a wide range of vigour; moreover they proved to be very readily propagated by both hard and softwood cuttings and by layering. Present field trials indicate that certain selections of this hybrid are influencing sweet cherry cultivars in the direction of compactness and early cropping. Tydeman also intercrossed selected clonal mazzards such as 'Malling F12/1' and 'F1/3'; the latter he also selfed and obtained one uniquely dwarfed mazzard which appears to have a vigour controlling effect on sweet cherry. Unfortunately it is a shy propagator.

The John Innes Institute, England, has long been interested in the possible use of 'genetic dwarf' *P. avium* as dwarfing rootstocks (7, 10). These are seedlings from sweet cherry cultivars, some of which yield over 25 per cent of dwarfs. These dwarfs are recognised by their crimped leaves when in the seedbed. They certainly have a distinctly dwarfing effect on the scion but, so far, they have been difficult to propagate vegetatively and the seedlings themselves are slow to reach budding size.

FUTURE PROSPECTS

In cherry rootstocks, a dwarfing influence and ease of vegetative propagation are the priorities. The potential is enormous and breeders and propagators still have a great field to explore. Hybridisation clearly offers immense opportunities of combining the desirable features of graft compatibility, growth and form, ready propagation and resistance to disease. Work so far has indicated some promising species and hybrids (Table 1) but the work should be extended and developed. It behoves the plants breeder, the propagator, the pruner and chemical-control enthusiast to get together to make a concerted attack upon cherry growth-control problems, but it is the tree raiser who must provide the vital built-in basic dwarfing character by combining suitable rootstocks and scions in his nurseries. Incidentally, dwarfed trees will be planted more closely than vigorous and the nurseryman will have to provide many more trees than before to fill the orchard area. Instead of planting less than 30 trees per acre at 40 feet square, well over 400 trees will be needed at a spacing of 10 feet.

Table 1. *Prunus* species and hybrids of promise as dwarfing rootstocks for sweet cherries

Rootstock	References	Comment
P avium E M 4/158	4, 9	Distinctly dwarfing Somewhat difficult to multiply vegetatively
P avium J I genetic dwarfs	7, 10	Distinctly dwarfing. Seedlings Difficult to propagate vegetatively. Slow to attain size for bud-grafting
P avium x *P pseudocerasus*	9	Very easy to propagate. Selected clones induce compact early-cropping trees Indications of higher resistance to disease
P canescens	5	Somewhat dwarfing Mist propagated
P dropmoreana	4	Some selections may prove dwarfing. Readily rooted under mist
P fruticosa	1, 2, 8	Distinctly dwarfing Propagated by layering and also under mist
P incisa	3	Somewhat dwarfing. Readily rooted under mist.
P mugus	5	Dwarfing Young softwood cuttings taken early will root under mist

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THE PROPAGATION OF HOLLY [*Ilex Aquifolium*] UNDER DOUBLE GLASS

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The use of double glass frames is not new. Before misting techniques came into favour some 20 years ago, double glass frames were in fairly general use for the propagation of a wide range of plants, notably conifers, broad-leaved evergreens, deciduous shrubs and herbaceous subjects.

It was altogether by chance, while rooting certain conifers under double glass, that I discovered the conditions and the routine methods adopted were favourable to the rooting of the common English holly and its many cultivars. Since it needs no expensive electrical equipment, electricity, or water and requires a minimum of attention, I still prefer this method to mist propagation. It is foolproof and labour saving. Once the cuttings are rooted, they can be left *in situ* for several weeks without fear of nutrient starvation.

Success in rooting under double glass depends on a number of favourable factors. (1) properly constructed frames, (2) a suitable rooting medium, (3) growths at the right stage, (4) use of root-inducing auxins, (5) maintenance in the frame of moisture-saturated atmosphere, and (6) prevention of wilting by shade conditions and high humidity.

Construction of Frames. For the benefit of our younger propagators, familiar mainly with mist techniques, and probably not acquainted with the construction and use of double-glass frames, let me explain how they are set up. The frames used are of the standard English type to take 6 ft. by 4 ft. lights. The height at the back of each run of frames is 18-20 inches and at the front 12-14 inches. The runners at 4 ft. 1 inch centres are movable to facilitate working in the frames while inserting cuttings.

Inside the frames and running lengthwise with them are fitted two boards 4 ft. 11 inches apart to support Dutch lights. These boards are of 7 inch by 1 inch timber and are made level with each other. This is imperative as the Dutch lights must be dead flat when in position, otherwise water vapour, when it condenses on the inside of the glass, would tend to run to the lowest point and drop off. It is vital to the system that the inside of the glass is kept uniformly misted over, since this gives a clear indication of satisfactory humidity within the frame.

Aspect of Frames. To obtain the maximum heating effect from the sun's rays the frames should be faced towards the south, but if this is not convenient to the general layout of the frame yard, a westerly aspect appears to be quite satisfactory. To avoid excessively high temperatures within the frames and possible scorching of the cuttings, the glass of the English lights must be heavily shaded until dull conditions are common in October, when the shading should be removed. No scorching of the foliage will take place so long as the inside of the Dutch glass is misted over, even although the temperature between the upper surface of the Dutch light glass and the inside of the English lights is around 90°-95°F.

Rooting Medium. The medium that has consistently given me the best results is a mixture of three parts by volume of springy sphagnum moss peat and one part by volume of sharp sand, such as is used for making concrete. The peat should be broken down thoroughly and well-moistened before mixing with the sand. The medium is placed inside the 7 inch deep wooden boards in the frame to a depth of 3-4 inches when lightly firmed. Avoid packing the medium as this may create problems when inserting the cuttings and may also affect the moisture/air relationship during rooting. Between the top of the medium and the inside of the Dutch light glass should be a space around five inches. Previous to the insertion of the cuttings, wet the medium thoroughly, then allow it to drain for at least a day.

The Cuttings and Their Preparation. Many of the former failures to root hollies can be traced to the use of either immature growth or to too old wood. My own experience indicates that, at least for double glass propagation, mid-to the end of August is the optimum time to take cuttings, but a better guide is to delay starting propagation until the current shoots have stopped growing and the terminal, or last leaf on the shoot, has become hard and leathery.

The growths selected for cuttings should be of moderate vigour, rather than over-vigorous, free from leaf miner toms, and preferably of current season's growth. If such growths are in short supply as can happen with the Hedgehog or Porcupine varieties (*Ilex aquifolium* 'Ferox'), two-year-old wood may be used and will root satisfactorily and just as readily as current wood. Each cutting, when prepared, should measure from 3-4 inches in length, be cleanly cut under a node and then wounded by cutting off at the base on one side of the stem, a thin strip of tissue about one inch long so as to expose the cambium layer.

Before inserting the cuttings, dusting the wounded area and base of each with a root-promoting auxin is desirable, although not essential. I used to use a 1% home-prepared indolebutyric acid powder, but now obtain equally satisfactory results from the proprietary rooting powders, Seradix No 3 and Rhizopon AA. The former contains 0 8% IBA, the latter 1%.

To insert, the prepared cuttings are just pushed into the moist medium to a depth of 1-1½ inches and at a spacing of 2x2 inches. Any difficulty experienced in the insertion would suggest that the medium has been over-compacted. On completion of the 'sticking', give a thorough watering, then cover with the Dutch lights and then the shaded English frame lights. No further watering is likely to be necessary for several weeks. So long as the inside of the Dutch lights are mist-coated, leave well alone.

Once the cuttings are rooted, start giving air by propping up alternate Dutch lights, but leave them in postion until growth becomes really active in March-April, when they may be removed entirely. The English lights, however, should be left on the frames until all risk of frost has passed, ventilation being given on favourable occasions. An occasional watering will be necessary until planting out takes place, which may commence towards the end of April. As the young new growths of holly are very tender and easily damaged by frost and drying cold winds, some protection is desirable. This may be given by covering with nets over a light framework or by wooden lath frames.

RESEARCH INTO BUDDING ACERS AND OTHER DIFFICULT SUBJECTS

B. H. HOWARD

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Nurserymen have difficulty in obtaining a high proportion of successful unions when budding ornamental cultivars of Norway maple on to seedling rootstocks by the traditional shield or T-budding method, and low percentage stands are not uncommon even after re-budding when earlier buds have died. In the past, this problem has not been pressing because where buds have failed, rootstocks have been grown-on to produce the common Norway maple which has been used for general amenity purposes. The current demand from new development corporations and other large-scale buyers for large numbers of high quality trees of specified cultivars has, however, shown the need to improve techniques of tree production.

Chip budding. Potential for improvement lies in the replacement of traditional shield budding by chip budding, which involves the substitution of a wedge-shaped piece of scionwood bearing the bud for a similar shaped piece of rootstock tissue, rather than the addition of the bud shield to the rootstock tissue, To insert, the prepared cuttings are just pushed into the moist medium to a depth of 1-1½ inches and at a spacing of 2x2 inches. Any difficulty experienced in the insertion would suggest that the medium has been over-compacted. On completion of the 'sticking', give a thorough watering, then cover with the Dutch lights and then the shaded English frame lights. No further watering is likely to be necessary for several weeks. So long as the inside of the Dutch lights are mist-coated, leave well alone.

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Nurserymen have difficulty in obtaining a high proportion of successful unions when budding ornamental cultivars of Norway maple on to seedling rootstocks by the traditional shield or T-budding method, and low percentage stands are not uncommon even after re-budding when earlier buds have died. In the past, this problem has not been pressing because where buds have failed, rootstocks have been grown-on to produce the common Norway maple which has been used for general amenity purposes. The current demand from new development corporations and other large-scale buyers for large numbers of high quality trees of specified cultivars has, however, shown the need to improve techniques of tree production.

Chip budding. Potential for improvement lies in the replacement of traditional shield budding by chip budding, which involves the substitution of a wedge-shaped piece of scionwood bearing the bud for a similar shaped piece of rootstock tissue, rather than the addition of the bud shield to the rootstock tissue, by sliding it under the rind as in T-budding. The substitution process in chip budding results in the matching of cambia of stock and scion, with the result that a good union forms within a few months of budding, leading to uniform and vigorous growth the following spring, in contrast to the variable and usually weaker growth resulting from T buds where union formation is often delayed.

When firmly tied with polythene tape in such a way as to avoid compressing the actual bud, chip buds have shown a number of advantages over shield budding. These include higher bud-take and larger nursery trees of *Tilia platyphyllos* 'Rubra', *Ulmus* x *hollandica* [*U vegeta*] 'Commelin', and a range of ornamental *Malus* and ornamental *Prunus* (1).

The quality and uniformity of nursery apple trees from chip buds are also superior to those from shield buds, and when the normally high level of bud-take in dessert apple trees was reduced by severe winter frost injury, chip buds survived in greater numbers than shield buds (2).

Acers. Chip budding has also shown considerable potential for Norway maples. Although commercially acceptable levels of bud-take have not yet been obtained owing to the lateness of budding, preliminary trials with the cultivar, Crimson King, have shown almost a threefold increase in bud-take from chip budding compared with shield budding.

It has been demonstrated in an unreported I.P.P.S. nursery trial[1] that bud-take in the cultivar, Drummondii, can also be improved to a similar extent by budding in mid-June as budwood of the current season becomes available, rather than two months later

By bringing together treatment optima in this way the potential exists to improve levels of success with such difficult-to-propagate species. In current trials, using chip budding to investigate seasonal budding effects, promising results have been obtained with cold-stored budwood used before the current season's growth is available

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[1] I P P S Nursery Experiment No 3, 1969, James Coles & Sons, The Nurseries, Thurnby Leicester

Discussion

In response to an enquiry from Bill Flemer about the tying in of chip buds, Brian Howard replied that the most effective was polythene strip as it completely encloses and prevents water loss; rubber strip was only effective if completely overlapping, and "Fleischauer" ties had proved ineffective. The President asked whether the bud should be enclosed and was told ideally all but very big buds should be enclosed. Chris Thomas, however, emphasized the importance of removing the strip as soon as possible to prevent any 'sleepy' effects — usually five weeks was sufficient.

Ralph Shugert was interested in the speed of operation. Brian Howard replied that at East Malling skilled shield budders had been able to chip bud marginally faster, but the point was that greater productivity was achieved (i.e. fewer failures occurred) with this technique. Jolly Batchellor disagreed, suggesting that failures in shield budding could be due to excessive damage to the cambium. However, Brian Howard pointed out that the important cambium was at the bottom of the cut and was not severely damaged.

Finally, Brian Howard concluded by emphasising that the research worker produces the technique and that it is up to management to adopt it and adapt it to nursery conditions.

NEW CONCEPTS IN BUDDING AND GRAFTING EUCALYPTUS

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The beauty of the red-flowering eucalyptus (*Eucalyptus ficifolia*) has led many horticulturists and nurserymen to seek means of propagating selected trees vegetatively, because production by seed is totally unreliable. (4, 13, 17). A very few species of eucalyptus propagate easily from cuttings or air layers, but *E ficifolia* does not. Reports by horticulturists of an occasional success in grafting these plants has led the author to try different techniques over the past 25 years, with no success. A meeting with I. J Thulin[1] in 1970 rekindled the author's interest, for Thulin had developed in New Zealand a technique for grafting eucalyptus on very young vigorous stock. (16)

[1] I J Thulin, Forest Research Institute, Rotorua, New Zealand

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In January, 1971, attempts were made using the information obtained from Thulin and, although these grafts were not successful, the scions lived long enough to indicate that if the techniques and procedures were refined and improved, successful grafting might result.

California State Polytechnic University provides no facilities or exempt time for investigative research so the study was carried on at the author's home. Because of this situation no formal controlled experiment was set up. Careful records were kept of dates, materials, and techniques. By using previous experience, making careful observations, and by playing hunches, it was possible in two years to go from 0% of the grafts living more than one month, to a situation where 90% of the grafts lived two months, with 20% continuing to live up to the time of this writing (18 months). This improvement was a strong indication that the grafting techniques were suitable because good unions occurred in 98% of the grafts. The death of the primary bud was the major cause of the decline in percentage. Some scions, with the original primary bud alive and in apparently good condition, remained alive — but dormant — for as long as eight months.

GROWING THE ROOTSTOCK

Eucalyptus ficifolia and *E calophylla* are so closely related that it is difficult to distinguish one from the other, and in Southern California there are a good many hybrids between the two species. *Eucalyptus calophylla* seedlings were used for rootstock as most authorities consider them to have a better root system and a more vigorous habit of growth than *E ficifolia* (2, 9, 14). Normal procedures were followed in collecting and storing the seed. Because of some fungus problems the seeds were dipped in a fungicide solution and air-dried before using. After trying many systems of growing the seedlings, it was found that direct seeding to pots was the most satisfactory from all standpoints. A UC mix type of soil was used for all growing. First germination usually occurred by the fifth day at which time the seeded pots were uncovered, and placed in direct light. Normal procedures were followed in shifting up to larger containers, and plants were staked as needed. The only unusual technique was that of using the flame of a torch rather than a knife to remove the root curl. This was found to be easier, faster, more positive, and resulted in less damage to the plant.

At all stages the weak, undesirable, or mallee type plants were discarded By the end of the fifth month most of the plants were 18" or more in height and 3/16" in diameter and ready for grafting. A few hours before grafting all leaves and buds in the area of the graft were removed, and the stem of the rootstock was thoroughly scrubbed with a disinfectant. This area was usually 4" to 8" above the lignotuber and, in most cases, there were some leaves or growth below this point.

BUD SELECTION

Because of the nature and habit of growth of the eucalyptus, and the manner in which it forms its buds, the only place on the tree where good plump vigorous buds could be consistently found was in the blossoming cluster (3). Although Penfold (11), Pryor (12) and Thulin (16) speak of using scions with no visible buds, and having the accessory, or adventitious buds, develop, we had little success in this respect with *E ficifolia*. In only two cases did these buds develop.

In handling the scion wood and bud sticks, the only treatment that varied from the normal, was that of drenching them with a solution containing a disinfectant, and an antidessicant. The wood was then shaken to remove excess liquid, air-dried, and stored at 40°F until used. It appears the fresher the scion wood the more successful the grafting. No wood was used after 48 hours storage.

GRAFTING

The most successful grafts were accomplished with the normal side graft about 4" above the lignotuber. The disinfectant on the stock and scion plus the antidessicant on the scion seemed to be of major importance. Another graft that appears to be useful and successful is a modification of the "rind graft" suggested by L. M. Hodgson[2] who indicated this was used in grafting eucalyptus in South Africa. The rind graft as shown to me is much like a bark graft in that the scion is cut on an acute slope, and slid down along the cambium of a decapitated rootstock. We found that the top growth of the stock was quite important for the survival of the scion. With this in mind, we developed a cutting blade that would make a concave surface of the base of the scion The scion is slipped into a regular T-cut as used in budding. By altering the arc of the blade it is possible to make a cut that will perfectly match the curve of any stock so that 100% cambium contact can easily be obtained. Although only limited use of this graft was made, it proved to be easier to do and gave excellent unions. It is believed that the modified "rind graft" could be useful in many situations.

BUDDING

All attempts to bud *E ficifolia* with the normal, and usual buds were unsuccessful. It appeared that the injury to the root-

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[2] L M Hodgson, Officer in charge for the Secretary of Forestry, Forest Research Station, Politsi, North Transvaal, Republic of South Africa

stock caused by the horizontal cuts across the phloem tissue causes an excessive amount of callus, which either prevented a good union or caused the plant to force out the bud. To overcome this excessive callus we used the "Jack-knife Bud" where only a small slit is made in the phloem. The stock is bent over toward the cut; with a little effort this slit may be opened for the insertion of the budshield. Once in place, the shield is pulled down well below the cut so as to be in an area that has not been exposed to the light and air. When the bud is in place the rootstock is straightened up, and the bud properly secured. By this procedure very little callus forms, the inserted bud is held firmly in place, and a neat clean union takes place.

SPECIAL TREATMENT AND AFTER-CARE

We could find no references or authority to substantiate our belief that the cut surfaces of the scion or stock (of eucalyptus) when exposed to light and air — even briefly — either dry out or form a substance that is incompatible with the formation of a good graft union. Several techniques were tried to overcome this problem The most successful was the use of boiled distilled water to coat all cut surfaces as soon as possible. Results show that grafts and buds so treated were more successful than those not treated.

Thulin and Faulds (16) in New Zealand indicated that the eucalyptus were very susceptible to bruising. When it was found that the normal wrapping with thin plastic or rubber tape was causing injury a switch was made to masking tape. This 3/4" tape was not wrapped around but just pinched around and stuck to itself. This provided the necessary tension to hold scion and stock together yet allowed a freedom for growth which is most essential (5, 16)

This spring we girdled the stock under some of the grafts and buds. This was done with a razor blade and the cut was just through the phloem No damage occurred and it appeared that the girdled grafts grew faster and made better unions than those not girdled

For the healing period of the graft and bud unions, a small plastic sleeve--provided some shade, 100% humidity, and nearly sterile conditions. The balance of the plant was left in full sunlight and allowed to grow under normal conditions (7, 8, 10, 15). Through the clear plastic it was possible to observe any activity of the buds. As growth appeared the plastic sleeve was ruptured allowing an equalization of the humidity, and when the plant had adjusted, the entire sleeve was removed. No wax or other protectant was used

As new growth pushed out, the rootstock was bent over, broken over, and gradually reduced. The top of the rootstock was never fully removed until the scion had produced fully mature leaves. Stubbing back usually resulted in death of the stock.

Grafted plants kept in the plastic house with minimum temperatures of 65°F during the winter set blossoms regardless of size. Plants left outside under normal conditions remained in a vegetative growth until warm weather in late spring, when they also set blossom buds.

SUMMARY

1. It appears that cleanliness of stock and scion is of greater importance than at first realized.
2. The use of an antidessicant on the scion is advantageous.
3. Keeping air from all cut surfaces is desirable.
4. Girdling may be beneficial to grafts and buds.
5. The plastic sleeve over the grafted area appears to have merit over enclosing the entire plant in plastic. The use of grafting waxes or other sealants proved detrimental to the graft
6. The use of masking tape provided adequate tension and protection without damaging the grafts.
7. The use of the flame from a torch proved to be the easiest and most thorough means of eradicating root curl on the smaller sized pots.
8. Although not mentioned in the report, the author using the same techniques mentioned above was able to graft *Eucaluptus sideroxylon* and *E citriodora* on seedling *E. calophylla* although only six plants each were grafted, two of each are still growing well at the end of seven months.

PROBLEMS

Based on the author's experience, observations, reading and correspondence in the field, the important problems to be solved are.

1. Compatibility
2. Dormancy of buds and scions
3. A fungus growth that seems to attack the grafted plants.
4. Selection of the most suitable rootstock.

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THE NEXT TEN YEARS

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The future for the grower of ornamental plant material in eastern United States looks very exciting if some of the things that are now on the wings come into center stage. It seems clear that from the standpoint of the plant propagator and grower, that the plant breeder will have to consider many new factors in selecting his offspring for introduction.

Some of the things that we should expect are selection for greater disease resistance, for earlier blooming and fruiting in the life of the plant, and for developing plants that lend themselves more readily to production. The plant breeder must help the grower increase productivity by such methods as selecting types that are more self-branching, respond well to optimum growing conditions, hold up well under the stress of the market place and perform well for the consumer. New leaf types and shapes are needed to lend interest to the landscape planting when the material is not in bloom or fruit. Greater cold and winter wind resistance would be desirable in our part of the country, where winter temperatures can go to -25°F. A breeder might develop new habits for existing plants such as a new azalea from Japan that has bright red flowers but has the growth habit of a ground cover. Tree forms of rhododendron that are hardy would have wide application. More and more the plant breeder must consider the grower, for if he cannot make money on producing the plant it will not be grown in important quantities

Toward the end of the next ten years cell fusion could be making some important contributions to the ornamental plant material field. This process, in which cell walls are dissolved, thus allowing the fusing of two unlike cells, will then permit these newly-combined cells to grow and differentiate into a new plant. It is in the very early stages now and could take many years, but could also come on fast. It could provide an abundance of new plant types.

In the U.S most plants are now grown in containers and in the northeastern states most of these crops must be given some sort of winter protection. New types of houses will be developed which will form a continuous cover of a large area instead of the individual curved type houses now used. If some form of polyethylene is still used there must be a way of recovering the energy that is in the poly, rather than dumping it. Perhaps a method would be to shred it and have it become a part of the growing medium.

New vaulted roof glass covers will be developed. This will be thin but very strong, chemically-treated glass that will need no metal supports between gutters. It will be very break-resistant and will automatically increase in color density as incoming radiation increases and thus provide the right amount of light for the crop.

Heating will mostly be done in the soil below the floor as this method allows the storing of heat from bright days for recovery at night or during overcast perioss. The method is available now and since most of the heat comes off as radiant heat (70%) and only 30% as convection it allows you to have a ceiling temperature of only 73°F while having a floor temperature of 72°F. The heat can be off for three days, with an outside temperature of 20°F and the house temperature will only drop 8 degrees because you are still pulling from the vast heat sink in the ground. The plant leaves will be the warmest object in the house at sunset and thus greatly reduce the tendency for disease to become established at night in the free moisture on the leaves All the irrigation water will be circulated through the floor and be brought up to room temperature before application. It costs no more to heat the water before application than after and could save quite a shock to the plants.

Growing media will tend to come from the organic wastes of society. Many different materials will be used, from processed garbage, paper, cardboard, plastic and organic waste from other industries. At the present time we are using ground bark, which is a waste product from the paper and lumber mills.

Irrigation waste, rich in nutrients and insecticides, will no longer be allowed to be dumped into streams. The waste water will have to be clean enough to drink which means we will have to re-use most of our irrigation water. This might be done by chlorinating it, monitering the salt levels and then either stripping or adding nutrients as needed. Another approach is to have the irrigation waste applied to a secondary crop which might be less sensitive, such as corn or wheat. The run-off from this area might then run off to a holding pond for growing algae which, in turn, can feed Amur fish, which can then be eaten!

The present methods of tissue and soil testing will be supplemented by new photographic methods which will show in color, without the need of complex equipment and chemicals, what is needed and where the excess may exist. It may also show disease problems before they can be detected by other means

In the area of irrigation and feeding, the greenhouse and nursery industry is highly automated and will continue to become more effective, reliable, and less expensive, which will allow more and better growth in less time. As the space a plant occupies becomes more expensive the grower will go to many means to reduce the time the plant occupies that space. This gets back to the breeder because if the new plant does not give the grower the proper return for a given "space-time slot" then he will grow something that will. The grower will be looking at a world market and will become very flexible in his ability to shift from growing one crop to another to maximise his return on investment. Flexibility will spell profits and inflexibility will mean disaster in the times ahead in North America.

A MEASURE OF THE CONSISTENCY OF THE RESPONSE OF CUTTINGS TO PROPAGATION TREATMENTS AS A GUIDE TO THE VALUE OF EXPERIMENTS ON NURSERIES[1]

B. H. HOWARD

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Abstract. Twenty-three experiments on the propagation of conifers and other woody plants by stem cuttings were done on nurseries by members of the Society The experiments fell into three groups and within each group the same member repeated the experiment in a second year under the same conditions as on the first occasion Treatments investigated the effects of basal wounding in association with other factors which could influence the wounding response Group 1 experiments examined the effect of wounding and the influence of an incision or slice wound on rooting In Group 2 the effect of auxin applied before or after making the wound was investigated. In Group 3 wounding was examined in association with the use of a liquid or powder formulation of root-promoting auxin, with subsequent rooting in a 'wet' or 'dry' regime

Within each group, wounding consistently improved rooting but the response to all other factors was variable and inconsistent Significant interactions of wounding and other treatments with nurseries and with years revealed unidentified factors which influenced the rooting response of cuttings to these treatments

INTRODUCTION

Between 1970 and 1973 three groups of experiments co-ordinated from East Malling Research Station were undertaken by members of the G B. & I. Region, with the object of determining the general value of wounding stem cuttings and of understanding

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the mechanism behind the wounding process in terms of uptake of auxin and water.

Each group of experiments involved different treatment combinations which also differed in their complexity. The first year's results showed that great variability between nurseries occurred in the response to anything other than the main effect of wounding, even when in Group 3 the species, clone and origin of the cutting material was largely standardised. It therefore became necessary to assess the type of information these experiments could provide. Each experiment was repeated to obtain further information on the consistency of response between nurseries and on the consistency within nurseries in different years at the varying levels of treatment complexity. Only data from members contributing results in both years are discussed.

MATERIALS AND METHODS

Group 1. In 1972 six experiments were undertaken to compare unwounded cuttings with those wounded by the removal of a slice of tissue penetrating the wood at the base of the stem, and with those wounded by two incisions made with the point of a knife on opposite sides of the stem base. All wounds were up to 1 in. in length, differing in size between nurseries but being similar in size in different years on any one nursery After wounding, cuttings were treated with auxin to the depth of the wound, or its equivalent, and placed under intermittent mist in a randomised layout with each treatment represented by five replicates with 20 cuttings per plot Four of the six experiments were done using X *Cupressocyparis leylandii* and all were repeated in 1973 Full details are given in the appendix

Group 2. In 1970 six experiments were undertaken to compare unwounded cuttings with those wounded by a single basal slice, either preceded or followed by application of auxin to the depth of the wound or its equivalent. Replication and plot size were the same as for Group 1 experiments. Six different species were used and propagation conditions varied accordingly. These experiments were repeated in 1973 and full details are given in the appendix.

Group 3. In 1970 eleven experiments were undertaken to compare factorially the effect of wounding by removal of a single slice of tissue with unwounded cuttings, followed by application of 4,000 ppm indolyl butyric acid (IBA) as a proprietary powder formulation (Seradix 2) or dissolved in 50% ethanol and used as a 5 second 'quick dip'. Cuttings were then placed under intermittent mist in a 'dry' regime with relatively infrequent misting or were placed in a 'wet' regime where supplementary water was given, usually with a fine-rose watering can. Three replicates with 15 cutting plots were used and the experiment was repeated in 1973. X *Cupressocyparis leylandii* clone 2 was used throughout, supplied to those members not having a local source by distributing branches from trees growing at the Glasshouse Crops Research Institute (G C.R.I.). Full details are given in the appendix.

Participants recorded the cuttings by placing them in five categories ranging from 'dead' to 'excellently rooted' and the data was sent to East Malling to be treated in two ways. Analysis was carried out on the percentage of rooted cuttings irrespective of grading, and also on weighted values obtained by multiplying the totals of the best rooted cuttings by a factor of 4 and the totals of progressively poorer grades by x3 or x2. Callused cuttings received a 'weighting' of x1 and dead cuttings were ignored. The weighting method gave emphasis to the production of the heavily-rooted cuttings preferred by nurserymen and the data presented in the tables were obtained in this way. Results were generally similar from both methods but attention is drawn to some differences.

Table 1. Weighted score for rooting per cutting related to the presence and type of wound (maximum potential = 4)

Group 1 Nurseries	Year	Slice wound	Incision wound	Control No-wound	Horizontal means	
1	1972	3 06	2 97	2 66	2 90)	2 34
	1973	1 59	2 06	1 67	1 77)	
2	1972	2 63	2 51	2.44	2 53)	1 99
	1973	1 54	1 53	1 28	1.45)	
3	1972	2 87	2 91	3.17	2 98)	2 92
	1973	2 82	2 90	2.84	2 85)	
4	1972	2 16	2.04	1 87	2 02)	1 39
	1973	0 79	0.83	0 63	0 75)	
5	1972	3 53	3 42	3 30	3 42)	2 77
	1973	2 43	2 27	1 66	2.12)	
6	1972	2 93	2 70	2 32	2 65)	2 65
	1973	2 84	2 85	2 26	2 65)	
Vertical means		2 43	2 42	2 18		

SE of vertical means ± 0 052 with 96 df
Significance levels
Slice and incision wounds v control P<0 001
Slice v incision wound N/S

RESULTS

Group 1. In eleven out of the twelve possible comparisons one or other of the wounding treatments was superior to the unwounded control (Table 1) and the general benefit of wounding (slice and incision) was significant (P-0.001). There was no overall difference due to the type of wound employed. In 1972 the slice wound gave slightly better results than the incision method, while the reverse trend occurred in 1973 and only in two cases was the treatment order of effectiveness similar in both years.

The relative improvement due to the overall wounding effect (both methods v control) was greater in 1973 than in 1972, the interaction being significant (P-0.01) in terms of percentage rooting but not on the basis of weighted data. The overall rooting level was also much poorer in 1973 than in 1972. The value of wounding (both methods vs control) differed on different nurseries, the interaction reaching a significance level of P-0.1.

Group 2. In eleven out of the twelve possible comparisons one or other of the treatments which included wounding was superior to the unwounded controls (Table 2) and the general benefit of wounding (with auxin application before and afterwards)

Table 2 Weighted score for rooting per cutting related to the application of auxin before or after wounding (maximum potential = 4)

Group 2 Nurseries	Year	Auxin before wounding	Auxin after wounding	Control, auxin but no-wound	Horizontal means	
7	1970	3 60	2 05	3 35	3 00)	2 22
	1973	1.93	1 35	1 04	1 44)	
8	1970	1 61	1 49	1.00	1 37)	1 33
	1973	1 22	1 59	1 05	1 29)	
9	1970	2 49	2 03	2 48	2 33)	2 05
	1973	1 76	1 74	1 80	1 77)	
10	1970	1 23	2 34	1 16	1 58)	2 01
	1973	2 41	2 83	2 12	2 45)	
11	1970	2 14	2 07	1 38	1 86)	2 11
	1973	1.96	2 86	2 26	2 36)	
12	1970	2 98	2 94	2 08	2 67)	2 63
	1973	2 95	2 78	2 06	2 60)	
Vertical means		2 19	2 17	1 81		

SE of vertical means $\pm$ 0 054 with 96 df
Significance levels
Wounding (auxin before and after) v control $P < 0\ 001$
Auxin application before wounding v afterwards N/S

was significant (P-0.001). There was only a small and non-significant effect due to the timing of the auxin application, but there was a signifficant interaction with years (P-0.05) and only in two cases was a similar order of treatment success observed in both years. Overall, results for 1970 were better than for 1973 but nurseries differed greatly possibly because they used different species. Accordingly, the interactions between nurseries and overall wounding (at both times of auxin application) and between nurseries and the time of auxin application were significant (P-0.001)

All higher order interactions of overall wounding, or time of auxin application with years and nurseries were also significant (P-0.05). Percentage rooting showed identical trends throughout.

Table 3. Weighted score for rooting per cutting related to wounding and the formulation of IBA (means of 'dry' and 'wet' regimes, maximum potential = 4)

Group 3 Nurseries	Year	Wounds Powder IBA	Wounds Liquid IBA	No wounds Powder	No wounds Liquid	Horizontal means	
13	1972	2 17	1 69	2 04	1 50	1.85)	1 91
	1973	1 97	2.52	1 77	1 64	1 97)	
14	1972	2 08	0 90	0 50	0 20	0 92)	1 56
	1973	2 58	2 19	1 86	2 16	2 19)	
15	1972	2 49	2 87	0 96	1 42	1 93)	1 78
	1973	2 30	2 21	1 02	0 97	1 63)	
16	1972	2 83	3 50	2 17	2 58	2 77)	2 34
	1973	2 29	1 54	2 31	1 53	1 92)	
17	1972	2.82	2.23	2 56	2 55	2.54)	2 12
	1973	1 74	1 76	1 59	1 69	1 69)	
18	1972	2 04	2 14	1 97	2 29	2 11)	2 13
	1973	2 30	2 20	1 99	2 11	2 15)	
19	1972	2 38	2 62	1 67	2 43	.2 27)	2 42
	1973	2 12	3 07	2 03	3 02	2 56)	
20	1972	1 84	1 88	1 86	1 21	1 70)	1 12
	1973	0 58	0 58	0 64	0 38	0 54)	
21	1972	2 19	2 07	1 72	1 71	1.92)	2 02
	1973	2 23	1 53	2 57	2 14	2 12)	
22	1972	2 66	2 69	1 72	2 11	2 29)	2 56
	1973	2 94	2 78	2 77	2.81	2 82)	
23	1972	2 68	2 76	2 52	2 39	2 59)	2 52
	1973	2 17	2 69	2 34	2 66	2 46)	
Vertical means		Wound = 2 23 Powder 2 05		No wound = 1 87 Liquid 2 05			

SE of vertical means ± 0 031 with 264 df
Significance levels
Wounding v controls P<0 001
Powder v liquid formulation N/S

Group 3. Results for wounding and IBA application are given as overall means of the 'wet' and 'dry' conditions, and the latter are considered separately because these treatments, which were represented only once on each nursery with no opportunity of separate statistical analysis, interacted least with other factors.

Seventeen out of the twenty-two possible comparisons showed an overall improvement from wounding (Table 3) and this effect taken over all nurseries was significant (P-0.001). On the other hand, the use of powder or liquid formulations of IBA gave identical results overall (Table 3), with 12 comparisons in favour of the powder and 10 in favour of the liquid formulation. The response to wounding differed with years, being relatively more beneficial in 1972 than 1973 (P-0.001). In terms of rooting percentage the significance level of this interaction was P-0.05. The response to both wounding and IBA formulation differed between nurseries even though in these experiments the same cultivar was used throughout (P-0.001). Higher order interactions also existed. Out of eleven nurseries, six were consistent and five inconsistent and six not in the response to IBA formulation.

The effect of 'wet' or 'dry' propagating regimes was negligible, the overall mean rooting score being 2.05 and 2.04 respectively. Eleven of the twenty-two comparisons were in favour of the 'wet' regime and eleven not. Only four nurseries obtained consistent results in favour of one or the other regime in both years. Interactions with other treatments were least for the moisture factor, reaching a probability of -0.05 only in association with the formulation of IBA used. (P-0.01 in terms of percentage rooting)

DISCUSSION

These results clearly show that although the relative value of wounding differed in different years it was generally beneficial. The effects of type of wound, time of auxin application, or type of IBA formulation varied between experiments, such factors apparently being of secondary importance relative to the presence of the wound and use of auxin in some or other form.

The significant interactions of both wounding and auzin treatments with nurseries clearly shows that local conditions exert a strong influence on the rooting process, especially in Group 3 experiments where the same cultivar was used throughout Such factors are likely to include the condition of the cutting material and the detailed way in which it is handled by staff who changed from year-to-year in some of these experiments. Observation of propagation procedures and conditions on nurseries with reasonable yearly consistency, but which differed with respect to treatment responses, such as Nos. 14 and 19 in Group

3, could provide a clue as to the nature of these unidentified factors. However, it is unlikely that their detailed investigation in search of propagation mechanisms could be undertaken elsewhere than at a Research Station where close and continuous observation is possible. The main function of the Society's experimental programme involving commercial nurserymen should be aid in the development of new research techniques by testing their general application over a wide range of conditions and subjects

APPENDIX

Group 1.

1) A B MacDonald, Hadlow College of Horticulture, Kent X *Cupressocyparis leylandii*
   a) 4-2-72 to 19-5-72 Cuttings treated with Seradix No 2 and placed under mist with 21°C basal temperature
   b) 7-2-73 to 26-4-73. 'Conditions as for previous year'
2) P D A McMillan-Browse, Brooksby Agricultural College, Leicestershire X *Cupressocyparis leylandii* (clone 2)
   a) 12-1-72 to 10-5-72 Sub-terminal cuttings treated with Seradix No 2 and placed under mist with 21°C basal temperature
   b) 9-1-73 to 15-5-73 'Conditions as for previous year, but cutting material of poorer quality'
3) D G Pope, St Bridget Nurseries, Exeter, Devon *Elaeagnus pungens* 'Maculata' ('Aurea Variegata')
   a) 8-2-72 to 26-5-72 Tip cuttings treated with 4,000 ppm IBA alcoholic solution and placed under mist with 17°C basal temperature
   b) 10-1-73 (weaned from end of May) to 23-8-73 'Conditions as for previous year except for 21°C basal temperature
4) C G Thomas, Long Ashton Research Station, Bristol X *Cupressocyparis leylandii*
   a) 25-1-72 to 2-5-72 Cuttings treated with Seradix No 2 and placed under mist at 21°C basal temperature
   b) 25-1-73 to 4-5-73 'Conditions as for previous year'
5) D N Whalley, Glasshouse Crops Research Institute, Littlehampton, Sussex *Viburnum* x *bodantense*
   a) 16-5-72 to 6-6-72 Tip cuttings treated with Seradix No 2 and placed under mist at 18°C basal temperature
   b) 22-5-73 to 14-6-73 'Conditions as for previous year'
6) F Willard, A Goatcher and Son, the Nurseries, Washington, Sussex. X *Cupressocyparis leylandii* (clone 2)
   a) 2-2-72 to 24-5-72 Tip cuttings treated with Seradix No 2 and placed under mist at 16°C basal temperature
   b) 2-2-73 to 23-5-73 'Conditions as for previous year'

Group 2

7) M G Adcock, Hillier and Sons, Winchester, Hants Rhododendron 'Lady Clementine Mitford'
   a) 21-9-70 to 10-6-71 3 0 in cuttings with 1 0 in slice wound and treated with 5,000 ppm IBA in alcoholic solution, placed under mist with 20°C basal temperature

b) 9-1-73 to 12-7-73 'Conditions as for previous year except for a higher sand content in rooting medium'

8) D M Donovan, F Toynbee Limited, Bognor Regis, Sussex *Polygonum baldschuanicum*

a) 11-1-70 to 5-4-70 3 0 to 4 7 in nodal hardwood cuttings with 0 6 in slice wounds and treated with Boots Hormone Rooting Powder, placed under mist with 24°C basal temperature

b) 14-1-73 to 15-4-73. 'Conditions as for previous year'

9) J I Hulme, University of Liverpool, Botanic Garden, Ness, Cheshire *Juniperus sabina* 'Tameariscifolia'

a) 12-2-70 to 7-7-70 3 0 in lateral cuttings with trimmed heel with 0 5 in slice wounds and treated with 1,000 ppm IBA in alcoholic solution, placed under mist with 21°C basal temperature

b) 5-2-73 to 23-5-73 'Conditions as for previous year'.

10) J G D Lamb and J C. Kelly, The Agricultural Institute, Kinsealy, Dublin, Eire *Prunus laurocerasus* 'Otto Luyken'

a) 16-1-70 to 10-2-70 2 0 to 2 8 in nodal cuttings with 0 8 in slice wounds and treated with Seradix No 2, placed under mist with 21°C to 24°C basal temperature

b) 7-2-73 to 12-3-73 Slightly longer cuttings but otherwise 'conditions similar to the previous year'

11) C H R Madge, East Malling Research Station, Kent Apple rootstock, 'M 26'

a) 19-3-70 to 16-4-70 24 0 in basal hardwood cuttings propagated without mist, 0 7 in slice wound and treated with 2,500 IBA in alcoholic solution at 21°C basal temperature

b) 14-3-70 to 12-4-70 'Conditions as for previous year'

12) F Willard, A Goatcher and Son, Washington, Sussex X *Cupressocyparis leylandii*

a) 27-1-70 to 14-9-70 4 0 to 6 0 in nodal tip cuttings with 0 6 in slice wounds and treated with Seradix No 3 Placed under mist with 16°C basal temperature

b) 5-2-73 to 23-5-73 'Conditions as for previous year'

Group 3 — All X *Cupressocyparis leylandii* (clone 2)

13) M G Adcock, Hillier and Sons, Winchester, Hants

a) 21-1-72 to 14-7-72 3 0 to 6 0 long cuttings with heel. Basal temperature 19°C in a medium of 1 peat 3 sand^{+} Supplementary water given at 3 to 4 day intervals

b) 21-1-73 to 21-5-73 *'Conditions as for the previous year'*

14)*D N Clark, Notcutts Nurseries Limited, Woodbridge, Suffolk

a) 18-1-72 to 16-5-72 Lateral cuttings with brown base Basal temperature 21°C in a medium of equal parts peat and grit. Supplementary water given at unspecified frequency, no mist during dull weather

b) 16-1-73 to 15-5-73 'Generally wetter conditions than in previous year'

15) Miss L W Dick, West of Scotland Agricultural College, Ayr

a) 2-2-72 to 23-5-72 6 0 to 8 0 long cuttings Basal temperature 24°C to 27°C in a medium of 3 peat 1 sand Supplementary water given daily

b) 2-2-73 to 22-5-73 'Conditions as for the previous year'

16) A B MacDonald, Hadlow College of Horticulture, Kent

a) Early February to 12-6-72 Basal temperature 21°C in a 2 peat, 1 grit, 1 sand, medium

b) 2-5-73 to 4-7-73 No conditions specified

17) P D A McMillan-Browse, Brooksby Agricultural College, Leicestershire

a) 12-1-72 to 10-5-72 4 0 to 5 0 long three dimensional subterminal cuttings with brown bases Basal temperature 21°C in a medium of 1 peat 1 grit Heavy supplementary watering each morning

b) No conditions specified, but experiments repeated in other groups conformed between years

18)*J M Richardson, E R Johnson (Nurseries) Limited, York

a) 19-1-72 to late May. Medium of 4 peat 1 lime-free sand. 'Dry' area watered infrequently by can, 'Wet' area received intermittent misting.

b) 9-1-73 to 31-5-73 4 0 to 6 0 in trimmed cuttings Medium as in previous year with basal temperature of 21°C 'Dry' area received intermittent mist Wet area was misted and received supplementary water. Rain water was used throughout.

19) J P Sutherland, North of Scotland College of Agriculture, Inverness

a) 2-2-72 to 25-5-73 Apical three dimensional cuttings with brown bases Basal temperature of 21° to 24°C in a medium of 1 peat 1 sand.

b) 5-2-73 to 8-6-73 'Conditions as for previous year with cuttings in the 'dry' regime covered at night with polythene and those in the 'wet' regime given a light supplementary spray each morning

20)*C G Thomas, Long Ashton Research Station, Bristol

a) 25-1-72 to 2-5-72 3 0 in long cuttings. Basal temperature 21°C in a medium of equal parts peat and sand Supplementary water given each morning Benomyl applied against botrytis infection after 8 days.

b) 25-1-73 to 4-5-73 'Conditions as for the previous year'

21)*A Turner, Royal Horticultural Society Gardens, Wisley, Surrey

a) 20-1-72 to 23-5-72 10 0 in cutting Medium of equal parts sphagnum moss peat and Thames River grit.

b) 9-1-73 to 2-7-73 6 0 in cuttings with a heel, with bottom heat of 21°C in the medium

22)*D N Whalley, Glasshouse Crops Research Institute, Littlehampton, Sussex

a) 9-2-72 to 9-5-72 6 0 in long lateral cuttings with brown bases Basal temperature of 21°C in a medium of equal parts peat and grit Supplementary water given at 2 day intervals.

b) 16-1-73 to 17-4-73 'Conditions as for the previous year'

23) F Willard, A Goatcher and Son, Washington, Sussex

a) 1-2-72 to 25-5-72 4 0 to 6 0 in tip cuttings Basal temperature of 16°C in a medium of equal parts moss peat and grit Mist applied during the day only, with supplementary water applied at unspecified intervals as required by weather conditions

b) 2-2-73 to 24-5-73 'Conditions as for the previous year'

Glasshouse Crops Research Institute cutting source

+It is assumed that ratios are by volume throughout

HORMONES AND PROPAGATION

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INTRODUCTION

That plant hormones have a marked effect on the rooting of cuttings has been recognized for some 40 years, since it was first demonstrated that apption of the auxin-type hormone, indolyl-3-acetic acid (IAA), will stimulate rooting in stem cuttings of variousspecies. For many years the *auxins* (which chemically are indole derivatives) were the only known natural plant hormones, but in the last 15 to 20 years it has become recognized that therc are several other groups of natural plant hormones, including the *gibberellins* and *cytokinins*, which are growth promoting substances, *abscisic acid*, which often behaves as a growth inhibitor, and *ethylene*, the first known growh regulating substance which is a gas. These various types of hormone are very different from each other chemically. Thus, the gibberellins are terpenoid-like compounds with a fairly complex structure, while the cytokicns are purines, being substituted adenines or closely related substances. There are now about 40 known naturally-vcurring gibberellins, but the number of identified natural cytokinins does not exceed about 10.

As well as the natural hormones there is a wide range of synthetic substances which have hormone activity. Thus, there are quite a number of substances which will stimulate the rooting of cuttings, including the well-known compound indolylbutyric acid (IBA). There is also a wide range of substances with cytokinin activity, including a number of substituted ureas. However, so far the gibberellins have proved too difficult to synthesize and only the naturally-occurring substances are available at present.

Each of these types of hormone has a wide spectrum of effects, and while each type of hormone may have some effects which are unique, in many cases two or more types of hormone may affect the same process, e.g. stem growth. For example, it has been known for many years that a developing bud on a woody shoot will stimulate division in the cambium in the stem below it, and it was later found that the stimulating effect of a bud can be partly replaced by applying IAA to disbudded twigs. Since developing buds themselves produce IAA which is transported downwards in the stem it is very probably that the stimulating effect of an expanding bud on the cambium is due to the natural auxin which it produces.

When gibberellins were recognized to be natural plant hormones, it was found that gibberellic acid would also stimulate division of the cambium to some extent but, whereas when IAA alone is applied, the cells derived from the cambium form xylem (wood), when GA is applied they form phloem (bark). However, when both IAA and GA are applied together their combined effect on cambial division is very much greater than with either alone, and active xylem and phloem production takes place. Since developing buds produce gibberellins as well as auxins, it seems likely that the natural cambial stimulus produced by buds includes both types of hormone. These findings suggest that it may be useful to apply a mixture of IAA and GA when making a graft, in order to stimulate cambial activity and improve the likelihood of a successful graft union.

The other growth-promoting type of hormone, the *cytokinins*, also stimulates cell-division. There are a number of cases where cytokinins have been reported to stimulate cambial division, but it has no effect with some woody species. However, it also stimulates the disorganized type of cell division which leads to callus formation. Moreover, when cytokinin and auxin are applied together to pieces of tobacco pith in sterile culture, the effect depends upon the relative concentrations of the wo hormones: when the concentration of auxin is high and that of cytokinin is low then the pith cells will proliferate and regenerate *roots*; but when the level of cytokinin is high and that of IAA is low, then *buds* are regenerated. This finding probably has some significance for propagation by root cuttings, since this depends upon the cutting regenerating not only roots from the "lower" bud, but also buds from the "upper" end. The eminent French plant physiologist, the late Dr. Jean Nitsch, studied the hormone changes occurring in pieces of chicory root during regeneration, and found that they passed through a phase in which relatively high concentrations of the natural cytokinin accumulated at the top, and likewise auxins at the base of the cutting, *before* bud or root regeneration had occurred. Thus, the natural pattern of regeneration in root cuttings may be understood in terms of the distribution of natural auxins and cytokinins which occurs within them.

The other two types of natural hormones, abscisic acid (ABA) and ethylene, are important for propagation problems mostly indirectly, through their role in seed and bud dormancy. However, it has been reported that ABA will promote rooting of cuttings in a few instances, such as in adult ivy [*Hedera helix*]. In this latter case it is thought that the ABA acts by inhibiting the effects of the natural gibberellins, which are inhibitory to rooting in some species. Thus, the effect of ABA is apparently to inhibit an inhibitor of rooting! Ethylene has marked effects upon germination in a number of species, stimulating the germination of dormant seeds in some cases and inhibiting it in others.

It is characteristic of hormones that they are produced in one part of the plant and have effects in some other part. Thus auxins appear to be produced at the growing points of the shoot and to move downwards in the stem from there. Cytokinins are apparently formed in the root tips and move up into the shoot with the sap. Gibberellins appear to be formed in the tips of both shoots and roots.

HORMONES AND THE ROOTING OF SOFTWOOD CUTTINGS

Cuttings of many herbaceous plants can, of course, be very easily rooted without any special hormone treatment. This does not mean, however, that hormones are not involved in the rooting of such plants, but simply that the natural hormone levels are sufficiently high to ensure "natural" rooting. Young developing leaves, whether in the terminal bud of an actively growing leafy shoot, or the expanding resting buds of a woody plant in the spring, contain high levels of natural auxin, presumably IAA, which moves predominantly downwards in the stem. When a cutting is taken, the downward-moving auxin will accumulate at the base of the cutting and presumably reach a high enough level to stimulate root initiation. When an external source of auxin, such as IBA, is applied it is simply stimulating and augmenting the natural process. No doubt the effectiveness of layering is partly due to the fact that the cut in the stem blocks the downward movement of natural auxin and leads to the accumulation in the downward-pointing part of the layered stem.

What we have said about the rooting of cuttings of herbaceous plants no doubt applies equally to "softwood" cuttings of woody plants, i.e. the auxin produced in the young developing leaves at the growing point moves downwards and accumulates at the base of the stem. However, it is well-known to horticulturalists that, in many species, as the season progresses there is a decline in the rooting responses of softwood cuttings.

What is the reason for this seasonal variation in rooting ability? One possible explanation might be that many woody plants, in contrast to herbaceous ones, cease extension growth and set a terminal resting-bud by September, if not earlier. It is known that when the growing point ceases to produce actively-growing young leaves, its level of auxin production falls drastically. Thus, it would seem quite possible that the decline in rooting ability in the later part of the growing season, which is observed with softwood cuttings of many woody species, is due to the fall in auxin production when a resting bud is "set".

We have investigated this question in *Populus* x *robusta* (11). We compared the rooting abilities of softwood cuttings which had either (a) an active growing point, (b) a dormant terminal resting bud, or (c) had had their active growing points removed leaving only mature leaves. Somewhat to our surprise the differences in rooting response were relatively small (Table 1), although the cuttings with an active growing point gave the highest percentage of rooted cuttings and the highest number of roots. Moreover, further studies indicated that dormant leafy cuttings contained no less auxin than actively growing ones. Although mature leaves produce less auxin than young expanding ones, it would appear that even fully expanded, mature leaves of poplar produce sufficient auxin to allow good rooting ability in the absence of an active growing point. Whether the same situation applies to leafy cuttings of other woody plants is not known, but it has been reported recently that removing the growing point of dahlia cuttings actually improves the rooting response (2), apparently because the growing point competes with the rooting region of the stem for nutrients and so removal of the shoot tip makes more nutrients available for root formation.

Apart from "internal" factors within the shoot itself, such as the presence or absence of an active growing point, there are various environmental factors which affect rooting and which may account for seasonal trends in rooting ability. An important environmental factor is the seasonal variation in day length. It is well-known that many woody plants are sensitive to daylength and tend to form resting buds as the days get shorter in the fall, but from our work with poplar described above it would appear that the seasonal decline in daylength cannot be attributed solely to the cessation of extension growth later in the season. However, there are a number of reports that daylength may affect the rooting ability of leafy cuttings, quite apart from its effects upon extension growth (see Smith and Wareing (10), for the relevant literature). Thus, Waxman (13) showed that if the source plants of *Cornus florida* cuttings were kept under either 15 hour or 9 hour days for 4 months prior to taking cuttings, the "long day" cuttings rooted readily whereas the "short day" ones failed to root. Similar results were obtained with *Populus* x *robusta* (9). On the other hand, in a survey of 26 woody ornamental species, Baker and Link (1) found that the majority of species did not show any significant response to daylength treatments.

We have investigated the effects of daylength on the rooting of softwood cuttings of *Populus* x *robusta* taken at monthly intervals from 26 May to 22 September, from stooled plants growing in the open. The cuttings were placed in a rooting medium and maintained under either 18 hour or 9 hour days. We found that the percentage of cuttings rooted and the average number of roots formed were both higher under long days than under short days. However, there was a steady decline in the rooting ability of even the "long day" cuttings taken on successive dates.

Moreover, this decline was accompanied by a corresponding decline in the levels of auxins extracted from the cuttings.

Howard (6, 7) has shown that in apple and plum cuttings there is a marked decline in the rooting ability in the early winter (Nov - Dec) and that this effect cannot be overcome by applying IBA. Thus, it appears that the decline in rooting response in the fall is not simply due to a decline in the levels of endogenous auxin. It is possible that in deciduous species this decline in rooting ability in the late autumn — early winter period may be due to leaf-fall. Certainly, we have found that leafy cuttings of forsythia taken in October and placed in mist formed many more roots than corresponding defoliated cuttings. If the autumn decline in rooting response is due to leaf-fall, then the stimulating effect of leaves on rooting must be due to the supply of substances other than auxins, since otherwise it should be possible to obtain a good rooting response at that time by applying IA, whereas we have seen above that this is not the case. The cause of this seasonal decline in rooting ability in the autumn merits further study.

HARDWOOD CUTTINGS

There is a marked seasonal periodicity in the rooting of hardwood cuttings. Thus, cuttings taken in late autumn — early winter (Oct - Dec) frequently show a very poor rooting response, whereas from January onwards the rooting response improves steadily (6, 7). It is also known that the rooting of hardwood cuttings in the spring is stimulated by the presence of an expanding bud, and that disbudding markedly reduces the rooting response (3, 8). By contrast, disbudding hardwood cuttings in October either has little effect or may actually increase rooting. Thus, it would appear that it is only non-dormant buds which stimulate rooting.

Since the buds of many temperate woody species require a period of chilling to overcome the dormancy of their buds, it seemed likely that the improved rooting response as the winter progresses may be due to the fact that the buds gradually lose their dormancy as their chilling requirement is met. We, therefore, compared the rooting responses of chilled and unchilled cuttings of *Populus* x *robusta* and found that rooting was very much greater in the chilled than in the unchilled cuttings (10). We also studied the rooting responses of chilled and unchilled *disbudded* cuttings and found that disbudded chilled cuttings formed many fewer roots than cuttings with chilled buds. However, chilling improved the rooting response even of the disbudded cuttings, suggesting that chilling has a promotive effect on rooting over and above its effects upon the dormancy of the buds, and that chilling may, in fact, enhance the rooting ability of stem tissues directly and independently of any effects on the buds. Parallel studies on the levels of the endogenous auxins in relation to chilling and disbudding indicated that there were higher levels of auxins in chilled than in unchilled poplar cuttings, but disbudding appeared to have little effect on the auxin levels. However, it is possible that some auxin had already been produced by the buds on the parent plant, before the cuttings were taken and disbudded.

Not only does the presence of expanding buds have a stimulating effect on rooting, but also upon cambial activity. Thus, disbudded shoots of poplar show little renewal of cambial activity in the spring, but the effects of the buds can be replaced by applying IAA and GA (see above). Thus, so far as the cambium is concerned, the stimulatory effects of the buds in the spring appears to be mediated through the hormones which they produce. It is reasonable to think, therefore, that the stimulatory effect of non-dormant buds on rooting is also attributable to the hormones they produce.

Howard (7) reported that disbudding had little effect on the progressive increase in rooting response of Myrobalm plum cuttings during the winter, and concluded that "changes in the capacity of the cuttings to root between autumn and spring are not related to the state of activity of the buds on the cutting as influenced by the winter environment". However, it should be noted that Howard applied IBA to the bases of all cuttings in his experiments, and this treatment would obscure any effect of disbudding mediated through reduced endogenous auxin levels. Nevertheless, his results are interesting in that they show that there is a progressive increase throughout the winter in the rooting response of stem tissue to applied auxin. Thus, in addition to the effects of chilling on the dormancy of the buds, chilling appears to increase the responsiveness of the stem tissues to auxin, a conclusion which is consistent with the effect of chilling on disbudded poplar cuttings observed by Smith and Wareing (see above).

As well as increasing the production of auxins by the buds, chilling also leads to an increase in content of cytokinins in *Populus* x *robusta* shoots (5), and of gibberellins in other species (12). The extent to which changes in hormones other than auxins are involved in rooting responses needs further study.

CONCLUSIONS

Although it is clear that natural plant hormones are closely involved in several aspects of plant propagation, it is also clear that our understanding of their role is very incomplete in many ways. Not only do we need more intensive studies on the function of the well-known auxin-type hormones, but we also need to find out how the recently discovered gibberellins and cytokinins are involved, either directly or indirectly. Moreover, it is becoming increasingly apparent that the rooting of cuttings involves other endogenous substances in addition to hormones, such as the terpenoid factors involved in the rooting of ivy cuttings (4), and we need to know how such factors interact with hormones in controlling root initiation, cambial activity and other processes bearing on vegetative propagation.

Table 1. Effect of resting bud and decapitation on rooting of leafy cuttings of *Populus x robusta*. From Smith and Wareing, (11)

Type of Cutting	Mean No roots per cutting.	Percentage rooting	Mean No leaves per cutting	Root/leaf number ratio
A With dormant apices	9 2	96 4	4 6	1 98
B With active growing points	8 1	75.0	4 0	2 00
C Decapitated	7 6	82.1	2.9	2 64

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TECHNICAL SESSIONS
Wednesday Morning, December 5, 1973

The twenty-third annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:35 a.m. in the Saddlebrook-Washington Rooms of the Chicago Marriott Hotel, Chicago, Illinois. President H.B. Tukey, Jr., was moderator for the opening session.

PRESIDENT TUKEY: Good morning. We will now begin the 23rd annual meeting of the Eastern Region of the International Plant Propagators' Society. We have a very large attendance at this meeting with about 350 registered so far. We also have a very fine program for you, which was put together by your Vice-President, Dave Paterson.

With us this morning we have Mr. Rene Koch, who is Chief Horticulturist for the Chicago Park District who brings us greetings from the Mayor's office.

MR. KOCH: This is the windy city, but I am not going to be a windy speaker. On behalf of the Mayor of Chicago who could not make it today because he is working on the city budget and also on behalf of Edmond Kelley, the Superintendent of the Park District, I welcome you to Chicago.

PRESIDENT TUKEY: The following telegram as been received from Mayor Daley, "I know that your Society contributes greatly to gardening and this ultimately benefits homeowners and our parks. I want to extend warmest greetings to everyone attending your convention and I hope it is a great success. Sincerely, Richard J. Daley, Mayor."

At this time we will move into our program. I feel it is appropriate that being in the State of Illinois we start off with a representative of the University of Illinois, Dr. Jack Gartner, who will tell us about the use of hardwood bark in container production.

THE USE OF HARDWOOD BARK AS A GROWTH MEDIUM

J.B. GARTNER, S.M. STILL, J. E. KLETT

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Growers of ornamental crops in the Southeast and the West Coast of the United States have used bark as a soil amendment or as a growth medium in container growing. In the Southeast the southern pine species are used and on the West Coast the

Douglas-fir, redwood, and western red cedar, are predominant trees harvested for lumber and pulp. Growers in the Northeast and Midwest have only recently utilized bark as a soil amendment. In this area the trees harvested are hardwood species such as oak, hickory, maple, walnut, and ash. In the past there was considerable speculation that bark and sawdust of hardwood species was toxic and growers were afraid to use these materials as soil amendments.

Recently, new laws were enacted and producers of bark wastes could no longer dump or burn these residues. Therefore, they were interested in finding other ways of disposing of them. Growers of ornamental crops have become more interested in artificial growth media and are switching to container growing as labor and land prices increase. Sphagnum peat and sand have been standard soil amendments in the past and growers have been looking for substitutes since the cost of sphagnum peat is steadily increasing.

In 1966, Bosley (3) reported success in growing rhododendrons in well-aged bark of hardwood species. This stimulated the interest of Midwest growers in the use of hardwood barks as a growth medium. No information on the use of hardwood bark as a growth medium was found in the literature. Lunt and Clark (5), Allison (1) and Bolin (2) all reported success in using softwood species as a soil amendment for container growing. The only problem they encountered was a suppression in growth from the lack of nitrogen.

In 1967, work was started at the University of Illinois on the use of hardwood bark as a growth medium. Since more than one research project is being discussed, the different problems encountered are presented as separate topics.

PHYSICAL PROPERTIES OF BARK

The paper industry is the largest supplier of hardwood bark in the Midwest. They utilize mixed species and this was used for the initial experiments.

At first we were concerned about particle size. When the hardwood bark is hammermilled to pass through a 12.8 mm screen, 0.7% are larger than 6.4 mm, 12.9% between 3.2 and 6.4 mm, 17.6% between 1.6 and 3.2 mm, 17.6% between 0.8 and 1.6 mm, 9.7% between 0.5 and 0.8 mm, and 26.5% smaller than 0.5 mm. Plants were grown in the various particle sizes; in particle sizes less than 0.8 mm, poor growth resulted due, in part, to poor aeration. When grown in particle sizes above 6.4 mm, poor results were obtained due to rapid drying and low moisture. Experiments were then established to determine the percent of particle sizes needed. The percentages of particle sizes were varied as to the percent below 0.8 mm and the percent above 3.2 mm. Good results were obtained when there was between 20 and 40% particles below 0.8 mm. Satisfactory growth was obtained when 10 to 20% of the particle sizes were above 6.4 mm. When hammer-milling the bark to have tha majority of particle sizes fall below 12.7 mm, they fall well within this range.

Bark is hard to wet if it is allowed to dry out; water it thoroughly the first two or three waterings. If it does dry out, it may be necessary to add a wetting agent to wet it.

NITROGEN UTILIZATION

Nitrogen depletion occurred in our first experiments, which followed the recommendations of Lunt (5), who developed procedures for growing in fir and pine bark. We were unable to overcome the nitrogen deficiency using a commercial fertilizer with a 12-12-12 analysis without running into problems of high soluble salts.

Three slow-release forms of nitrogen were selected: urea formaldahyde (38% N), magnesium ammonium phosphate (7% N) and Osmocote, a plastic coated balanced fertilizer (18-6-12). Osmocote gave the best results, equivalent to or better than that obtained with the standard mix of equal volumes of soil, peat and perlite as reported by Gartner, *et al*. (4)

Five N sources, i.e. urea, ammonium sulfate, ammonium nitrate, calcium nitrate, and sodium nitrate were studied. Ammonium nitrate was consistently the best source of nitrogen, as found by Gartner, *et al*. (4)

We are now attempting to determine why a balanced N source has to be used; perhaps it is a lack of nitrifying bacteria or a pH factor may be involved. When an ammonical source of N is used the pH of the medium decreases and when a nitrate source is used it increases. We find that it takes about 2% N in the form of ammonium nitrate to satisfy the decomposition of bark or 2 lbs/cu yd. With softwoods, an ammonical source of nitrogen can be used without difficulty.

pH FACTOR

As recommended by Lunt (4), we incorporated lime at the rate of 10 lbs/cu yd and the results were poor. Soil analysis revealed high pH values; the more bark in the mix the higher the pH (5). When 2/3 bark by volume was used, the pH ran as high as 8.5. We then studied the use of lime with bark using 1, 10, 20 and 40 lbs/cu yd. As indicated in Table 1, the greater the lime amendments, the higher the pH and the poorer the growth.

Table 1. Influence of lime level on pH* of various media at start of experiment and the highest pH measured.

	Lime Added lbs/cu yd							
	0		10		20		40	
	pH		pH		pH		pH	
Medium	Start	High	Start	High	Start	High	Start	High
Soil/peat:perlite	4.3	6.4	5.2	6.5	5.8	7.0	6.2	7.2
Soil:bark:perlite	5.0	7.2	5.8	7.5	6.2	7.5	6.0	7.8
Soil:bark	4.9	7.8	6.0	7.8	6.0	8.0	6.4	8.0

*pH read by Beckman Model B pH meter in saturated media paste.

If the bark was kept moist with distilled water the pH increased from 5.2 to 6.2 after 30 days. Spectrographic analysis of the bark showed calcium averaging 4.0% on a dry weight basis. It was found that calcium and magnesium were not needed, as there were sufficient amounts in the bark for good plant growth as reported by Klett, *et al.* (5). Analysis has shown the bark to have sufficient micronutrients for growth and we have had no deficiency problems.

PHYTOTOXIC PROPERTIES OF BARK

Our early studies did not indicate any phytotoxic properties of the bark. In the experiments on particle sizes, however, we seemed to have some plant inhibition. When bark leachate was used to water seedlings, germination and growth was suppressed. This bark had been harvested in mid-winter, which was the only difference from previous bark utilized.

It was found that by composting moist for a period of 30 days we could overcome the inhibition. Experiments were then designed to determine if all species contained this inhibitory action and if the time of year the bark was harvested was a critical factor.

In greenhouse experiments an apparatus developed by Koeppe and Bell (7) to determine phytotoxic properties was utilized. Rooted cuttings of chrysanthemum were grown in crocks of quartz sand connected to a crock filled with bark. A complete nutrient solution was circulated through the system daily. The nutrient solution was monitored every 3 days, keeping it at a pH of 6.0-6.5 and constant in nutrients.

Bioassays of aqueous bark extract using oat coleoptiles (9) and a cucumber seedling germination test were also used to study the inhibition.

The following species were tested for phytotoxicity: sycamore, white oak, red oak, ash, maple, cottonwood and walnut. Samples of bark from each species were taken from three trees of each species within 5 days of being harvested. This was done at three seasons of the year: summer, fall and winter. All samples were ground, air dried, and quick frozen to prevent any microbial activity.

The degree of inhibition varied among species and the season of the year (Table 2). Sycamore had the least inhibition and ash, maple, cottonwood and walnut the greatest. Most inhibition occurred with bark harvested in the winter months and the least in the summer. If the bark was aged for 30 days, being kept moist with distilled water and turning daily to insure good aeration, the inhibition was overcome (Table 3). In the greenhouse experiment, the different species required different amounts of nitrogen to maintain the proper level and different amounts of H^+ to maintain the pH as shown in Table 4.

Table 2. Mean elongation of oat, cucumber, and chrysanthemum for different seasons using various hardwood barks.

	Fall			Winter			Summer		
Treatment	*Oat mm	Cucumber mm	'Mum cm	*Oat mm	Cucumber mm	'Mum cm	*Oat mm	Cucumber mm	'Mum cm
10^{-6} M IAA	8.01			7.20			7.67		
Water	3.84	52.25	20.5	3.83	51.51	22.0	4.47	49.76	17.0
Sycamore	4.38	55.70	20.9	4.66	51.27	16.8	5.03	37.60	18.6
White oak	4.32	51.44	18.4	2.59	35.40	11.8	2.87	45.45	12.0
Red oak	3.74	45.13	20.0	3.04	33.55	10.8	3.40	39.73	12.0
Ash	3.40	41.45	18.8	2.62	30.85	12.8	3.67	17.76	15.9
Silver maple	3.09	45.18	16.0	2.11	26.86	9.1	4.00	26.63	16.3
Cottonwood	2.86	57.20	——	3.42	39.43	——	4.10	38.00	——
Black walnut	1.34	35.88	16.8	2.06	16.99	12.5	3.20	28.21	11.1
LSD .05	.80	3.50	6.3	.45	4.79	6.3	.37	6.15	6.3

*Treatment for oats included addition of IAA to each bark extract.

Table 3. Mean elongation of oat and cucumber using fresh and 30-day aged hardwood barks.

	*Oat		Cucumber	
Treatment	Fresh mm	Aged mm	Fresh mm	Aged mm
10^{-6} M IAA	8.20	7.97		
Water	5.37	4.54	45.78	45.78
Sycamore	5.34	6.66	32.59	49.56
Ash	3.80	5.96	31.55	55.00
Red oak	3.78	6.24	20.61	53.05
Black walnut	3.20	4.21	20.09	56.05
Silver maple	2.62	6.46	8.66	45.88
White oak	2.54	4.01	24.25	49.74
LSD .05	.58		4.34	

*Treatment for oats included addition of IAA to each bark extract.

Table 4. Meq. of H^+ added to maintain a pH from 6.0 to 6.5 and meq. of $-NO_3$ added to maintain solution at 15mM after 20 days.

	H +	$-NO_3$
Sand	30	45
Silver maple	60	280
Black walnut	250	270
Red oak	280	600
Ash	360	450
Cottonwood	445	480
Sycamore	515	625

Using paper chromatography, ten compounds having various degrees of inhibition in the bioassays were isolated. Work on the identification of these inhibitors is continuing. Experiments were designed to see if rate of decomposition had any effect on the inhibitors or their breakdown. the evolution of CO_2 from decomposing bark was measured by an incubation unit designed by Stotzky, *et al.* (10). A greater CO_2 production would mean greater decomposition and consequently a higher need for nitrogen. Fresh winter barks from sycamore, hackberry, cottonwood, and silver maple were incubated for 30 days. Hackberry and silver maple released twice as much CO_2 as did sycamore and cottonwood (Table 5) indicating that the latter two barks might not require as much nitrogen.

Table 5. Total amount of carbon released from decomposing bark over a 30-day period.

Bark	Carbon (mg)
Silver maple	258
Hackberry	223
Cottonwood	146
Sycamore	145

To check this, chrysanthemums were grown in the four freshly harvested barks. On the basis of height and dry weight measurements, chrysanthemums grown in sycamore and cottonwood bark were better than those grown in hackberry and silver maple bark. We also found that the plants grown in silver maple and hackberry, particularly silver maple, were slower in rooting than those grown in cottonwood and sycamore bark. Plants grown in maple bark had a very poor root structure until 4 weeks after the cuttings were potted. After this period of time, an adequate root structure was evident. Further studies with fresh bark, and bark composted for 30 days, showed the inhibition was almost eliminated after 30 days of composting (Table 6).

Table 6. Effect of species and age of bark on dry weight of chrysanthemums grown in 2/3 bark and 1/3 sand.

Species	Dry Weight (g)	
	Fresh	Aged (30-day)
Silver maple	20.0	31.7
Hackberry	16.8	27.5
Sycamore	27.5	41.8
Cottonwood	33.7	33.1

LSD .05-7.1

RATES OF BARK USED AND AMENDMENTS

Initially we substituted the ground bark for peat in our standard mix of 1/3 soil, 1/3 peat and 1/3 perlite by volume. Now we are utilizing 2/3 bark and 1/3 soil or sand, by volume. In our experiments we found no difference between soil and sand. The sand we use is a coarse masonary sand; most growers prefer using sand as it is readily obtained and is uniform from place to place.

Due to inhibitors, we have found that it is essential to stockpile the bark mix for a minimum of 6 weeks. During this stockpiling procedure it is essential to keep the mix moist — at least 60 to 90% moisture.

From our experiments we have derived the following formula which several commercial growers are utilizing in Illinois for production of their crops.

To each cu yd of mix, when utilizing 2/3 bark and 1/3 sand, you must add 6 lbs. of ammonium nitrate, 5 lbs. of superphosphate, 1 lb. of elemental sulphur and 1 lb. of iron sulfate. This should then be mixed in a drum or rotary mixer to obtain a thorough mix. After mixing, it should be stockpiled moist for a minimum of 6 weeks. After stockpiling, it is ready for use. The amount of nitrogen recommended is only for offsetting the decomposition and it is, therefore, still essential to fertilize at every watering, using a complete nutrient solution of a 20-20-20 analysis, utilizing a 250 ppm of N. This may vary according to the crop, depending on its nutrient requirements.

Advantages of Bark:

1. Bark is fairly economical and readily available.
2. Bark has an excellent waterholding capacity.
3. It provides a well-drained and well-aerated medium that is difficult to overwater.

4. The plants are able to obtain water readily from the bark; bark mixes do not seem to dry out rapidly.
5. Bark contains all minor elements essential to plant growth.
6. It is light in weight and easy to handle.
7. Preliminary experiments indicate a reduction in nematode population when using bark.
8. Ion exchange capacity exceeds that of peat and increases with age.

Precautions

1. Lime cannot be added. The pH rises as the bark ages; bark contains 3½ to 4% calcium by dry weight.
2. Nitrogen must be added. Ammonium nitrate is the best source and should be added at the rate of 6 lbs. per cubic yd. Avoid using urea and straight ammonium sources.
3. A thorough mix must be obtained by using a rotary-type mixer.
4. The bark must be stockpiled for 6 weeks prior to use.

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PRESIDENT TUKEY: We do have time for a few questions.

BILL CURTIS: It is my understanding that on the West Coast when bark is stockpiled with Osmocote we have problems with root burn.

JACK GARTNER: Yes, you can get too much fertilizer release under those conditions. We are not recommending Osmocote anymore; we now recommend ammonium nitrate stockpiling for about 60 days. The pile should not be too large and should preferably be turned at least once during this time. We have noticed some heating during stockpiling with temperatures of 140^0 to 150^0 F during the first 10 days but this gradually goes down.

JIM WELLS: You're putting in 6 lbs. of ammonium nitrate to overcome nitrogen deficiency, what is your fertilization program thereafter?

JACK GARTNER: This depends upon the crop but usually runs about 200 ppm N using a balanced source such as 20-20-20 or 20-10-5, applied with each watering. With high N crops we may go up to 250 or 300 ppm N.

VOICE: Would there be an advantage to dissolving the fertilizer and applying it to the bark to have it absorbed into the product, much like a Pro-mix, or is this what you are accomplishing by stockpiling?

JACK GARTNER: I believe you might get into trouble with non-uniform distribution by dissolving and adding the fertilizer to the bark, though I understand some growers in Ohio are doing it this way. I have not tried this method yet, but as long as you get uniform distribution through the bark it should work.

BRYSON JAMES: Did you measure your nitrogen levels before and after composting, to arrive at the 6 lb. rate?

JACK GARTNER: We established this on an empirical basis at first, actually getting our best results at 9 lb. but there is some danger of burn, so we settled on the 6 lb. rate. In addition, two laboratory procedures — rate of bark decomposition and the circulatory system — both gave nitrogen values of around 2% actual N.

RICHARD BOSLEY: I want to commend you on what you have done. I do wish to comment on how the N gets distributed through the bark by our method which uses urea as the N source. The bark is composted in layers using 3 to 4 lb. of urea per cu yd. This is covered with polyethylene and almost immediately the bacteria begin coverting the urea to ammonia gas and this is how the N is distributed through the pile. I suspect this also does a good job of killing any pathogens which might be present. At warm temperatures, the reaction is usually complete in 48 or so hours; this can be determined by raising the poly and if you smell ammonia it is not complete.

JACK GARTNER: You then add dolomitic limestone afterwards don't you?

RICHARD BOSELY: Yes, after composting we add any other ingredients, e.g. sand, peat, etc., with which we may wish to ammend the medium.

JACK GARTNER: The point I wish to make is that we went to ammonium nitrate to avoid the drop in pH we got when we used urea or the increase we got when we used only nitrate. Ammonium nitrate avoids a pH shift which has to be corrected after composting. Our two methods are probably giving the same result.

PRESIDENT TUKEY: Thank you Jack, you have certainly gotten us off to a good start. Our next speaker is from the Cooperative Extension Service in Ohio and Fred Buscher will be talking about determining air-filled pore spaces in container media.

DETERMINATION OF AIR-FILLED PORE SPACE FOR CONTAINER-GROWN NURSERY STOCK

FRED K. BUSCHER
Cooperative Extension Service
The Ohio State University

and

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Restricted soil aeration in soil mixes for container grown plants can 1) be the greatest limiting factor in the development of an extensive root system, 2) can impair the essential process of respiration of an established root system that retards both water and nutrient absorption, 3) prevent the orderly functioning of essential biological processes associated with good soil fertility, and 4) increase the probability of root disease problems.

The water content in container plant production remains near field capacity under irrigation. The air-filled pore space following drainage to field capacity is an important aspect of soil mixes. It is through air-filled pores that gases are exchanged between the soil mixes and the atmosphere. This pore space is influenced by the amount and type of amendments used in the soil mix. Since we cannot yet predict water and air-filled pore conditions for different mixes, each grower must measure air-filled pore space for his own mix.

A way to determine the air-filled pore space after drainage (at field capacity) is as follows:

1. Slowly immerse the container plant into a larger volume of water until the water begins to appear at the surface of the soil mix in the container. The object of slow wetting is to avoid trapping air in pores. Be careful not to let any water enter from the top of the container.

2. After water has appeared at the surface of the soil mix, quickly remove the container and set it into a bucket or watertight container and record the weight in ounces or grams. Call this weight, W_1.

3. After weighing the container, remove it from the bucket and allow it to drain for 24 hr away from drafts, direct sun, or high temperature, to avoid excessive evaporation.

4. After 24 hr. reweigh the container in the same bucket or watertight container used in step 2. Call this weight W_2.

5. It is necessary to determine the volume occupied by the soil mix in the container. Mark the top of the soil line around the inside of the container. Remove the soil mix, clean out residues, line the container with a very thin polyethylene plastic or saran wrap. Refill the container with water to the soil line, mark and weigh. Call this weight W_3. Empty water from the container and reweigh. Call this weight W_4. Remember, keep the units of weight for all measurements in either ounces or grams.

6. Compute the percent air-filled pore space at field capacity by dividing the loss in weight (W_1 - W_2) by the volume of the soil mix (W_3 - W_4), and multiply the quotient by 100.

Example:

a) weight of saturated 2 gal/container of rhododendron and bucket = 5100 grams (W_1)

b) weight of container and bucket after draining 24 hr = 4300 grams (W_2)

c) weight of drained water = 800 grams (W_1 - W_2)

d) weight of container plus water up to the soil line = 5250 grams (W_3)

e) weight of container without water = 600 grams (W_4)

f) volume of soil mix = 4650 grams (W_3 - W_4)

g) divide weight of drained water (800 grams) by volume of soil mix (4650 grams) = 0.17

h) multiply by 100 for percent air-filled pore space of 17%.

Values for the best percent air-filled pore space for container growing have not yet been established. However, a good farm soil to produce good corn should be at least 10%. A range of about 15-25% air-filled pore space would be desirable for container-grown ornamentals. Plants susceptible to root rot diseases, for example rhododendron, may grow better at the higher levels of air-filled pore space. This is important along with a good program of disease prevention and sanitation methods.

PRESIDENT TUKEY: Thank you very much Fred. Are there any questions?

CHARLIE PARKERSON: Can we use your method on a medium right out of the mixer or must there be a plant growing in it?

FRED BUSCHER: The method can be used immediately, but the medium should be firmed into the container. Decomposition during the growing season will cause changes but by running some preliminary tests and keeping records you should be able to formulate the mix you want.

H. SINGLETARY: As pore space increases can you give any correlation to moisture retention?

FRED BUSCHER: No, I can not, but I do know that it drains faster and takes more frequent irrigation.

JIM WELLS: As the growing medium deteriorates, must we continually check the pore space and adjust our watering practices accordingly?

FRED BUSCHER: That is exactly what I am suggesting.

PRESIDENT TUKEY: Our next speaker is John Sparmann of Quincy, Florida, who is going to tell us about container stock in his part of the country.

PROPAGATION AND GROWING OF CONTAINER STOCK IN NORTHERN FLORIDA

JOHN P. SPARMANN

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Climatic conditions in our area make in possible to grow a wide variety of plants which are hardy in northern temperate zones. A longer growing season and the need for very little protection make it economical to ship these plants to northern markets. We generally have mild winters, temperatures drop to the low teens occasionally, and I have seen the ground remain frozen for as long as 5 days at a time. Average annual rainfall in Quincy is 54 inches, with extremes of 30 or 84 inches.

Propagation by cuttings is done from May through February. The cuttings are taken from 1 or 2 yr old container stock, and we like to let the time the cuttings are taken coincide with the time the plants need pruning.

Cuttings are taken from healthy and well watered plants. They are washed in fungicide solution, wounded by means of stripping and cut to a uniform length. Each worker gets a small wooden stick, previously cut to insure this uniformity. Cuttings must be short and stocky, in order to produce a bushy plant. Most cuttings are stuck in flats after being treated with a hormone powder. IBA in talc is used from 0.2 to 2% in strength, depending on cultivar and condition of the cuttings.

The rooting medium consists of 50% Canadian or Maine peatmoss, 25% perlite, 25% washed river sand by volume, and it is mixed at our mechanized mixing plant. The medium is put into galvanized metal trays which stand a lot more abuse, than common wooden flats, and can be washed and sterilized very easily. Conveyors in our propagating house let us handle these flats in an assembly line-like manner. The flats are taken to a shaded mist area by means of farm wagons, where conveyors again simplify the handling.

All tools and tables are washed daily with a solution of L-F 10. For our mist system we use Flora Mist foggers with a 1/32 inch orifice opening at a spacing of 4 feet. Timeclocks regulate mist requirements and are set according to weather conditions. Fungicides are applied weekly.

When the cuttings are rooted and sufficiently hardened off, they are fertilized with the help of a fertilizer proportioner and are included in the routine nursery spray program.

In September the cuttings are potted into 3 or 5 inch plastic pots. On a long potting table along one wall of our potting shed, we pot about 16,000 plants per day by hand. For the past 2 yr we also employed the use of a small potting machine. The main purpose of this machine is to prevent roots from being curled, which often occurs when bareroot cuttings are being handpotted. The mix is supplied from the outside of the building through chutes in the wall. Metal trays rolling on conveyors carry the plants to a specially built flat wagon, with the capacity of 1,200 three inch pots. The wagon takes the plants under a shower of water and then to polyethylene houses, where they are placed on benches, again with the help of portable conveyors.

The houses are shaded with tobacco shadecloth (20%) and are equipped with gas-heaters, fans, and manually operated watering systems. Fertilizing is done by means of handwatering and the help of a fertilizer proportioner. Regular soil tests, made on a Solubridge, prevent over fertilization. The plants are handpinched as needed, which is usually twice between October and March.

During the fall and winter months some of our juniper cuttings are stuck in open mist beds in native sandy soil, which has previously been treated with methyl bromide. These cuttings are put directly into 1 gal containers the following fall and winter. Our mix consists of Canadian peatmoss, Michigan peatmoss, perlite and sand. Except for the sand, these materials come in by railroad and are unloaded directly into our mix-building. Conveyors throughout the building let us do this in a short time and with a minimum of effort.

Bales and bags of peatmoss and perlite are rolled over a belt conveyor 25 ft long and 2 ft wide, and are split open to allow the materials to fall onto the belt. One man shovels a thin layer of sand on to the belt as it travels by. Ingredients such as lime, deildrin, fungicides, fertilizers, etc. are spread over the peatmoss on the belt. The belt then takes the material to a shredder-mixer-transporter. A water nozzle mounted at the end of the transporter belt adds some water before the mix falls onto a truck.

At the end of March we start potting our plants out of the polyethylene houses. The plants are placed in metal trays for transportation and again with the aid of conveyors taken to the shade, where they are potted into 1 or 2 gal containers. As of this time, we still do our potting into containers by hand.

Women pot the plants at a potting wagon and place the finished containers on conveyors behind them. This potting wagon is 18 ft long with one high side. The mix-truck backs up to this high side, and the mix is shoveled onto the potting wagon. Finished containers on plywood pallets are rolled to the end of the line, and are placed in beds, eight 1 gal or six 2 gal containers wide. The planting wagon is moved once a day, leaving space for a days production between the wagon and the previously planted containers. Plants are watered-in by hand immediately; after that overhead irrigation takes over.

After the plants have grown about 6 months in 1 or 2 gal containers under 30% shade, they are spaced 6 or 8 inches apart. Proper grading of the land where containers are placed and roadways are located is most important. Downpours of 4 or 5 inches of rain on one day are not uncommon in our area and can present a big problem if the water can not drain rapidly.

All azaleas and certain *Ilex* varieties remain under shade until shipped. Plants are hand-pruned as required (twice a year for most plants) and fertilized through the overhead irrigation system. Most containers grown in this fashion are marketable 18 to 24 months after the plant has been propagated. A certain amount of 1 gal containers are upgraded to larger containers, such as 3, 4 and 5 gal, and grown for 1 or 2 more years.

Being located in a somewhat depressed farm area, we have not been plagued by the acute labor shortages that most of the northern growers experience. I suppose, this is the reason why we still do a number of jobs by hand, which could be done with the use of machines.

TOM LANDZAAT: What fungicides do you use on your cuttings and do you rotate them?

JOHN SPARMANN: We use mostly M45 at 1 lb/100 gal and occasionally we use Benlate but it is used only once.

BILL BENNETT: Would you repeat how you use the Treflan?

JOHN SPARMANN: We use 1.4 lb/1000 sq ft of 5% material every 8 weeks. The plants are spaced out after 4 to 6 months so this means only three treatments at the most. If we were to apply Treflan after spacing, 75% of the material would end up on the plastic beneath the cans and eventually end up in our water supply as the result of run-off.

PRESIDENT TUKEY: Thank you very much, John; we will be down there in 2 years and it looks like you have lots of things to show us when we get there.

The title of our next paper is, "VPD and Poly in Plant Propagation", and it will be presented by Mr. Slezinsky.

VAPOR PRESSURE DEFICIT AND POLYETHYLENE IN PLANT PROPAGATION[1]

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Michigan State University
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INTRODUCTION

Over the last 30 years propagators have successfully used mist to control water loss from cuttings during the period of root regeneration. There are many excellent references on the subject (5, 6, 8, 9, 13). Emphasis has been on the use of mist to cool the leaves of the cuttings. This results in lowering the vapor pressure within the cutting, thus reducing the vapor pressure deficit (VPD) between the leaf and the ambient atmosphere which, in turn, reduces loss of moisture by transpiration. However, another method of reducing the VPD is to increase the relative humidity of the ambient atmosphere. At a relative humidity of 100%, the VPD (mmHg) at any temperature is zero. Humidity control received some attention by propagators (1, 3, 7, 10) over the years, but most propagators have relied on mist.

Since 1953 many propagators have utilized polyethylene film in plant propagation. Coggeshall (2) propagated difficult-to-root plants in a plastic case. Warner (12), Van Hoff (11) and others have used and discussed the advantages of polyethylene film in the propagation of cuttings.

MATERIALS & METHODS

The purpose of this study was to determine if maintaining a high relative humidity around the cuttings was as good as or better than intermittent misting. Six propagation chambers, 4 ft square and 3 ft tall were constructed within a greenhouse by slightly modifying the design of a conduit polyhouse (4).

Two chambers and an open mist area were constructed on each of three benches. Clear and milky, four-mil, polyethylene sheeting was stretched over separate chambers and stapled to the wooden frames on three sides. One side remained unstapled for ease of entry. But this was closed and sealed with an easily removable lath strip after the cuttings were stuck.

An intermittent mist system was constructed to service the three open bench areas plus one clear and one milky poly unit. An atomized mist system was developed for two of the chambers,

[1] Paper No. 6636 Michigan State University Agricultural Experiment Station. East Lansing Michigan.

one clear and one milky unit. Two 1/4 JH pneumatic atomizing nozzles were used, one per unit. The air supply line contained a pressure regulator, a solenoid valve and a line strainer. An air pressure of 10 psi was maintained. Two 500-liter plastic bottles served as reservoirs to supply water to the system. Both systems operated daily from 7:30 a.m. to 5:00 p.m. The atomizing unit was continuous and the intermittent mist was on for 2.5 sec. every 5 min. The two remaining chambers were misted daily with a Fogg-it nozzle.

The rooting medium consisted of a 1:1 mixture of sphagnum peatmoss and sharp sand. Four species were used in the experiment: boxwood [*Buxus sempervirens*], forsythia [*Forsythia x intermedia*], firethorn [*Pyracantha coccinnia* 'Lalandei'] and weigela [*Weigela florida*]. Semi-hardwood, tip cuttings were prepared, dipped in a 15% captan solution and then the basal 1/2" portion was treated with 8000 ppm of IBA. Three replicates of 20 cuttings per species were stuck in random rows in each of the 9 propagatin units, during the evening of October 14 and 15.

Three hygrothermographs recorded air temperature and relative humidity within the polyhouses and in the open mist beds. At weekly intervals the instruments were moved to previously unrecorded plots.

Root quality index values were obtained for each replicate. Forsythia, firethorn and weigela were well-rooted and rated on November 17 and boxwood on December 29. Individual cuttings were graded on the basis of 5 for heaviest rooting, 3 for medium and 1 for light. The data were then analyzed for statistical significance employing orthogonal comparisons.

RESULTS

Relative humidity of the polychambers was maintained close to 100%. The relative humidity of the open mist areas fluctuated considerably from 100% during the day when the system was on, to a low of 42% at night when the mist was off.

All the polychambers had temperatures higher than the open mist beds; temperatures in the clear polychambers were higher than those in the milky chambers. But chambers with mist were cooler than those without mist. The highest termperatures were recorded shortly after noon on sunny days. The temperature of the rooting media did not vary substantially among plots, averaging $67^{0} \pm 2^{0}$ F, both during the day and the night.

All cuttings rooted extremely well in the clear-polyhouse with atomized mist (Table 1). The cuttings remained turgid and free of any visible surface deposit; whereas, the cuttings in the intermittent mist became coated with a white mineral deposit within a few weeks.

Table 1. Average root index values for selected semi-hardwood cuttings rooted in various environments.

Plot	Mist System	Average Index Values Boxwood	Forsythia	Pyracantha	Weigela
Clear Poly	Atomizing	84.7	96.0	94.0	91.3
	Intermittent	81.3	93.0	76.0	85.7
	Manual	68.7	88.3	77.3	82.3
Milky Poly	Atomizing	65.3	81.7	41.3	64.3
	Intermittent	60.0	85.0	51.3	51.0
	Manual	51.3	86.3	35.3	44.7
Open Bed	Intermittent	56.9	61.2	57.0	68.2

When the data were analyzed employing orthogonal, comparisons (Table 2), *it was found that cuttings of boxwood,* forsythia and firethorn rooted significantly better in the polyhouses with mist than in the open mist beds. But the weigela data did not show significant difference. However, cuttings in the clear polychambers rooted significantly better than those in the milky houses except for the forsythia which rooted equally well in all polychambers.

Table 2. Orthogonal comparisons of selected environments for propagation of cuttings.

Comparison	Significant Rooting Boxwood	Forsythia	Pyracantha	Weigela
Poly + Mist vs. Open + Mist	X	XX	X	—
Clear Poly vs. Milky Poly	XX	—	XX	XX
Clear Poly + At. Mist vs. Clear Poly + Int. Mist	—	—	X	—
Milky Poly + At. Mist vs. Milky Poly + Int. Mist	—	—	—	X

X = significant difference at the 5% level
XX = significant difference at the 1% level

Both misting systems proved to be successful in maintaining a high relative humidity within the chambers. Cuttings of all species rooted well, although cuttings of firethorn rooted better in the atomized mist-clear-polychamber than in the intermittent mist-clear-polychamber.

It appears from these results that maintaining a high humidity around cuttings to produce a low (close to zero) VPD is a significant factor in maintaining cuttings in a vigorous condition during root regeneration. This was best accomplished in this experiment by use of a clear-polychamber equipped with atomizing nozzles. Although cuttings rooted well in the clear house equipped with an intermittent mist system; they did not have as good an overall appearance as did the cuttings rooted under atomized mist.

Since this experiment was done in the fall, the results may not be fully applicable in summer, under high intensity sunlight. It may be that a milky polychamber would be best for that time of year.

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LARRY CARVILLE: I assume the temperatures you gave are air temperatures; did you use any bottom heat and what was your shade factor under the milky poly which you used?

J. SLEZINSKY: We used no bottom heat, the temperatures were air temperatures, and we made no light measurements under the plastic so I can't tell you what the shade factor was.

RICHARD BOSLEY: You mentioned noticing mineral deposits on the leaves of cuttings under intermittent mist; did you analyze the water?

J SLEZINSKY: No, we did not. The water is that supplied by the University and I do know that it is high in calcium.

PRESIDENT TUKEY: Thank you Jim; we will have to hold the rest of the questions for the Pot Pourri.

Our next talk is about low cost propagating structures and will be presented by Carl Orndorff.

LOW COST PERMANENT PROPAGATING STRUCTURES

CARL ORNDORFF

Kalmia Farms Nursery
Clarksville, Maryland 21029

This is not an experimental project, but the reporting of the changes and upgrading of our propagating facilities over a 15 yr period at the Kalmia Farms Nursery at Clarksville, Md.

Low cost does not mean only construction costs, but also general maintenance costs, operating costs such as heating fuel and general labor operating costs.

Our firm operates a 328 acre wholesale nursery, growing mostly winter hardy woody plant materials in medium and large sizes. We cater to the landscape contracting business in the Mid-Atlantic area, with 90% of our business in a 50 mile radius that covers the Washington and Baltimore markets.

Our firm was originally in a rural area, in what is now the suburban Maryland-Metropolitan Washington area. During the late 1950 period, we moved to the rural area 20 miles west of Baltimore and 25 miles north of Washington. Again Washington and also Baltimore are moving in on us very fast.

In the late 1950 period, we had to start a new propagating facility at our new location. We had on hand one new 52 x 23 ft conventional "A" frame glass house. This we erected as a starter

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In the late 1950 period, we had to start a new propagating facility at our new location. We had on hand one new 52 x 23 ft conventional "A" frame glass house. This we erected as a starter at our new location, with plans to add several larger houses. At about this time several new products and new methods of propagating became available. This caused us to take a long hard look at our future facilities and methods. We have since built four additional 72 x 20 ft houses.

We considered seriously the following before building these houses:

1. Cost of building materials and amount of construction labor required.
2. Reducing the cost of maintenance; especially, reglazing, repainting, and general repair costs.
3. Increasing the general efficiency of the buildings, especially reducing heating costs. Also, increasing the ratio of useable area to total area.
4. Reducing operating costs by using labor saving devices, such as gravity conveyors, automatic controlled heating, automatic controlled ventilation, automatic watering, improved feeding methods and improved shading methods.
5. Also, such problems as non-drip ceilings involving condensation, long-life non-drip elevated benches and the elimination of fungus from walls, walks and benches.
6. Our most serious consideration was having a heavier and stronger plant to go directly to the fields. Our aim was to harvest a larger percentage of saleable plants and cut the time from planting to harvest and to have a superior product to sell at harvest.

With these objectives in mind, we made the following changes from our former facilities and methods:

1. We changed our design from the conventional "A" roof to a flat roof and placed each house against the next with common side walls. This reduced the exposure to cold weather to only the flat roof and the two ends. This exposes about 65% of the area of a normal "A" frame house. We also lowered the roof to between 7 and 8 ft to lower the volume of heated area. Our roof drainage grade was one inch of fall per foot. We considered curved or "Quonset" type designs but vetoed these because of larger area exposure and the more serious problem of snowload. Six to eight foot drifts are common with us.
2. Our next change was from glass to sheet fiberglass for superior insulation, lower labor installation costs, elimination of glazing and reglazing costs, elimination of air and

water leakage, the lower cost of shading and the ability to withstand our extreme snowload. Fiberglass is reasonably elastic under snowload, while glass will break easily. Our shading is 55% polypropylene netting, bound and eyeleted, fastened flat on the fiberglass. This is used from April to October and is easily put in place and removed. The life expectancy is unknown, but indications to date are extremely good.

3. Another change was the elimination of all painting of wooden parts, this being replaced by treatment with **water-based** copper wood preservatives. This saved painting and repainting and also greatly lengthened the life expectancy. We have in use treated greenhouse benches of western white cedar up to 14 yrs old, still in perfect condition. This is far superior to the expensive cypress and redwood lumber. Also for ungalvanized metals, we changed from enamel metal paints to primer metal paints with red lead or zinc chromate base to reduce the frequency of painting.

   An unanticipated payoff has been the elimination of all fungus on or in the houses, benches, pots or plants. We have found none of any type at any time. No fungicides have been used. We do not know if it is due to the fungicidal characteristics of the wood and metal preservatives, to the light and insulation factors of the sheet fiberglass or the design of the flat roof buildings with their absence of condensation drip. We installed a turbulating fan in our first fiberglass house to take care of ceiling condensation and drip, but found it unneeded.

4. Other savings in both construction materials and construction labor was the elimination of all poured concrete. Building blocks laid with mortar was used only where earth retaining walls were required. Elsewhere all walls and footings were building blocks laid dry and filled with washed pea gravel for locking in position. Building blocks were laid on the side and used for all walks and steps. These automatically became the edgings for all ground beds; therefore serving a dual purpose.

5. A most profitable change was the doubling of useable space by using both elevated and ground beds. Elevated beds 36" to 42" tall and 32" to 36" wide are used over ground beds 36" to 42" wide. This gives excellent light to the ground beds, which are used for plant materials having low light requirements, for seedling flats and for root cuttings. This system cannot be used in "A" frame houses

unless the sidewalls are extremely high; which then adds heavy additional heating loads.

Bench floorings are of treated 6" wide western white cedar, laid crossways, spaced 1" apart, and covered with 1/8" galvanized hardware cloth. Edge boards are the same 6" material. All beds are filled to the top with coarse perlite. This has a dual purpose, acting as a mulch and checking all drip into the ground beds. Also perlite is used because of light handling weight, sterile quality and high water absorption but slow water release.

6. Additional changes of more common useage were from conventional lift type ventilation to exhaust fans with soft plastic input distribution tubes. Yeating is oil-fired hot water with separate thermostats and circulating pumps for each house. One line of 1-1/2" fin type radiation goes around the perimeter of each house under the elevated beds.

   Watering is by automatic mist in the rooting house and by hand in the growing areas. Due to the use of perlite, hand watering is required only about once weekly in the summer and every 2 to 3 weeks in winter. Feeding is by a simple siphon system, therefore clogging prevents an automatic mist system being used in the growing areas. Sprinkler heads cannot be used due to excessive water on dual height beds.

   Gravity conveyors for handling filled flats lighten our work load.

Have these changes made any problems? None of serious consequence. Our largest, but very infrequent, is snow removal. We have had 4 ft of drifted snow on part of the roof. Snowload weight is not the problem. Insulation is so good, we cannot melt the snow by raising the interior temperature. If ambient temperatures are reasonably high after a snow fall, it clears quickly. If daytime temperatures remain low, hand removal may be necessary.

To summarize the results of our planning and almost unbelievable luck, our most important result at this time of energy crises seems to be the saving of heating fuel. Insulation and sealing is so efficient that the thermostats call for heat during the day only on the most extremely cold and windy periods.

An analysis of our fuel consumption as we expanded is as follows:

1. Three years operating only the "A" frame glasshouse, 52 x 23 ft, we consumed an average of 2659 gal/yr.

2. Two-year average consumption for the glasshouse and our first fiberglass house, 72 x 20 ft, was 3570 gal/yr. This is above our total average but both years were extremely cold with frozen ground 2-1/2 to 3 ft deep.
3. Five-year average consumption for the glasshouse and two fiberglass houses both 72 x 20 ft was 3709 gal/yr.
4. Three-year operation of the glasshouse plus four fiberglass houses (two of the latter were operated at just above freezing temperatures) consumed under 4000 gal/yr.

Cost comparisons are difficult because two fiberglass houses are carried at temperatures similar to the glass house and two just above freezing. Being mindful of this fact, one must realize the area has been increased 500%; while fuel useage has only increased by 60% from that used by the glass house in 3 yrs of operation.

The real labor saving is in the operational features of the propagating houses. Our facility operates at full capacity all year. Our output is approximately 200,000 plants annually. These are all in 3" clay pots and are heavier than liners available on the open market. Our liners go directly to the field and are machine-planted. Our losses are nil and the growth rate is excellent.

The total facility has been handled by one woman. She makes, pots and beds all cuttings; performs all watering, feeding and seeding tasks.

The whole layout is not impressive as a showplace, but it makes up in what it is short on appearance by being long on performance. We are able to lock the doors and be away for a full week at any time of the year.

PRESIDENT TUKEY: We are a little behind schedule so we will have to hold questions for later. Our next talk — by Jim Kyle — is entitled, "New Propagating House Using Plastic Pipe Bottom Heat".

NEW PROPAGATION HOUSE USING PLASTIC PIPE BOTTOM HEAT

JAMES H. KYLE

Spring Hill Nurseries Co.
Tipp City, Ohio 45371

The past few years have shown a need for additional propagation space at Spring Hill Nurseries. One specific crop which we wanted to expand was evergreen liners.

Over the years we have rooted *Taxus, Juniperus,* and *Thuja* species in many ways. Cuttings have been stuck in outdoor frames, greenhouse benches, flats on greenhouse benches moved outdoors when rooted, and even some under outdoor mist. We wanted to expand using the best of what we had done in the past. A good production area was to be built with reliable control of heat and other environmental conditions. The space would have to be flexible to use for other crops.

The 180 x 15 ft poly tunnel was constructed like other houses in the area. The floor, however, was submerged 2 ft underground. A hole was excavated 3 ft deep, sloping to a 12 inch drain tile at one end. Pipes were driven into the ground to support the structural hoops. A concrete footer was poured to support precast concrete slabs, with 2 inches of styrofoam insulation on the outside. These slabs act as sidewalls and retain the soil.

Cuttings were stuck in coarse sand and the flats placed on the floor of the house. Originally we planned to use electric cable, but the cost of a new electrical service together with the cost of the electric cables caused us to look at other methods.

The other choices were copper pipe, iron pipe, or plastic pipe. Copper pipe and iron pipe are short-lived because of electrolysis when buried in the ground. Plastic pipe has been used in homes for hot and cold water, but when I contacted a heating engineer he said it was an insulator and he was not sure if it would be satisfactory for heat. However, it does not deteriorate under the ground like iron or copper pipe.

Once the decision was made to proceed with CPVC plastic pipe, the problem was sizing the pipe and boiler. The only charts available were snow-melting for iron and copper pipe, none for plastic.

The decision was made to use 1/2 inch plastic pipe on 6 inch centers. This pipe was buried half way in 8 inches of sand. The cast iron boiler was sized according to the amount of pipe installed; however, with the low temperature (140°F) of operation it was oversized.

The boiler (Figure 1) was installed mid-way in the house so each end could be controlled separately. A thermostatic control, with a capillary tube buried in the sand, gives positive temperature control at the rooting zone. Plastic pipe will not hold up at temperatures over 180°F so dual boiler controls, one overriding the other by 10°F were installed to prevent over heating. Heavy duty Bell and Gosset circulating pumps are run continuously to give even heating throughout the house. Antifreeze was put in the circulation system to protect from freezing in case of heat failure.

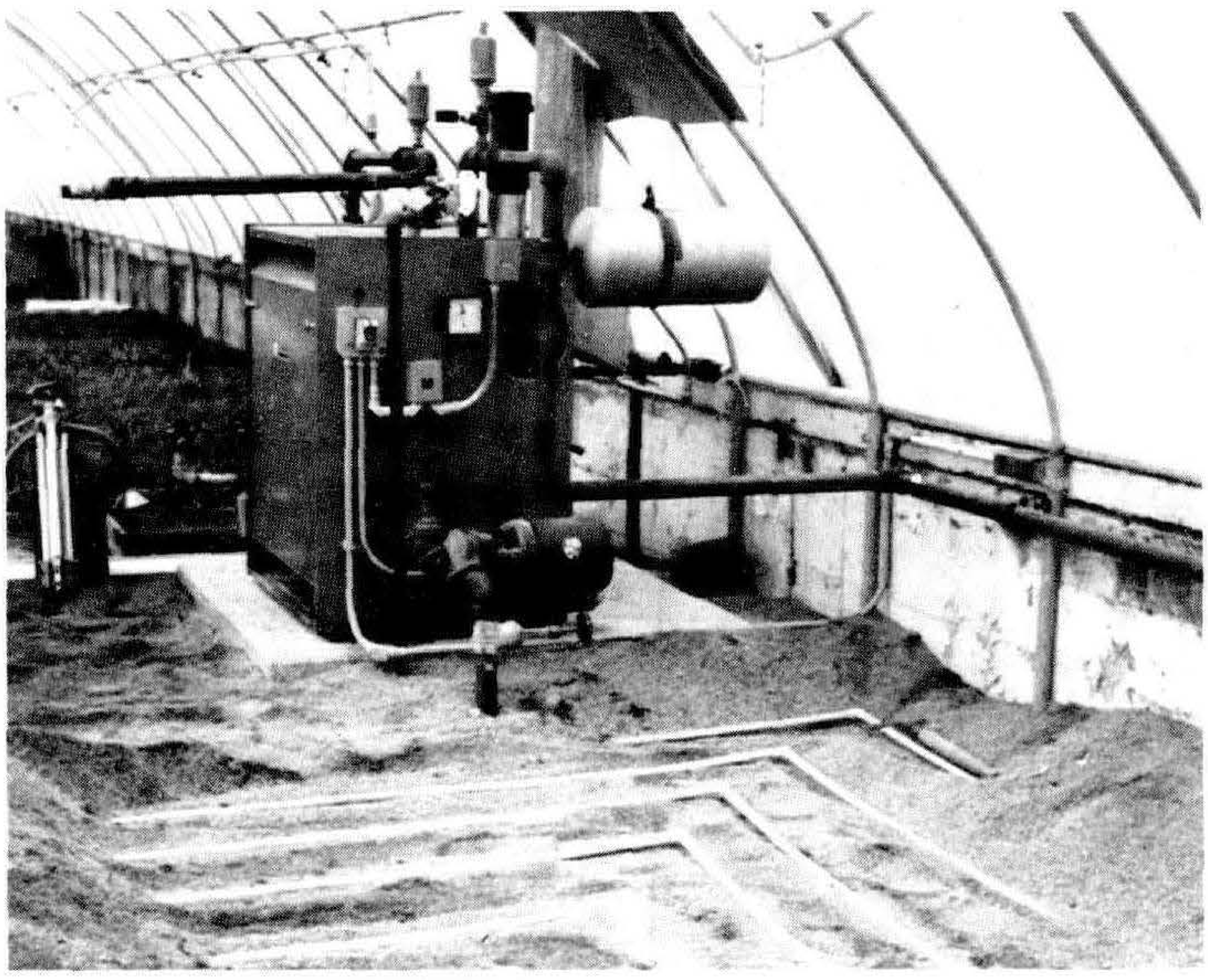

Figure 1. Boiler, circulating pump, and plastic pipe (exposed for picture).

For environmental control inside the house, a Windmaster Model DC241H fan, was installed with a motorized louver at the opposite end. Universal model 150FA heaters were hung at each end to be used in case of boiler failure or elimination of high humidity. The natural gas shortage necessitated installation of propane for this house. We have the necessary parts on hand to convert to natural gas. All other houses in the area have natural gas heaters.

Our propagator, Mr. Andy Brumbaugh, stuck 204,600 evergreen cuttings using a 5 sec dip of 50 grains NAA plus 50 ml isopropyl alcohol and 500 ml water. These cuttings were stuck in December and january. most were rooted within 60 days. the rooting temperature was held at 68° to 72°F and all but 100 or less rooted. (Figure 2).

Figure 2. Cuttings stuck in coarse sand in flats.

The buried pipe gave us good bottom heat with a cool top temperature. A high humidity was present until the hot days of spring. The poly was then painted with white latex paint to aid in cooling the house. During the early summer the cuttings were shaded with Saran shade cloth. It was removed in late July to harden off the cuttings prior to planting in field beds. A mist system has been installed for summer production and direct-seeded perennials make use of the bottom heat in early fall.

The house cost $2.41/sq. ft. to build. However, with an estimated life of 10 years or more, we feel the cost is reasonable. Electric cable could have been installed at 37 cents less per square foot, but at our electricity rate, cost of operation would have more than doubled. Propane for the operation of the boiler from November 27, 1972 to May 10, 1973 cost $747.00. This is a cost of 0.00364 cents per rooted cutting. If conditions change and we can switch to natural gas we expect to save an additional 40%.

Records show we have a direct cost of 0.00939 cents each to root cuttings. This includes all labor, heat, electricity, chemicals, and poly. We have not included overhead and invested capital in this cost.

We had excellent results the first year with this house, but to the best of my knowledge plastic pipe has not been tested and proven for heating. I would only recommend its use on a trial basis. Extreme care is necessary when cementing all couplings to prevent leaks. Air pressure testing, prior to filling with liquid, is advised.

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BRUCE BRIGGS: Have you had to go back and make any repairs to the plastic lines?

JIM KYLE: No; we took extreme care in assembling the lines and the temperature of the water is never heated over 140^{0}F. The lines are bedded in sand.

CHARLIE HESS: What rooting medium are you using?

JIM KYLE: Coarse sand.

LARRY CARVILLE: Are you using 4 mil, double wall, inflated poly?

JIM KYLE: No, it is a single layer of 6 mil. There is no reason to use double poly; we're concerned only with supplying bottom heat, it could freeze on top as far as I'm concerned.

PRESIDENT TUKEY: Our next speaker, Gied Stroombeek, is going to tell us about an inflated, controlled-temperature propagating structure.

CONTROLLED TEMPERATURE OVER-WINTERING PROGRAM

GIED STROOMBEEK

Roemer Nursery, Inc.
North Madison, Ohio 44058

When I was approached last May to give a short talk on the subject of a "Controlled Temperature Over-Wintering Program", it seemed like a perfectly good topic for the 1973 Propagators' meeting. Little did I realize at the time that we were heading for a full-fledged energy crises come winter.

Before I comment on how this crisis might affect the over-wintering program, I would like to describe it to you. The program concerns mainly vulnerable container-stock and this refers to: (A) broadleaf material that is somewhat tender, e.g. evergreen azaleas; (B) broadleaf and deciduous stock that is root-tender at low temperatures; e.g. Japanese and American holly, cotoneaster varieties and pyracantha.

This stock is pushed together tightly in Quonset structures during early November. The huts receive a thorough spray of 3 lbs. Captan plus 1 lb. Terraclor per 100 gal with a quality sticker like Vapor-guard or Nufilm added; this spray is applied just prior to covering. The huts are covered with two sheets of opaque copolymer 4-mil film 26 ft wide. The edges of the sheets are draped in shallow furrows dug alongside the huts with an angled snow blade behind a tractor. The tractor covers the furrows up again which secures the plastic one way. Next 1 x 2 inch wood strips are stapled onto the kickboards by means of an air powered staple gun.

Poly sheets are laced down with 3 inch strips of gusseted poly. The ends of the huts have dutch-doors; the top part folds down to allow for easy ventilation and quick closing when the weather turns cold or wind velocities increase rapidly. The huts remain ventilated as long as possible, usually on an on-and-off schedule up to Christmas and whenever the weather warms up during the winter. In the huts a small, shaded-pole blower (60 to 100 CFM, 3,000 RPM) mounted on a small piece of plywood is installed in such a fashion that it blows air constantly in between the two layers of poly, keeping them 2 to 3-1/2 inches apart. This provides the air space required for optimum insulation and the efficient use of heaters.

The heater we use is a fan-forced portable LP gas heater with a 150,000 BTU output capacity and 7 lbs/hr fuel consumption. This heater is hung on one end of the hut about 10 inches down from the top. We do not install a flue but line up the heater with a 5 inch "peep-hole" in the door. We leave this hole open during cold weather so that the heater fan can draw in fresh air. The peep-hole facilitates the daily check-up without having to wrestle with snow blocked doors to enter. For a number of years we have been controlling the heater with a plug-in type thermostat which we locate away from the rather narrow heat jet stream moving through the top section of the hut. Depending on the size of the plants the thermostat will be approximately 10 to 18 inches above the top of the plants.

The temperature is set at 31° F which is the minimum setting for this type of thermostat. Some cost figures: gas heater, $134.65; plug-in thermostat, $11.25; pole blower, $9.00 to $10.50.

Now an explanation of how this heater works during cold weather. When activated by the thermostat the powerful fan pushes out a narrow jet stream of hot air through the top section of the house. The penetration effect of this stream is excellent. We have used this type of heater mostly in 100 ft huts and then the opposite end of the hut has the highest temperature reading. However we are using the same heater in huts that are 160 and 180 ft long with no more than a 4° to 5° F drop on the opposite end. The significant point is that we are heating only the top air layer in the hut. There is very little mixing of this air with the air in the plant zone. All we are doing is providing the container-stock with a warm air blanket in the top of the hut. During cold snaps when outdoor temperatures at night drop to 10°F or much lower we will have frost at the plant level with 1 to 1-1/2 inches of frost crust forming in the cans; night temperatures will go down as low as 26° to 28°F. This is exactly what we want. We have no desire to baby and "tenderize" our container-stock. All we want to do is to prevent a deep-freeze effect in our cans where the medium will freeze up to 2/3 of the way or sometimes even freeze solid.

Another advantage of zone heating is that there is practically no drying effect from the moderate amount of heating done. We usually turn sprinklers on, or hand water once in December and once more the end of February or early March prior to opening the dutch-doors permanently; this last watering is more to insure uniform moisture content during the hectic shipping season when we don't want to be bothered with having to do spot watering.

Back to the over-wintering huts: There seems to be enough air turbulence taking place to prevent any significant occurence of molds and fungi in the rather tightly packed houses. We maintain only a close watch and repeat our spray program on the evergreen azaleas.

The pole blowers and the heaters are not activated until truly cold weather sets in. At the 31° setting the heater will run from

2-1/2 to 3-1/2 hr over a 24 hr period with outdoor temperatures ranging from 5° to 20°F. At below zero readings maximum running time in a 100 ft hut will not exceed 4-1/2 hr.

LP gas tanks (1000 gal), which remain the property of the Gas Company, are installed for an installation fee. Each tank feeds five huts. Depending on the severity of the weather, tanks are refilled sometime during February before we go below 20% capacity; this is considered a safe minimum. If drawn too low contaminants, like sulfur, could be drawn into the house. This brings up the possibility of releasing other harmful combustion gasses into the huts since we do not install flues; we have never noticed any ill effects on the plants at the low temperature settings that we use in these huts, not even at the 45° to 55° F temperature that we maintain in some clear poly huts that we operate from late February through mid-April.

In those huts we store our early cannings. I am talking about 20-30,000 cans of cotoneaster cultivars and items like euonymus that we pot when the weather moderates at the end of February or March; this will keep our steady crew busy until the shipping season begins. With the help of this LP forced-air heater we can utilize these houses as forcing houses and obtain an extra bonus of spring growth by the time the poly comes off in mid-May.

Another important application is the storage of large numbers of peat-potted transplants placed in wire flats and overwintered under clear poly at 38 to 40° F. These are forced in March and April by gradually boosting the temperature to 40° to 55° F. Another advantage is that except during very cold weather we can send our men into these huts, turn the thermostat up to 45° F and have them do grading, labeling, trimming and fertilizing.

After the first week of March we turn the heaters off regardless of the weather and leave the dutch-doors open around the clock; by then the roots will have become active and the broadleaf stock has a true "life" appearance in contrast with similar unheated stock that, in our area, often is frost-bound until March 20. We can start shipping immediately to our customers who are a couple hundred miles south of us without having to wait for the cans to thaw out.

I would like to emphasize again that by turning the "heat-faucet" off, so to speak, and ventilating drastically in March, this stock will not be more than 5 to 10 days advanced over conventionally stored container-stock.

Now for the cost factors which are so important in justifying this method of over-wintering and, as mentioned before, what effect the developing energy-crunch might have on its feasibility.

In the past 3 years it cost us 3 to 4-1/2 cents more to over-winter a 2-gallon can in controlled temperature storage as compared to conventional storage. The variation being the amount of heating required under the different winter conditions. None of those winters could be considered truly severe. This cost figure will vary in each of the several nurseries in northern Ohio which have adopted this method since all of them use different temperature settings.

With the energy crisis entering the picture this storage method becomes a new ball game. But first let me say that horticulture in general, and propagation and container production in particular, are becoming a different ball game. Purchasing propane gas for our program is actually in the same category as securing fuel for greenhouses and for trucking next spring, or obtaining plastic cans and fertilizers for next season or poly sheets for covering ones' huts next fall.

We were fortunate enough to get our propane tanks filled last month by paying 40% more than last February. We are going to try to keep the controlled temperature storage going as long as possible by rolling with the punches. We are replacing most of the plug-in thermostats with ones that we can turn down much lower and then experiment with settings as low as 27° F. Also we will use the manual switches to keep the heaters turned off during the daytime and during minor cold spells. If we can reduce our propane consumption to just one fill-up per tank during the slack summer season, and if the price does not go beyond 50 cents per gallon, we might be able to keep this way of storage going. If the consequences of the energy crisis turn out to be more drastic than we can anticipate from here, then all bets will be off for this type of program as well as for a number of other growing methods established in our industry during the last 20 years.

PETE VERMEULEN: I was puzzled by your statement of having frost at the ground level, with the forced air coming in. Do you get no mixing for the entire length of the house?

GIED STROOMBEEK: There is a distinct difference between the temperature zones through the whole house. There is no or very little mixing of the zones; we have checked this out with thermometers set at various levels.

PRESIDENT TUKEY: Our next speaker is Francis Gouin from the University of Maryland; he is going to tell us about winter protection of container plants.

WINTER PROTECTION OF CONTAINER PLANTS[1]

FRANCIS R. GOUIN
Department of Horticulture
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Over the years nurserymen have used numerous methods for overwintering container-grown woody ornamental plants. In areas where snow is plentiful and early, ornamentals are over-wintered by laying the plants on their sides before the first snow-fall. Where winters vary from moderate to severe and where early winter snows are unpredictable, nurserymen have had to adopt other methods of winter protection. Deep cold-frames have been used by a limited number of growers with a high degree of success. A modified version of the deep cold-frame being used by some growers is a wide open trench, dug 18 to 24 inches deep in a well drained soil on a gentle slope facing north. The plants are packed tightly in the trench and mulched with sawdust, shavings, ground-bark, or wood chips.

Few growers have had 100% success over-wintering plants by packing them together on level ground and covering the containers with mulch. Peripheral containers generally become uncovered before and during the most severe parts of winter.

To overcome the high labor cost of mulching, many growers have constructed unheated plastic greenhouses covered with clear, white or aluminized polyethylene. In late fall the plants are packed container to container or stacked on the floors of these houses and watered thoroughly. The houses are generally kept tightly closed during the winter except for prolonged periods of high temperatures. Growers who have continued to experience repeated failures in over-wintering certain species have solved their problem by mulching the plants within these shelters, have installed heaters to maintain temperatures above freezing, or have discontinued container production. With our growing energy crisis, it is doubtful if fuels will be available for this purpose.

In areas where winters are not severe, some growers over-winter container plants by laying the plants on their sides and covering them with white or aluminized polyethylene, shade cloth, burlap or straw.

The winter survival of container-grown ornamental plants is dependent on many factors: root hardiness, soil moisture, wind, minimum temperatures, and fluctuating temperatures. The mulching of containers protects the roots from minimum and

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[1] Miscellaneous Publ No 848 Contribution No 4892 of the Maryland Agricultural Experiment Station, Department of Horticulture

rapidly fluctuating temperatures while frequent irrigations insure the roots adequate moisture and increases soil temperatures. Deep-shaded cold-frames protect both the tops and roots of the plants from minimum temperatures, minimize fluctuating temperatures, protect plants from drying winds and sun, and reduces water losses from evaporation or transpiration. Unheated plastic greenhouses protect the plants from rapid fluctuating temperatures, drying winds and sun, and excessive loss of moisture. Unheated greenhouses, however, do not protect plants from cold damage if subfreezing ambient temperatures occur (1). Laying the plants on their sides reduces the amount of foliage and stems exposed to wind and sun, resulting in less water lost by evaporation and transpiration; while the covering of the containers and plants with tinted polyethylene, shade cloth, burlap, straw or snow further reduce water losses, and minimizes temperature fluctuations.

The winter survival of container-grown ornamentals has generally been evaluated by the appearance of the plants in the spring. If evergreens still retain their green leaves and if deciduous trees and shrubs sprout new shoots, the plants are considered to have survived the winter without injury and the overwintering system is considered adequate. However, just because the top of the plant is alive does not mean that the plant has survived the winter months without injury. Roots of *Ilex crenata* along the outer edge of the root-ball are killed by temperatures of 20° F/ (1, 2). It has also been observed (4) that tissues of *Taxus cuspidata* roots near the base of the rooted cutting are more cold hardy than are primary tissues near the root tip. The heavy loss of roots along the periphery of the root-ball, then, would not necessarily result in death but could delay and reduce spring growth. It is this type of winter injury the nurserymen may not be aware of.

Nurserymen growing plants in containers should be aware of a short but important list of root-killing temperatures compiled by Havis (2). Depending on species, root-killing temperatures vary from 23° to 0°F. Because of the wide range among species in root killing temperatures, nurserymen should segregate the plants with high root killing temperatures that require maximum root protection from those plants that will tolerate root temperatures of near 0°F. Plants with the hardier roots require minimum winter protecting methods.

It is possible to provide maximum winter protection with minimal labor and without having to build over-wintering structures by covering the plants with Microfoam and polyethylene. This method has been tested successfully during the winters of 1971-72, and 1972-73 in Maryland.

The Microfoam[2] currently being recommended is 25GPS-1/4". It is 1/4" thick and comes in rolls 225 ft long and 4 ft wide. It is mildew and fungus resistant and remains flexible over a temperature range of -320° to 250°F. Its important nursery properties are: Thermal insulator with a coefficient thermal conductivity of 0.27 BTU/hr/ft^2/°F/inch, and its low bulk weight of 0.7 lbs. per cubic foot; the 25 GPS-1/4" permits 50% light transmittance. It can easily be spliced together with pressure tape to make wider blankets. If Microfoam is handled with care and stored in the dark when not in use, it should last 3 years or more.

The procedure currently being recommended to Maryland nurserymen over-wintering plants under Microfoam are:

1. Do not begin covering plants until minimum temperatures lasting several hours approach root killing temperatures. In central Maryland this is sometime around Thanksgiving.
2. Twenty-four hours before covering, irrigate the plants thoroughly.
3. In a well drained area lay the plants on their sides with the foliage laying over the pots. Pack the plants as closely as possible to conserve space.
4. Cover the plants with a single layer of Microfoam making certain that the edges touch the ground on all sides.
5. Cover the Microfoam with a single layer of clear polyethelene and seal the edges to the ground with soil.
6. In Maryland, plants are generally uncovered between March 1 to 15 depending on minimum temperatures.
7. If mice or other rodents are a problem, scatter a few mothballs around the plants before covering.

Air temperatures measured beneath the blanket on February 12, 1973 averaged 30°fi when the ambient air temperatures was 3°F. Temperature differentials were similar in 1972 studies. Root examinations immediately after uncovering and again one month later revealed that the plants had not suffered root loss. The following species have now been tested and are recommended for this method of over-wintering: *Ilex crenata*, *I. opaca*, *I.* x 'Foster No. 2', *I. cornuta*, *Buxus sempervirens*, *Prunus laurocerasus*, *Pieris japonica*, and *Pyracantha coccinea* 'Lalandei'. At present, the only plants not recommended are the evergreen azaleas. Azaleas over-wintered under Microfoam were serverely defoliated

[2] Supplied by the E I DuPont De Numours & Co (Inc) Film Department, Wilmington, Del 19898

by *Botrytis*. It may be possible to overcome this problem with a systemic fungicide.

The difference in growth at the end of the second growing season between a plant over-wintered under Microfoam and one over-wintered in an unheated plastic shelter is shown in Figure 1.

Figure 1. Two-year-old *Buxus sempervirens* plants in 8" containers with identical growing medium, fertilizer and irrigation in 1972 and 1973, but: Left — over-wintered under 25GPS-1/4" Microfoam and 4 mil poly; and, Right — over-wintered in an unheated plastic-covered shelter.

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JOHN ROLLER: What is the cost of that material?

FRANCIS GOUIN: Right now it's 2-1/2 to 3 cents/ft. I have some material that is 3 yrs old that was rolled up and stored in the dark after each use. It does have to be handled carefully or it will tear.

DON EMBREE: Do you find any difference if the foliage is laid under rather than over the container.

FRANCIS GOUIN: Yes, if it is laid under the container we get foliage rot; if it is laid over, the plants come out in excellent condition.

PRESIDENT TUKEY: Thanks to all our speakers for an excellent morning's program.

WEDNESDAY AFTERNOON SESSION
December 5, 1973

The afternoon session convened at 1:35 p.m. in the Saddlebrook-Washington Rooms. Mr. Ralph Shugert served as moderator.

SEEDLING PROPAGATION SYMPOSIUM

RALPH SHUGERT

Spring Hill Nurseries
Tipp City, Ohio 45366

We are fortunate to have five members who will share their expertise with us in the vast and complex field of seedling propagation. To illustrate the point, in Vol. 20 of the Proceedings, G.B.&I. member McMillan-Browse said, "Little information has been forthcoming on the propagation of viburnums from seed and all that comes to light from surveying the literature is confusion!" I can well appreciate his statement because all of us who have attempted sexual propagation of various species will understand the "confusion". In reviewing the literature for a background of a Seedling Propagation Symposium, there is data available in virtually all of the 21 volumes of our Proceedings. As I mentioned to the Manitoba nurserymen on Thanksgiving of this year, we must read all available data — and then learn from practical experiences.

For the information of our new members and guests, I hold the office of Historian on the I.P.P.S. Board, and in my files I have the Proceedings of the National Association of Propagating Nurserymen for their June 23, 1926 meeting held in Louisville, Kentucky.

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P.W. Zimmerman from the Boyce Thompson Institute presented a paper on seeds and seed germination in which he carefully summarized seed development and structure. The purpose of mentioning this is a comment he made regarding the term "after-ripening". Quoting, "We do not know what all goes on within the seed during this period, but strangely enough it takes place at a fairly low temperature". His paper also commented on seed source and the amount of worthless seed planted every year by nurserymen. That paper was presented over 47 years ago to an assembly of plant propagation-oriented nurserymen attempting to find answers to age-old problems. Today, do we really know and understand any more about after-ripening than our predecessors did in 1926?

The challenges of seed propagation shall perhaps always be with us, but we have all learned much just within the past decade. The major portion of this knowledge has been generated by the marvelous word, "SHARING"!

If I wished to learn the proper technique for germinating *Fraxinus nigra* seed, I would turn to our member Bill Cumming from the Morden Research Station in Manitoba and he would guide me step by step. The same would apply if I were puzzled with seedling propagation of *Helleborus nigra*, but turning to our member Case Hoogendoorn, again the guidance and counsel would be there for the asking. One could go on and on through the membership and the assistance is there for the asking! The creed of our beloved Society is "To Seek and To Share", and it is indeed a beautiful, meaningful motto. It is meaningful because it is practiced in today's nursery community.

I can well appreciate the thought undoubtedly going through some of your minds asking "what can I read to gain a background of knowledge until I attain practical experience"? The "Bible" of seedling propagation has been the USDA Woody-Plant Seed Manual. While the words of this publication have been fervently devoured by propagators, it was printed in June, 1948, and is now out of print. Work on the revision has been underway for several years and the updated publication is eagerly awaited by all interested in seedling propagation. This is a valuable reference without question, but the commercial seedling propagator needs more.

The next turning point would then be to the Proceedings of our Society, to carefully digest the words printed in regard to seedling propagation. We can, and should, profit from the experiences reported and the profit is truly two-fold. In a commercial endeavor, profitability is mandatory — we must show a profit — and the consistency of seed stands, season after season, will aid us in reaching this common goal. With some plant species this seems to be impossible, but we must keep trying to solve the problem on hand. Dennison Morey commented at the first meeting of the Western Region in this light by saying, "It is my belief that if there is any one general principle involved in plant propagation, it is this: significant progress will only be made when all possible knowledge is brought to bear in the most effective way. In connection with plant propagation, I am convinced that this objective can best be achieved by bringing all observations, regardless of how minor, into a common pool of knowledge." No one could make a stronger generality since we are all here really to help each other, and in so doing, to truly help ourselves more-so.

To our junior members, the challenges of seedling propagation can be vexing and frustrating, but at the same time, quite stimulating. I am a sentimentalist, and I say this unashamedly. There are very few things in this world that give me the comparable inner feeling of peace than watching seedlings growing in the spring of the year. It is a great and marvelous feeling, and I know that sensation has been appreciated by many in this room. It makes it all worthwhile because the birth of a plant heralds the spring. It is a tremendous feeling.

I suppose what I am trying to say to our newer members is that learning is achieved by reading, to obtain a background of knowledge, and then by application. Lastly, we have peers and mentors who patiently guide us in the proper direction. Peter Vermuelen used some words of free verse at one of our meetings that I have never forgotten:

"To weigh our fate, communicate;
Matriculate; participate;
Educate and elevate;
Create, collate and circulate;
Relate, debate, articulate;
Perpetuate; illuminate;
Generate, not imitate;
Innovate, then instigate;
Stimulate and propagate;
Reiterate — communicate."

So with Pete's words, we emphasize the deep need of communication — at work, at home, at this meeting. It is so very vital if we are to be that uncommon man.

This afternoon we are all going to experience the sharing by benefitting from the sage words of five good friends of mine, and devoted I.P.P.S. members. It is our fervent wish that you also shall share with your questions at the conclusion of these papers. We have allowed 30 minutes for questions and sincerely request your participation. The first speaker of our symposium will be Al Fordham from the Arnold Arboretum and recipient of our 1971 Award of Merit, discussing "Seed Dormancy".

DORMANCY IN SEEDS OF TEMPERATE ZONE WOODY PLANTS

ALFRED J. FORDHAM
The Arnold Arboretum
Jamaica Plain, Massachusetts 02130

In nature's scheme of things many remarkable adaptations have evolved which prevent germination of seeds at times unfavorable to seedling survival. While many kinds of seeds germinate on being provided with conditions such as moisture, air and warmth, other seeds refuse to do so even when given these favorable conditions. Such seeds are not prepared to develop and are termed dormant. This word stems from the Latin word *dormio* which means to slumber or sleep. Until the inhibiting conditions of dormancy are overcome, the seed is prevented from development.

Dormancies, often irksome to propagators, are functional in design. They are safeguards which nature has furnished to insure continuance of the species. If these protections did not exist and germination occurred during a warm spell in autumn or winter, the seedlings would perish during subsequent cold. Dormancies which cause germination to be erratic and extended over long periods of time lead to a reserve of seeds which stand ready to germinate during years when the species might not be fruitful. Some dormancies are simple and readily explained, others are complex and more difficult to understand.

DORMANCY IN SEEDS OF SORBUS

Sorbus seeds are contained in fleshy pomes which occur in a wide variety of attractive colors and usually are small in size. Natural dispersal is dependent upon birds who are fond of its fruits. The pulp furnishes food to the birds who in turn carry the seeds about in their digestive tracts until eliminated in droppings and scattered about the countryside. In the northeast this takes place in September and October. Were the seeds to germinate at this time they would no doubt fail to survive the cold of winter.

Seeds of most *Sorbus* species are prevented from germination only by dormant embryos. In nature this barrier is overcome out-of-doors by seasonal cold and the seeds are prepared to germinate with the advent of spring. Following is a list of *Sorbus* seeds which were prepared for germination by a 3 month period of cold stratification at 40°F.

Sorbus arnoldiana	*S. prattii*
S. aucuparia	S. x pseudovertesensis
S. bakonyensis	*S. randiensis*
S. cashmiriana	*S. reflexipetala*

S. chamaemespilus
S. commixta
S. discolor
S. esserteauiana
S. folgneri
S. hupehensis
S. intermedia var. arranensis
S. pluripinnata
S. pohuashanensis
S. rehderiana
S. rufo-ferruginea
S. sargentiana 'Warleyensis'
S. scopulina
S. sibirica
S. subsimilis
S. tianshanica
S. wilsoniana
S. alnifolia (response variable – seeds from some trees are double-dormant)

DORMANCY BY CONFINEMENT

An example of dormancy by confinement is found in seeds of the fire pines. Cones of *Pinus attenuata* (knob-cone pine) remain on the trees unopened for indefinite periods. Opening to release the seeds takes place only after the tree dies or its cones have been exposed to heat from a fire. Seeds confined within are insulated by the structure of the cones and survive despite heat intense enough to kill the tree. In the arboretum at Wakehurst Place in Britain a tree of *P. attenuata* has fruited consistently year after year. One branch has clusters of unopened cones which can be counted back for 16 years. Still further back on heavier limbs, cones perhaps 40 or more years old are now partly imbedded in the branches and remain unopened. In 1909, W.C. Coker investigated cones of *P. attenuata* and found viable seeds present in 20 or 30 year old cones.

DORMANCY IN SHOOTS OF AESCULUS PARVIFLORA

At the Arnold Arboretum the natural dispersal of *Aesculus* (horsechestnut, buckeye) is carried out by squirrels. The seeds are removed from the trees and buried to a depth of about 1-1/2 to 2 inches. Seed germination of most species takes place during the warm days of spring after a dormant condition in the embryo has been overcome by cold.

Seeds of *Aesculus parviflora*, (bottlebrush buckeye) however, ripen about mid-October and germinate a few days after they have matured. In the process of germination the cotyledon petioles elongate and carry the rudimentary plant out through the seed coat. In a few weeks the ample food reserves present in the thick fleshy cotyledons are exhausted by the rapid development of a large thick root system. Meanwhile, the shoot has grown to a length of about one inch and has gone dormant. Squirrels bury the seeds to a depth whereby the small shoots remain below the surface of the soil and therefore seedlings which develop in late autumn are protected and survive the winter. Occasionally the shoots fail to go dormant and continue to develop. Seedlings which do this would be eliminated by natural selection for they would not be prepared to survive the winter.

DORMANCY IN UNCLEANED SEEDS

The fleshy pulp which surrounds the seeds of many plant species can contain substances which nullify the effectiveness of stratification. If the pulp is allowed to remain the cold period is ineffective and the seeds remain dormant.

To demonstrate this, 100 fruits of *Prunus americana* (American plum) were divided into two lots and treated as follows: The pulp was removed from lot #1 and the seeds were combined with a dampened stratifying medium consisting of half sand and half peatmoss. The 50 seeds in lot #2 were allowed to remain within the pulp. Both lots were placed in polyethylene plastic bags, bound at the mouths with rubber bands to make them vapor proof. They were then put side-by-side in a refrigerator set at 40^0F after 3 months of stratification, the seeds were sown. by this time, the pulp in lot #2 had deteriorated into a mushy mass which was washed away.

The seeds were sown in plastic trays and placed in a warm greenhouse. In 21 days a uniform stand of 49 seedlings had arisen from the 50 seeds in lot #1 while no germination had taken place in lot #2.

Secondary Dormancy. After 5 months elapsed and germination still had not occurred in lot #2, the seeds were recovered, combined with a stratifying medium, provided with three months of cold stratification similar to that described above for lot #1. However, this treatment which had been so successful previously no longer had the same effect. Three months after they were sown 28 seedlings had developed but 21 sound appearing seeds remained ungerminated. During the earlier unsuitable pretreatments, the seeds had acquired "secondary dormancy".

DORMANCY IN SEEDS OF SOME MYRICA SPECIES

Fruits of *Myrica cerifera* and *M. pensylvanica* consist of small globose nuts enclosed in waxy coatings. Germination is hindered by a dormant embyro plus the presence of the waxy coating. Dormancy in the embryo can be overcome by 3 months of cold stratification after the wax has been removed. If the wax is allowed to remain, the cold is ineffective. The fruits ripen in late September and dispersal is accomplished by birds who eat the fruits and spread the seeds about the countryside in their droppings. In nature the waxy coating is removed in the digestive system of the bird and overwintering overcomes the barrier in the embryo.

To demonstrate these two barriers, fruits of *M. cerifera* were divided into four lots and treated as follows:

Lot #1 - uncleaned seeds sown at once.

Lot #2 - uncleaned seeds placed in cold stratification for 3 months at 40°F.

Lot #3 - cleaned seeds sown at once.

Lot #4 - cleaned seeds placed in cold stratification for 3 months.

After 3 months of cold stratification lots #2 and #4 were sown. Lot #4 which had been both cleaned and stratified produced a uniform germination in 20 days. Lots #1, #2 and #3 which were started at the same time as lot #4 had only a small scattering of seedlings with some newly germinated.

Myrica gale (sweet gale) needs only a period of cold to be prepared for germination. Its seeds germinated well after 3 months of cold stratification at 40°F.

DOUBLE DORMANCY

Dormancies of this kind are caused by conditions such as impermeable seed coats plus dormant embryos. The endosperm can also be responsible. Owing to the length of time required for germination they are called 2 year seeds. In nature, after being shed in autumn, such seeds go through the first winter without benefit from the cold because water has not penetrated the seed coats. During the following summer the seed coats deteriorate and permit the entry of water. Consequently, during the second winter the cold requirement is satisfied. With the advent of suitable conditions in spring, the seed, thus prepared, can germinate. Some plants produce seed in a given seed crop which germinate each year over a period of years. Variation in structure causes some seed to require more seasonal cycles than others to overcome inhibitors. This again is a continuance adaptation. Should the flora of an area be destroyed, there would be dormant seeds remaining to germinate and furnish revegetation.

EPICOTYL DORMANCY

Seeds in this category are characterized by dormancy in the shoot buds. The shoot fails to develop even though germination has taken place and a root is present. If a period of cold is not furnished to condition the shoot bud the roots will continue to grow until the food reserve in the seed is expended. When this happens the partly developed seedling will die. Seeds with epicotyl dormancy are found in *Paeonia*, *Chionanthus* and many of the *Viburnums*. Seeds of *Viburnums* with shoot-bud dormancy which ripen in July and August would perhaps have enough time to produce roots before the onset of cold weather. If so the cold of winter would condition the shoot-buds and shoots would develop in spring. Those ripening late in the season, however, would be categorized as two-year seeds. Their roots would not develop until the following summer, shoot-bud dormancy would be overcome the second winter and the completed plant would grow during the next spring.

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MODERATOR SHUGERT: Thank you, Al; a great paper. Our next speaker is Harold Pellett from the University of Minnesota. Harold and I first met in Nebraska several years ago where we both enjoyed some interesting propagation challenges. Harold's paper covers the puzzle of "Seed Stratification".

SEED STRATIFICATION

HAROLD PELLETT

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The term stratification was coined as a description of the common means of handling seeds during the period in which their dormancy conditions were satisfied. This is the practice of alternately placing layers of seeds between layers of moist sand or peat or other suitable media. The term is used today to describe all methods of storing seeds in a moist condition such as mixing the seed with the medium or fall sowing directly in the seed bed. When we think of stratification we commonly think of cold stratification to satisfy some internal dormancy problem, but storage of seeds in a moist medium under warm temperatures is also quite helpful in overcoming some types of dormancy, so we should say warm or cold to preface the word stratification depending on the conditions desired. A warm stratification period preceding a cold stratification is very helpful with some seeds time to produce roots before the onset of cold weather. If so the cold of winter would condition the shoot-buds and shoots would develop in spring. Those ripening late in the season, however, would be categorized as two-year seeds. Their roots would not develop until the following summer, shoot-bud dormancy would be overcome the second winter and the completed plant would grow during the next spring.

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OPTIMUM CONDITIONS FOR STRATIFICATION

There are four environmental factors that are required to satisfy the after-ripening requirements of certain seeds. These are moisture, low temperature, adequate aeration and a certain amount of time. These are described in considerable detail in the 1960 proceedings by Kester (8). in general, 32° to 41°F is optimum for cold stratification for most materials (3, 20) and a diurnal temperature range of 68 to 86°F (20) is best for warm stratification. The exact moisture level does not seem to be critical (12, 20). The length of time required varies greatly from one plant to the next (20).

PURPOSE OF STRATIFICATION

Stratification is used in the broad sense to overcome some of the various dormancy conditions that were described in the previous paper by Fordham. Warm stratification is sometimes useful to speed up the physical breakdown of a hard seed coat or perhaps an exterior pericarp that delays water imbibition and gaseous exchange. The moist medium and warm temperatures are conducive to bacterial action that speeds the decay of the exterior covering or seedcoat. Cold stratification conditions are necessary for the seeds to undergo certain metabolic conditions that are necessary to overcome internal dormancy often referred to as after-ripening.

Cold stratification often results in a faster rate of germination as well as in a higher percent germination. Cold stratified seeds also frequently will germinate at lower temperatures than non-stratified seeds (1).

There have been several excellent papers given at previous IPPS meetings — by Kester in 1960 (8), Reisch in 1962 (15), and Allen in 1967 (1), covering the topic of stratification. I would also like to refer to two other papers. These are the review by Amen, "A Model of Seed Dormancy" (2), and the review by Wareing and Saunders, "Hormones and Dormancy" (22).

There has been considerable work by plant physiologists in an attempt to gain a better understanding of the processes involved during after-ripening of seeds. Since the endosperm and cotyledons of seeds store high quantities of foods in the form of fatty acids and other large molecules that don't readily release energy in simple metabolic processes, some of the earlier workers studied under the hypothesis that the after-ripening process resulted in an increase in enzymes necessary for the metabolism of these fatty materials and a subsequent metabolism of these substances to simple sugars and other more readily available sources of energy. Kao and Rowan (9) found an accumulation of citrate, pyruvate, hexose monophosphate, sucrose and high energy phosphate during cold stratification of *Pinus radiata*. However the concentration of fatty acids was not significantly reduced. The concentration of the enzymes, lipase and invertase did not increase during cold stratification.

Barton and Bray (4) found an increase in concentration of some of the free amino acids during cold stratification of apple and tree peony seeds. However exogenous application of these materials failed to stimulate germination of dormant seeds.

With the improvement of techniques for identifying and quantifying levels of endogenous growth regulators there has been considerable activity in studies of the role played by these substances in regulation of seed dormancy. These studies have been quite rewarding and have shown a definite involvement of plant hormones in the regulation of internal dormancy. In many of these studies, inhibitors were found to be involved in the control of dormancy. During the cold stratification process, levels of these inhibitors decline (6, 11, 16, 23). These inhibitors can be found in either the embryo (23), the seed coat (16) or both (6). In other studies, growth promoting substances were found to be lacking or in low concentrations in dormant seeds, and were found to increase during the stratification process (11, 16, 21). These substances are commonly identified as one of the gibberellins, but the cytokinins (6, 11, 22, 24) and ethylene (7, 22) have also been found to promote germination. Although these studies have implicated the involvement of inhibitors and promoters there doesn't seem to be a simple control of the germination process by one hormone. Often the maximum level of a growth promoter is reached in a much shorter period of cold stratification than results in maximum germination (21, 24) or the level of an inhibitor is at the lowest point before maximum germination occurs (6, 11) 18). There appears to be an intricate balance of these growth regulators necessary before germination can occur. Inhibitors have been shown to prevent or retard the synthesis of gibberellins (17, 19). Perhaps the best piece of literature available on the subject is that written by Khan (10). He proposes a scheme, supported by research results, that shows that gibberellins are necessary for germination to occur. However, germination can be stopped by presence of inhibitors. A third group of hormones, the cytokinins can overcome the effect or counterbalance the inhibitors and enable germination to progress, but only if gibberellins are present (Figure 1).

	GIBBERELLIN	CYTOKININ	INHIBITOR	GERMINATION OR DORMANCY
1	+	+	+	G
2	+	+	–	G
3	+	–	+	D
4	+	–	–	G
5	–	–	–	D
6	–	–	+	D
7	–	+	–	D
8	–	+	+	D

Figure 1. Scheme proposed by Khan (10) to show hormone conditions that regulate internal seed dormancy

Although Khan's work was mostly with lettuce and some of the grasses and small grain crops that have a less intricate dormancy problem, his scheme could very well explain some of the results obtained in studies with seeds of some of the woody plants. Paul, et al. (14) and Biswas, et al. (5) working with loblolly pine seed found no or very little GA-like substances after 0 to 28 days of cold stratification and a high inhibitor level during the same period. After 42 days of cold stratification the promoter concentration increased gradually while the inhibitor level fell to almost zero. Exogenous applications of either GA_3 (100 mg/l) or kinetin (10 mg/l) resulted in good germination after 21 days of cold stratification, but GA_3 applications to non-stratified seeds only slightly promoted germination and kinetin gave no response to non-stratified seed. Diaz and Martin (6) working with peach found similar results. They found a synergistic effect of gibberellin and benzyl adenine, a cytokinin, in promoting germination but only after some cold stratification (Figure 2). They also found a rapid reduction in inhibitor (ABA) during the first two weeks of stratification while maximum germination required 12 weeks of cold stratification (Figure 3). In comparing a cultivar requiring a long stratification period to one with a shorter requirement they found more of the inhibitor in the cultivar requiring the longer period of cold stratification.

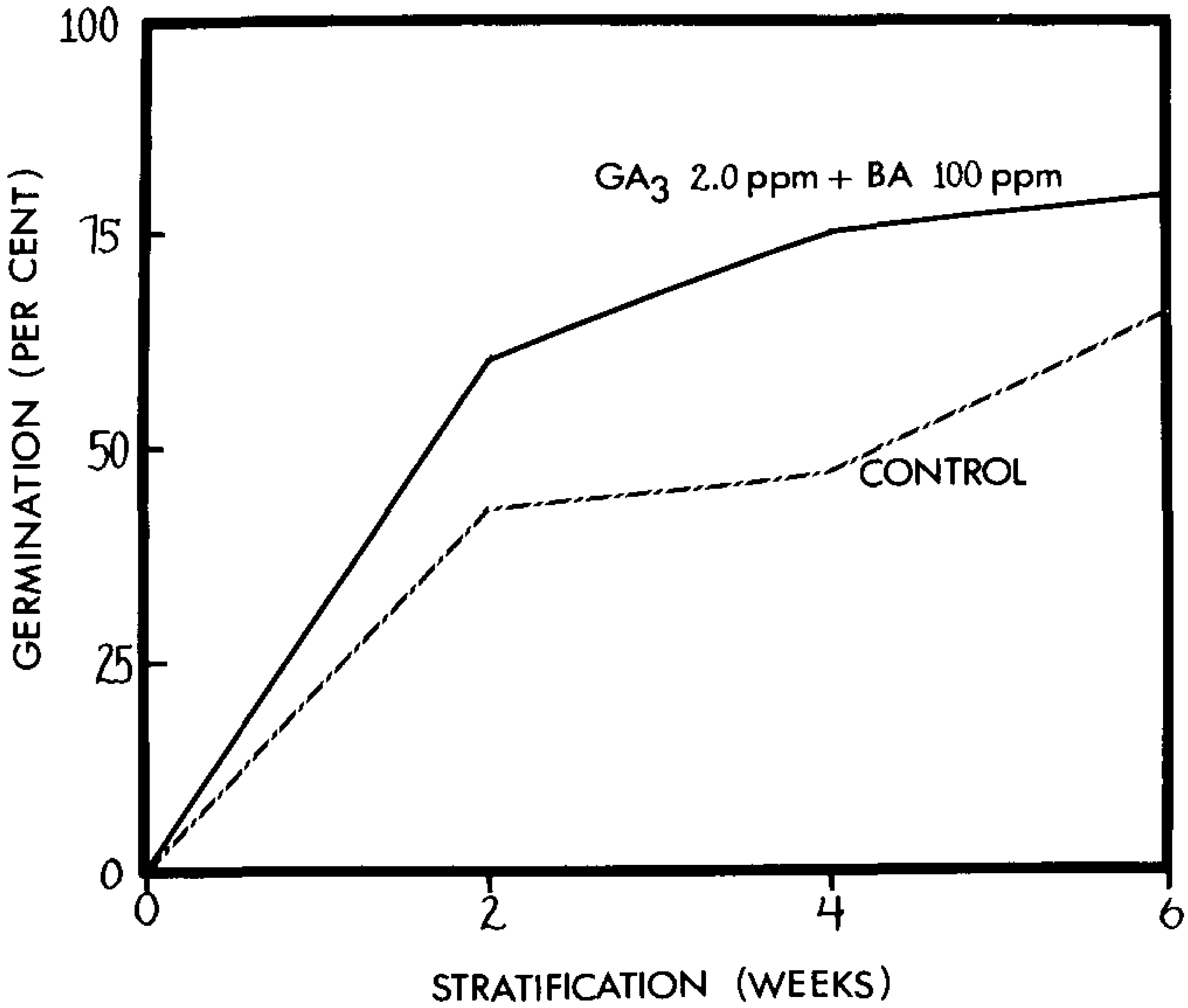

Figure 2. Effect of GA_3 and BA in stimulation of peach seed germination. From Diaz and Martin (6)

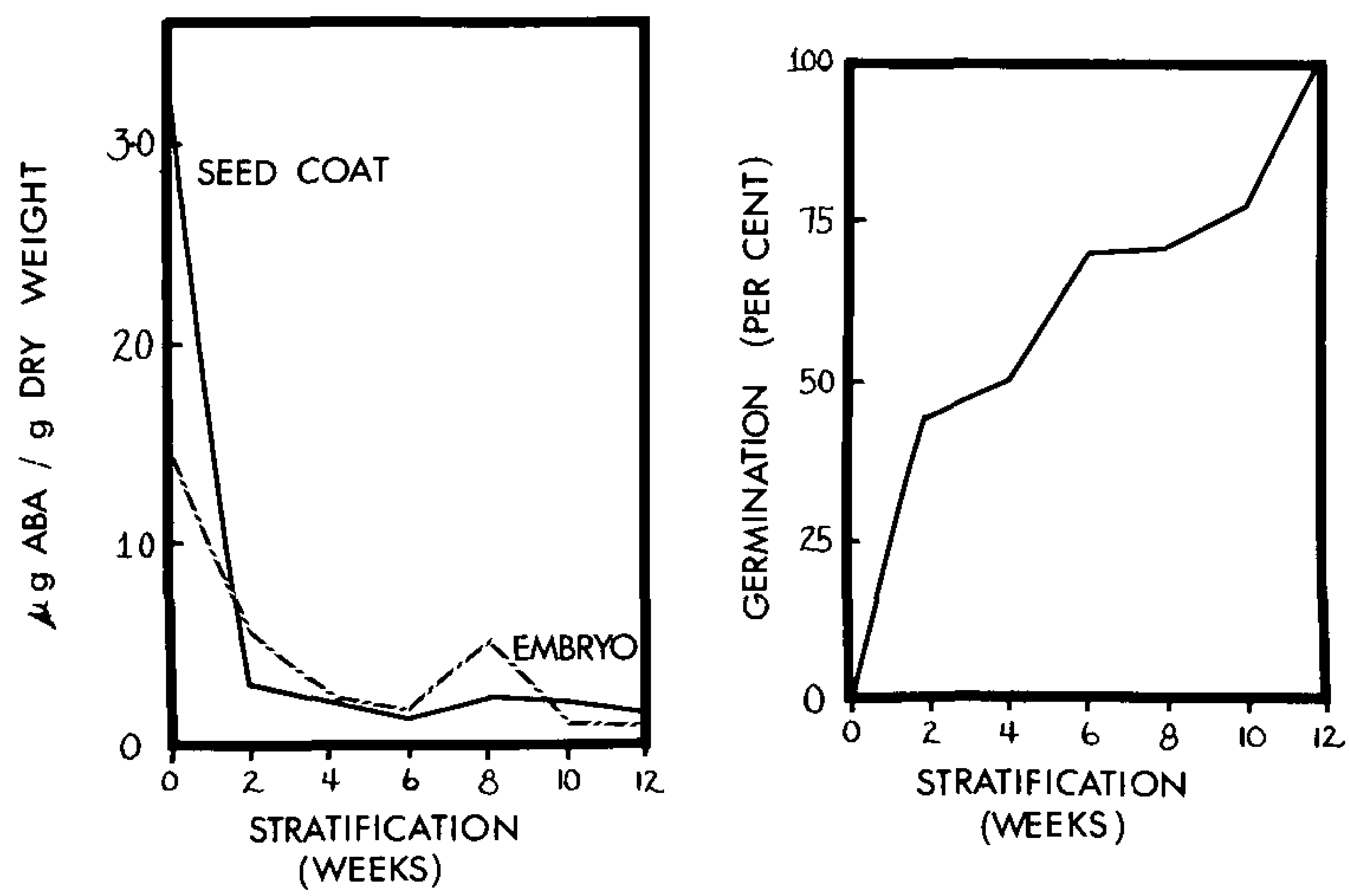

Figure 3. Inhibitor content and percent germination of peach seed after cold stratification of various time periods From Diaz and Martin (6)

Lin and Boe (11) working with plum seeds also found a rapid drop in inhibitor concentration (ABA) leveling off after 30 days of cold stratification, while a promoting substance (GA_3) continued to rise throughout a 90 day period (Figure 4). Application of GA and N_6BA (a cytokinin) resulted in germination of non-stratified seeds when the seed coat was removed but had no effect on whole seeds. An extract from non-stratified seeds reduced growth of the radical of stratified seeds (Figure 5).

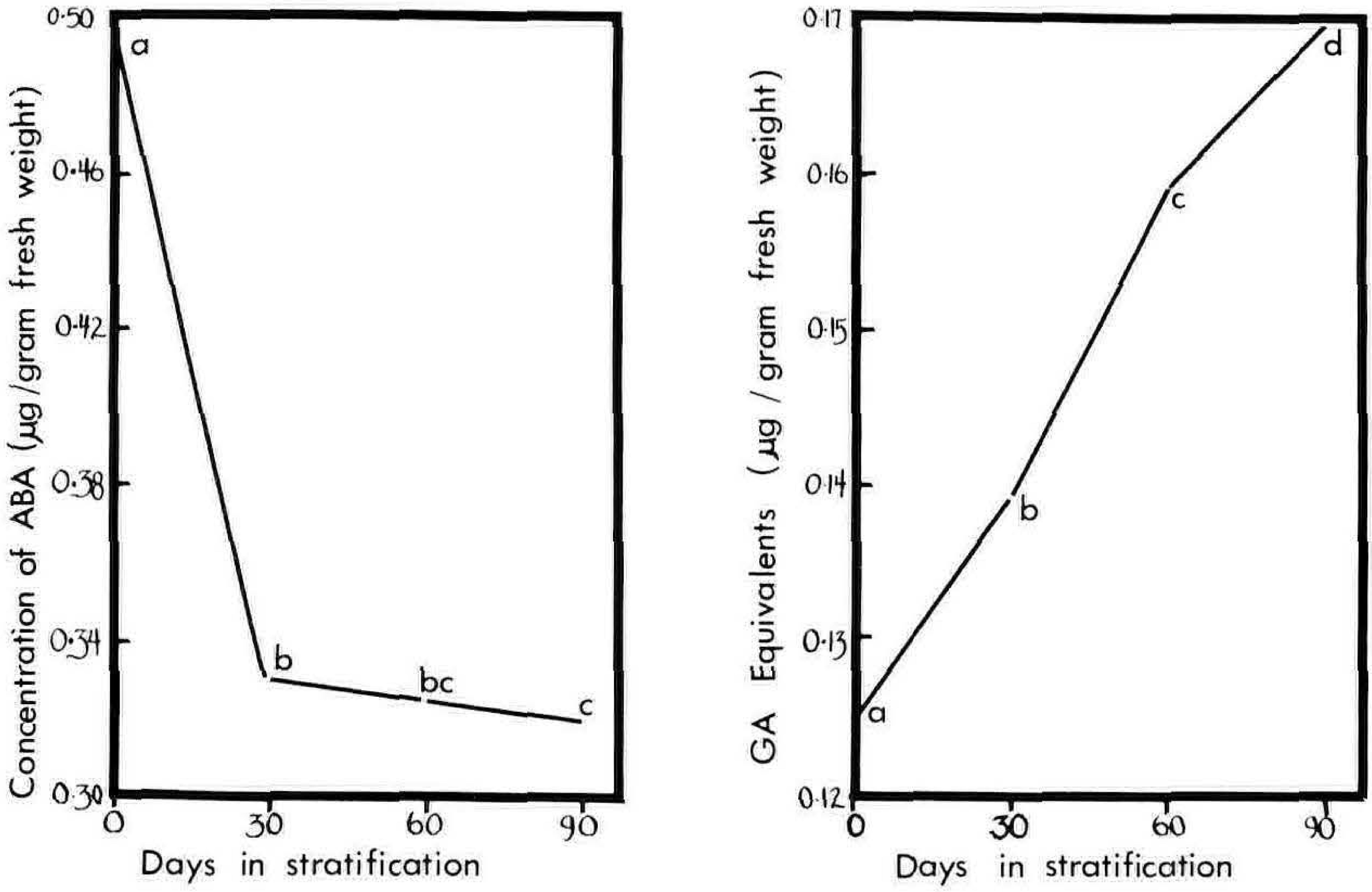

Figure 4. Concentration of inhibitor and promoter in plum seed after cold stratification of various time periods. From Lin and Boe (11).

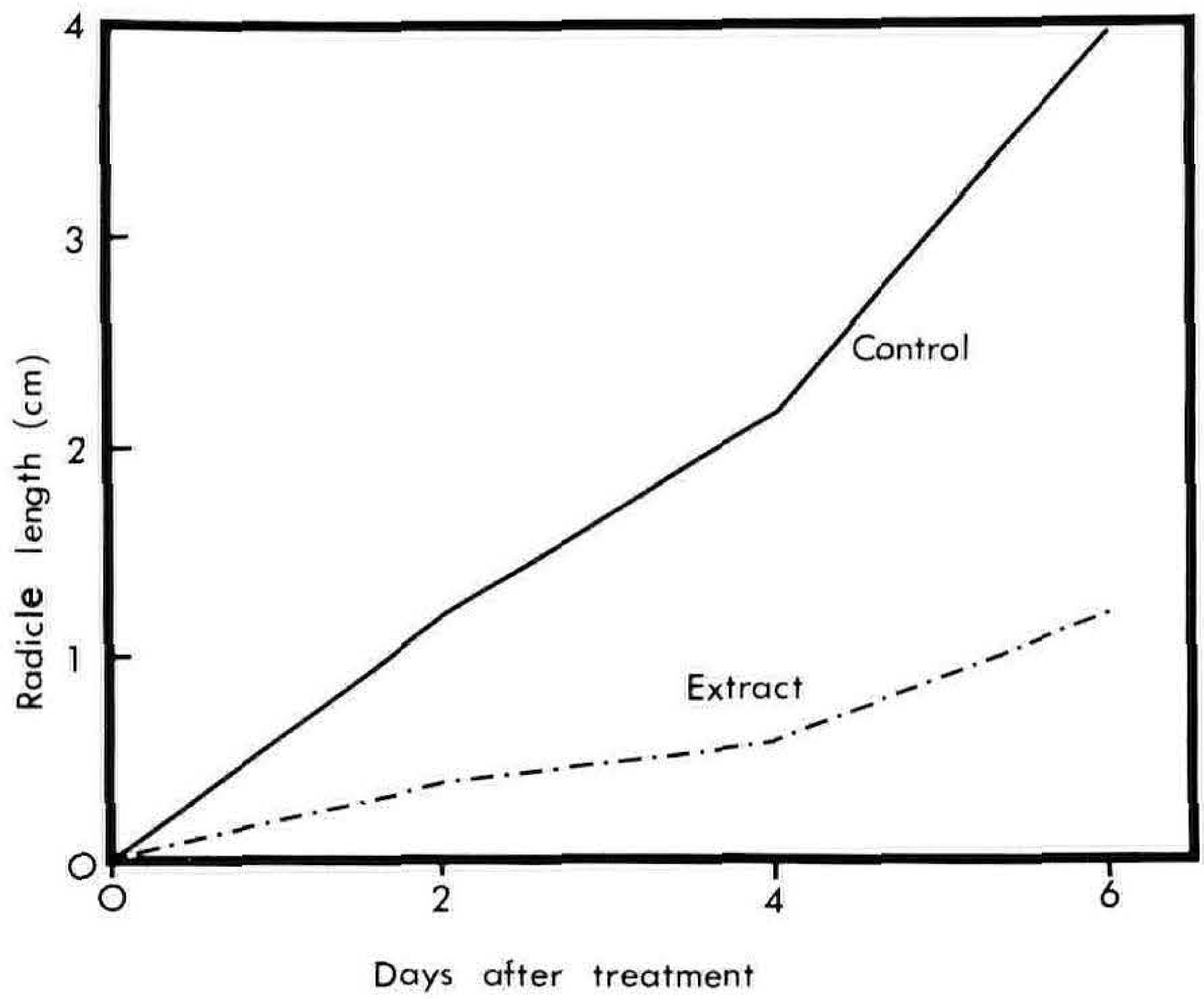

Figure 5. Effect of extract from non stratified plum seeds on growth of radical of germinating stratified seeds. From Lin and Boe (11).

Ross and Bradbeer (16) working with hazelnut (*Corylus*) found that the embryo in freshly harvested seed was not dormant but an inhibitor was present in the seed coat and pericarp. With dry storage, dormancy developed in the embryo. This dormancy could be attributed to the loss of promoter which occured during drying (Table 1).

Table 1. Levels of germination promoters (GA_3 equivalent) of *Corylus* seed collected fresh and after various dry storage and cold stratification treatments From Ross and Bradbeer (16)

	nmoles GA_3 Equivalent/seed	% germination at 20°C Naked Embryo	Intact Seed
Fresh seeds	87	77	16
28 days dry storage 2 days imbibed at 20°C	.02	12	3
28 days dry storage 28 days imbibed at 20°C	.01	12	3
28 days dry storage; 28 days stratification at 5°C	05	—	64
28 days dry storage; 28 days stratification at 5°C, 2 days at 20°C	94	—	64
28 days dry storage; 28 days stratification at 5°C; 7 days at 20°C	3 96	—	64

Concentration of promoter did not increase during cold storage, but increased rapidly (in 2 days) following removal from cold stratification. They found that a 28 day cold stratification or application of gibberellin could overcome the embryo dormancy that developed. Rudnicki (18) studying the inhibitor levels in apple seeds found that the ABA concentration dropped 20 and 40% respectively following 1 and 2 weeks of cold stratification. No ABA was found following 3 weeks of treatment. Exogenous applications of ABA inhibited germination of cold stratified seed, but greater concentrations of ABA were needed to inhibit germination as the length of stratification period increased (Table 2).

Table 2. Effect of applied ABA on germination of apple seed following cold stratification of various time intervals From data of Rudnicki (18).

ABA Applied ug/ml $^{-1}$	0	Days of Stratification 21	42	63	84
0.0	0	24.6	81.0	91.0	92.0
0.031	0	18.8	75.6	86.0	90.0
0.062	0	16.0	67.6	83.0	92.0
0.125	0	5.6	63.6	72.6	78.0
0.250	0	0.6	45.0	67.0	68.6
0.500	0	0	12.6	45.4	53.0
1.000	0	0	0.2	19.8	34.0
2.000	0	0	0	8.0	10.0
4.000	0	0	0	0	2.6

Webb, Wareing, and Van Staden (21, 24) found that 20, 40, and 50 days of cold stratification resulted in 15, 38 and 65% germination, respectively, of *Acer saccharum* seed. The greatest concentration of cytokinin was found after 20 days of stratification (Table 3), and the highest concentration of GA_3 was found after 40 days.

Table 3. Concentrations of cytokinin, gibberellins, and inhibitor in *Acer saccharum* seed following different time intervals of cold stratification From data of Webb, Van Staden and Wareing (24)

Stratification Days	ug/g Kinetin Equivalent 5°C	20°C	ng/g GA_3 Equivalent 5°C	20°C	ug/g ABA Equivalent 5°C	20°C
0	10	.10	2 0	2.0	826	826
20	5 92	1 19	23 0	21.0	—	—
40	1 18	70	37 3	12 3	—	—
50	99	57	4 0	27 6	018	373

In studies with *Acer pseudoplatanus*, Webb and Wareing (23) found that seeds with testa intact required cold stratification whereas bare embryos germinated immediately. The seed coats don't contain inhibitors but prevent leaching of inhibitors from the embryo. Kinetin at 1 mg/1 stimulated germination of intact seeds while GA_3 at concentrations of from 1 to 1000 mg/l had no effect. This again would fit the scheme proposed by Khan (10).

Thus, although naturally occurring plant hormones have been shown to play an important role in the regulation of the after ripening requirement of many seeds, it is quite apparent that an intricate balance of several hormones are involved in the control mechanism and that these conditions vary depending on the seed in question. Although there have been some positive results in use of the hormones, GA_3 and kinetin, as well as other chemicals such as potassium nitrate and thiourea to stimulate germination of some seeds, these chemicals have been only of limited effectiveness and will not give universal results as a substitute for the time-consuming and often cumbersome process of stratification. Looking on the bright side, there have been tremendous gains made in the knowledge of the role played by the plant hormones during the last 3 or 4 years. As our techniques improve and we learn more about the balances involved, I feel there is high hopes that in the not too distant future we will be able to apply a mixture of growth regulating chemicals to our troublesome seeds to achieve more consistent germination results.

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MODERATOR SHUGERT: Well done, Harold, our deep thanks. Tom Pinney, Jr. is next on the program speaking on "Seedbed Management".

SEEDBED MANAGEMENT

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Since the previous two speakers have discussed seed dormancy and stratification, this paper will assume that properly selected quality seed is on hand ready to plant. Furthermore, seed dormancy has either been overcome by stratification or will be in the field. This paper will deal with the system we use in seedbed management.

PREPARATION OF LAND

We use corn as a green manure crop prior to planting. Soil fertility tests are used to determine the necessary fertilizer to insure a good crop. The corn is planted with a grain drill at the rate of 1-1/2 to 2 bu/A. Because of our short season at Sturgeon Bay, we are only able to plow down one crop during a summer. By mid- to late-August the corn is plowed under and 50 lbs of actual nitrogen per acre is applied to hasten breakdown.

In order to obtain maximum benefit from fumigation, it is necessary to keep good soil moisture for several weeks prior to fumigating. This allows weed seeds to germinate or at least soften up to the point where they are much more susceptible to the fumigant. When the corn is sufficiently decomposed in mid- to late-September, we prepare the beds for fumigation. Fumigation must be done when the soil temperature is above 50°F. We use a jelled fumigant consisting of 70% methyl bromide, 28.75% ethylene dibromide and 1.25% inert ingredients (Ferguson Fumigants, Inc., 93 Ford Lane, Hazelwood, Missouri 63042). This material is comparatively safe to handle. We also purchased cannister openers and a metering device and then constructed our own three point hitch machine. The machine places the jelled gas approximately 6 inches in the ground, seals the surface with a roller, covers the bed with polyethylene and finally seals the edge of the polyethylene with dirt. We fumigate only the beds, leaving the aisles untreated. The polyethylene remains on for a minimum of 72 hours. Usually we remove it about a week prior to seeding in order to insure good aeration. Care must be taken in removing the polyethylene to insure that the unfumigated soil used to cover the edge of the polyethylene does not contaminate the bed area.

SEEDING

Each seed lot we purchase or pick is assigned a lot number. This remains with it throughout its life in the seedbed and transplant beds. As much detailed information as is available concerning each lot is recorded. Prior to seeding, germination tests are run on the evergreen seeds. Because it is difficult to run germination tests on deciduous seed in our system, we must rely upon the information furnished us from the collector. Many times this is not available because it is picked and sown almost immediately. We, therefore, must use past experience. A detailed schedule is developed which indicates what lot numbers are to be planted, the amount to be planted, the density at which it is to be sown, the total estimated bed footage required and seed coating to be used. As previously reported to this Society, we pellet almost all our evergreen seeds with methocel 4% sticker and thiram or captan fungicide. Recently we have begun to coat all of the smaller deciduous seeds with captan for visual ease in the seeding operation. We separate the seed into three groups; evergreens which are all held for 2 years, deciduous items held for 1 year and deciduous items held for 2 years. They are seeded according to these groups. This enables us to harvest blocks at a time.

We usually seed twice a year, planting our deciduous items in the fall and the evergreens in late spring or early summer. The seeding crew consists of two seeders, (one on each side of the bed) two counters, one recorder and one seed preparer and record keeper. The seed preparer and record keeper is the same person responsible for seed inventory, storage and the testing program. This person sees that the correct lots are fed to the seeders, the stakes identifying each lot are in place and draws a map showing the nursery, block, pipeline and bed footage of each lot. The recorder has a prepared schedule showing the lot numbers in sequence and the density at which they are to be sown. The recorder gives this information to the seeders for each new lot. They then proceed to seed by hand, one on each side of the bed. Immediately behind them, two to three people begin counting square foot sections of the seeded bed. The counting racks are divided into six sections for ease of counting. The counters sound off the density rate after each of their counts. This is heard by the seeders who adjust accordingly. The recorder writes down the amount of each count. This is totalled and averaged in the office after all of the seeding is done. This then becomes the actual seeded density count and is compared each year to our later field inventory density count.

Evergreen seeds are covered with beach sand and deciduous seeds with sawdust to a depth of 1/2 inch. We use a machine with a roller to apply the sand and a commercial flail type manure spreader to apply the sawdust. The sawdust is properly fortified according to fertility tests. This operation usually involves a crew of two people.

Shading racks 8 ft long are then laid directly on top of the sand or sawdust. In the case of deciduous items planted in the fall, these will remain on over-winter to prevent blowing of the sawdust and removed early in the spring as soon as our irrigation system is in operation. In the case of evergreen seedlings which are planted in late spring or early summer after the seeding is finished, we immediately begin to go through the area removing a row of shadings one at a time. Then a stake and wire system is installed and the shading replaced on the bed. The shadings are approximately 9 inches above the bed. We begin immediately to apply water and fertilizer through semi-permanent 2-inch aluminum laterals which are on 45-foot centers. Six beds are located between two laterals and the nozzles are 30 ft apart along the lateral, using Rainbird No. 20 heads with 1/8 inch orifices. Adjustable sprinklers are used on the ends to cut the coverage from 360^0 to 180^0. As the seeds are germinating, water and fertilizer are applied two or three times a day depending on the environment. The object is to keep the sand or sawdust just moist with good water and fertility relations in the sandy soil below. One person is completely responsible for all of the watering and fertility practices for the seed beds from this point on. The shade racks remain on the evergreens for the first summer and are then removed to properly harden off the plants for winter.

FERTILITY PROGRAM

As previously mentioned, the soil is brought up to a high fertility level prior to planting corn. We are especially concerned with phosphorus since it is expensive to add through our injection system. Once the seed is planted, all of our fertility program is done through our Milton Roy BIF Injector, designed by Soil & Plant Laboratory of Santa Clara, California. As the plants begin to germinate, we start out with a relatively low fertility program and gradually increase the levels of nitrogen and potassium during the summer. Since our soil is very sandy, we have little danger in developing too high a Solubridge reading for our conditions. Our normal schedule calls for two to three 1-1/4 hr injections per week. Built into our system are many fine safety features and we have as yet to have any burning in the field from malfunction. We use ammonium nitrate and ammonium sulfate as our nitrogen source and potassium chloride as our potassium source. We have just added a trace element injector to the system.

In our area the nitrifying bacteria seem to be very slow in returning to the fumigated soil. We, therefore, find it necessary to use ammonium nitrate early in the season and gradually shift to half ammonium nitrate and half ammonium sulfate. Under our conditions, we need the additional sulfur. The fertilization program is stopped at the end of August. In late October or early November we will give a late fertilization to any seedlings which are going to remain in the field over winter.

HERBICIDE CONTROL

We have been working with herbicides at our nursery since 1951 and still find we have a great deal to learn. The seed beds present a most difficult problem. The small, germinating, tender seedling is very much like the undesirable germinating weed. As has been reported many times, it is important to have the first set of true leaves on deciduous seedlings before using most herbicide materials.

We still find it the safest on evergreens to wait for the first herbicide application after the shadings are removed and they are hardened off for several days. We rely primarily on dacthal, propazine and diuron as our herbicides. We apply rates as low as 1/10 lb/A of active material of propazine and diuron. This has been highly effective in increasing the quality of control that dacthal will normally give. We use primarily paraquat to control weeds in the aisles and pipeline areas. The nozzles for spraying this material in the aisle are guarded so as to prevent drift into the beds.

PESTICIDE

We use a preventative program on all seedbed areas. The only evergreen seedlings that require pesticide application are the pines. Two applications of 2 lbs/100 gal of water of Sevin 50% wettable powder plus spreader-sticker gives complete control of the pine shoot moth. The deciduous seedlings are sprayed every 10 days from mid-June through mid-August with Sevin, maneb, captan, Metasystox R and a spreader-sticker. A most important point is to use whatever combinations of insecticide and fungicide are needed to control the pests in the nursery.

VISUAL AND ACTUAL FIELD INVENTORY

In late June a visual inventory is recorded to give the sales personnel a rough idea of what is available for sale that fall or the following spring. In August a detailed inventory is taken. At this time density counts are made with the same one square foot racks used at seeding time. The counts are again recorded for each lot number and average density for each lot is then established. The square footage is available from the maps, thus a total count is established. This total count is then discounted to allow for unsalable plants. The remaining salable plants are then divided into size categories and recorded in the permanent inventory. The office then records all incoming orders and keeps a running total of the availability of each variety and size.

been a mentor of mine. Hugh is an Eastern Region past-President and this summer was elected as Director for Region IV of the AAN. Hugh will now discuss, "Seed Source and Selection".

SEEDLING PROPAGATION — SOLVING THE SEED SOURCE PROBLEM

HUGH STEAVENSON

Forrest Keeling Nursery
Elsberry, Missouri 63343

One aspect of particular and growing concern to the seedling propagator is the matter of seed provenance and selection. As a background to this topic I should mention that at Forrest Keeling Nursery we grow a range of hardy deciduous trees and shrubs from seed — almost 100 species. These are grown in open field beds without shade but otherwise under intensive culture as regards irrigation, nutrition, disease, insect and weed control. A considerable portion of these seedlings are used by other nurseries as understocks. A somewhat larger proportion are used as liners for growing on into finished plants, either in the field or container. Still others (particularly our so-called "top-of-the crop") are purchased for re-sale to customers who plant them in their permanent or ultimate location. Mail-order firms, highway departments, conservation agencies and others are avid consumers of these larger seedlings.

Regardless of outlet or usage, we are ever more impressed with the importance of *seed source* in producing acceptable planting stock. Not that there is anything new to this concept. For many years foresters have been keenly aware of the vital factor of seed provenance. They have conducted exhaustive tree selection and breeding programs and have followed up with the establishment of seed orchards to produce superior forest trees and ones adapted to specific sites.

In arboriculture, ornamental horticulture or "amenity horticulture" as our English friends prefer, the problem is somewhat different. Foresters find that they must often select parent stock, or ecotypes, for narrowly-defined specific areas. For example, a selection of pine adapted to one side of a mountain may fail when planted on the other side. In our industry, selections must have wide adaptability to be of practical usage. Thus the danger of buying seed "out of the barrel" where parentage is unknown. This is not to disparage the commercial seed houses. We find they will cooperate in defining seed origin and parent characteristics where they have this information. The establishment of a seed row or seed orchard of your own from a proven selection is ideal, or collection from known and acceptable parent trees is similarly advantageous.

Most commercial species have broad native distribution. For example, red maple [*Acer rubrum*] is native from south Florida to Nova Scotia. Sugar maple [*A. saccharum*] is found from Louisiana to Newfoundland. Silver maple [*A. saccharinum*] grows natively from the Gulf to northern Maine. Pecan [*Carya illinoinensis*] is native from the Rio Grande to Wisconsin. Hackberry [*Celtis occidentalis*] is found from the Florida Keys to North Dakota. Redbud [*Cercis canadensis*] occurs from Florida to Minnesota; flowering dogwood[*Cornus florida*] from central Florida to Wisconsin; tulip tree [*Liriodendron tulipifera*] from Michigan to Mobile; honeylocust [*Gleditsia triacanthos*] from Texas to New York; northern red oak [*Quercus rubra (Q. borealis maxima)*] from Mississippi to Quebec. As the great bulk of usage of these trees is in USDA Zones 5 and 6 it is obviously important, if not vital, that seeds come from parent trees in these more northern latitudes.

Here are some critical examples in selecting parent seed plants:

Red maple [*Acer rubrum*] — as Dr Alden Townsend of the USDA Delaware Ohio Plant Laboratory has pointed out there is a tremendous variability of this species as to growth rate, fall coloration, seed dormancy and other characteristics according to location within its natural range We regularly had difficulty growing this species until we found a suitable Illinois type

Silver maple [*Acer saccharinum*] — northern nurserymen have found that seedlings from native trees south of Zone 6 will winterkill. On the other hand, we were forced this year to collect seed from S E South Dakota, the extreme northwest range of the species Resulting seedlings are much slower in growth than those from Zone 6 parent trees

Pecan [*Carya illinoinensis*] — we ran into all sorts of problems with northern cultivars supposedly grafted onto northern understock We suspect that the supplier in this case had actually used southern understock Now that we have changed sources and are using northern cultivars grafted on certified northern understock, we believe our problems are behind us

Chinese chestnut [*Castanaea mollissima*] — there are forest and orchard types of this tree Horticultural users want the orchard type

Redbud [*Cercis canadensis*] — trees produced from southern seed will winterkill in northern nurseries These nurseries insist on seedlings grown from native northern seed

Hazel [*Corylus americana*] — we find a wide variability in nut size of the native hazel Obviously the planter wants a type producing good crops of the larger nut

Crataegus spp. — Over the years we have planted many or most of the commonly used and offered clones and types of hawthorns The native species, particularly *C phaenopyrum*, *C crus-galli* and *C viridis*, the parent of 'Winter King', have proven so much more satisfactory under our conditions that we have dropped production of the exotic types

Eleagnus umbellata 'Cardinal', a USDA introduction, does not even resemble the species grown from imported Japanese seed 'Cardinal' is incomparably superior.

Carpathian or English walnut [*Juglans regia*] — last year we secured seeds of supposedly Carpathian walnuts from four different sources They varied greatly in growth and obvious hardiness We have settled on the outstanding source that has regularly been a good nut producer in an area where temperatures dip to 34°F

Golden rain tree [*Koelreuteria paniculata*] — some 50 years ago someone planted the streets of Clarksville, in north-east Missouri, with golden rain. These have developed into handsome specimens that we see commonly pictured in nursery catalogues. Though the species is supposed to withstand only -10°F these trees have been unimpaired at -25°F when trees raised from imported seed have failed

"Borderline" trees — there is a considerable group of highly-desirable tree species of borderline hardiness with us and throughout the important USDA 5 and 6 zones These include sweet gum [*Liquidambar styraciflua*], tulip tree [*Liriodendron tulipifera*], southern magnolia [*Magnolia grandiflora*] and flowering dogwood [*Cornus florida*] Southern seed sources of these species are wholly unsuited to the northern latitudes We have had disastrous results with clones of sweet gum where original parentage was unknown but likely from a southern source. Likewise seedlings grown from seed purchased abroad (the original parents had to be from some point in the U.S.) proved tender Our most satisfactory trees have been grown from native Illinois parents at the northern natural limit of *distribution*

Likewise, we believe it is vital to secure seed of these other "borderline" species from native trees growing toward the northern extension of their distribution

'Rem Red' honeysuckle [*Lonicera maacki* 'Rem Red'] — a USDA discovery that produces large quantities of bright red fruit and comes true from seed Distinctly superior the the species *L Maacki f podocarpa*.

Nanking cherry [*Prunus tomentosa*] — seedlings produced from northern plains windbreak plantings are incomparably more vigorous than seedlings grown from imported Japanese seed Some fruit tree growers had thought that the dwarfish Japanese seedlings might be better as a dwarfing understock for peach Apparently the results were not encouraging.

English oak [Quercus robur] — as is wellknown a high percentage (most) of the seedlings grown from the fastigiate form of English oak will come true As is also wellknown, the species is unusually susceptible to mildew About 20 years ago we secured a quantity of fastigate seedlings from Robert Simpson of Vincennes, Indiana, who had produced them from fastigate parent trees growing, I believe, in the Vincennes courtyard

These seedling trees, in turn, came into fruiting for us after about 6 years From progeny produced from these trees we were able to select individuals that not only exhibited the typical fastigiate form but also had a much heavier, leathery leaf free from mildew These third generation individuals are just now beginning to fruit and we soon hope to have markedly superior fourth generation seedlings

Rugosa rose [*Rosa rugosa*] — about 15 years ago we planted a seed-row from an Oregon fence-type selection of rugosa rose We have produced our seedlings from this row since it came into bearing The seedlings are not only vigorous with rich, dark foliage, but are also precocious, flowering and fruiting in the one-year seedbed Last year we gathered some 600 lbs of hips from these beds, enough for our current production This fall, flowering and fruiting in the resulting one-year beds is even more pronounced By regularly gathering hips from first-year seedlings, we assume this precocious character will be enhanced

Wentworth cranberrybush [*Viburnum trilobum* 'Wentworth'] — years ago we established a seed-row of 100 plants of 'Wentworth' cranberrybush secured from the Siebenthaler Co This is a selection made specifically for fruits that can be used for preserves, however, it is also a compact, upright grower with distinctive foliage Seedling progeny appear identical to the parent, at least as to foliage and growth habit

Yuccas — Here is one item that has been unreliable from the seed houses. When ordering *Yucca filamentosa* we have obtained Lord knows what. The logical and easy solution is to gather your own seed

Little-leaf linden [*Tilia cordata*] — seedlings grown from imported seed appear to be entirely satisfactory as an understock. However, they are not satisfactory to grow on. They want to make a bush rather than a tree and no amount of pruning and staking seems to bring them around to an arborescent form I suspect the seed is gathered from bushy forms where it can be readily collected.

On the other hand, seedlings produced from *Tilia cordata* parents growing in this country grow into respectable trees Other than for understock, I believe it would be highly desirable to collect seed from 'Greenspire' or silimar superior clones One cannot reproduce a clone by seedage, but the resulting tree should be better than the typical species.

MODERATOR SHUGERT: Excellent paper, Hugh; and we are indebted to you! Our fifth speaker, Hans Hess, is well known to all of us. This gentleman is an outstanding grower and shall share with us his experiences on the seeding of difficult species.

SEEDLING PROPAGATION OF DIFFICULT SPECIES

C.W.M. HESS, JR.

Hess' Nurseries, Inc.
Cedarville, New Jersey 08311

This topic is somewhat evasive in that we have no definition of what is a "difficult" species; what is difficult for one person may be very simple for another. I believe that it all terminates with enough experience to arrive at a successful conclusion — in this case a good stand of healthy seedlings. As an example, one of our members inquired some months back about the proper handling of *Myrica pensylvanica* seed. He explained that he had purchased seed, planted it the same fall he received it and had no success; this happened for several years. I inquired as to his handling of the seed and he explained that it was planted immediately upon receipt from the supplier. This will not do when planting bayberry seed. Bayberry seed has a waxy gray coating which is used in the manufacture of bayberry candles. This waxy covering must be removed prior to planting in order to obtain germination the spring after planting.

Some very popular species at present are the amelanchiers — known as June berry, shadblow, sarvis tree and other common names. These plants flower early in the spring and the fruit ripens, depending on the area, sometime during June. It must be foliage Seedling progeny appear identical to the parent, at least as to foliage and growth habit

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Some very popular species at present are the amelanchiers — known as June berry, shadblow, sarvis tree and other common names. These plants flower early in the spring and the fruit ripens, depending on the area, sometime during June. It must be picked as soon as it ripens, or even just prior to being fully ripe, the birds will get it before you do. It should be cleaned immediately, using either a commercial seed cleaner, or by rubbing the fruit through a screen, floating out the pulp. After it is cleaned by either method, plant it, or mix it with slightly moist peat and store until you are ready for planting. Do not let the seeds dry or there will be no germination, since they are very sensitive to drying.

Another species that needs to be handled almost in the same manner are the magnolias. Seed of *Magnolia kobus* purchased from Japan provides no seedlings whatsoever; seed picked locally and planted promptly or stratified until ready for seeding gives excellent germination.

Many people consider Japanese maple cultivars difficult to grow from seed; actually they should present no more problems than Norway maple. We have found that seed purchased from many suppliers does not give good consistent results for various reasons. One of the major problems is that there are two types of Japanese maple seed, à large-fruited and a small-fruited type. The small-fruited type, if received before the end of the year and planted promptly, will usually give a fair percentage of germination. The large-seeded type received and planted at the same time gives no germination. If the bed is kept properly mulched and weeded there is a fair chance of a reasonable percentage of germination the second year, very expensive at best. We have found that the best results for both large and small-seeded cultivars is obtained by collecting and planting the seeds during September for the New Jersey area; areas north or south would vary slightly. The seed must not be allowed to dry out or germination percentage will fall tremendously.

Viburnum cultivars have frustrated many people and yet there should be no serious problem with them. Seeds of most of the viburnums will germinate, or at least partially germinate, (root emerges) the fall after the seed ripens. These can be handled in two ways— you can either clean and plant the seeds the fall they ripen, maintaining a mulch and weed control through the summer, or you can stratify the seed after cleaning and plant the following fall. A word of caution, if you use the latter method, the seeds germinate (the radicle develops) depending upon the cultivar, anytime from July to November, so keep a close watch on the stratified seed to be sure it does not sprout before you get it planted.

Many people have had a problem with *Fagus sylvatica* and *Fagus americana*; here again the seed must not dry out. Usually seed of *Fagus* cultivars does not arrive from the supplier until sometime in late December or early January when the ground is frozen. Seedbeds are not at their best at this time; in fact, they may even be snow-covered. We have found that seeding *Fagus* as soon as the seeds are received, whether or not the ground is frozen, gives the best results. Have the beds prepared in the fall. If they are snow-covered, plow the snow off and plant; you will be pleasantly surprised by the results. Someone is sure to recommend stratifying the seed when you receive it and plant in the spring. This would be a very good approach except that *Fagus* seed partially germinates just as the frost begins to leave the soil and would be sprouted before you were able to plant if it was stratified.

Cornus mas, the Cornelian cherry, has never been easy from seed and very few growers, including ourselves, can produce a consistent crop of seedlings. The best method we have found is to keep the seed in stratification for 2 years before planting because of the dormant embryo. The few seedlings germinating the second year are forgotten. We also found that *Ilex opaca* is similar to *Cornus mas* and gives a small percentage of germination after 1 year, but gives a high percentage if kept in stratification for 2 years prior to planting. The dormant embryo and extremely hard seed combine to delay germination for 2 to 3 years. You can determine the potential germination percentage of *Ilex* seed in stratification by checking the ease with which you can cut the seed with your thumbnail. If you can easily cut the seed in half by pressing it against your index finger with your thumbnail the seed is ready for germination.

Some other species for which seed propagation is not difficult but which should be handled like the viburnums are: *Chionanthus virginicus, Syringa amurensis.* var. *japonica,* and *Clematis paniculata*. The seeds all germinate in late summer or early fall and should be planted immediately, mulched and maintained until germination the following fall.

In summary, for good success with any kind of seed, you must have good, fresh, viable seed. They must be properly cleaned and handled according to the requirements of the various species. Pick your own seed whenever possible if there are problems in getting good viable seed from a regular supplier. Clean, plant, or stratify the seed as quickly as possible after picking. Remember that the closer you can come to reproducing the situation provided by Mother Nature the more successful you will be.

MODERATOR SHUGERT: We shall now acknowledge questions from the floor.

CHARLIE PARKERSON: Al Fordham, how do you get the wax off of bayberries?

AL FORDHAM: We use only small lots and it can be done with hot water or by rubbing them through a screen.

HANS HESS: To elaborate on that point, a commercial seed cleaner will clean them very easily.

MODERATOR SHUGERT: For a small lot you might also use a Waring blender.

JIM WELLS: Is anyone using hot water or sulfuric acid for seed treatment?

HUGH STEAVENSON: We are using sulfuric acid for seeds with a hard seedcoat, especially the legumes. We use commercial sulfuric acid as it comes from the carboy. The USDA Seed Manual, to which Ralph referred, gives time periods for many species; there is quite a wide latitude. The acid is strained off with a screen and the seeds are rinsed with lots of cold water. A little baking soda in water is added to the seed to counteract any residue of the acid.

MODERATOR SHUGERT: As a comment from the chair, I want to point out that the acid method is dangerous if it is not adequately controlled. Because of this, and the fact that we treat much smaller lots of seed than does Hugh, I prefer the hot water treatment. But, as has been mentioned many times, when using the hot water method, test a small lot at the temperature you intend to use before you treat the entire lot.

JIM WELLS: Is anyone using steam as a treatment for controlling seed-borne diseases? I saw this being used recently in Australia.[1]

JOERGE LEISS: As Tom Pinney pointed out, I think it is sufficient to treat the seed with a fungicide.

DAVE DUGAN: I believe the process Jim is talking about is used for the control of virus, not fungal diseases. This should not be confused with the method Tom Pinney is using — which is for fungal diseases.

BRUCE BRIGGS: I would like to hear some comments as to whether a medium is necessary when stratifying seeds. Some of the large growers on the West Coast are treating the seeds with hot water and then placing them in poly bags without any medium.

MODERATOR SHUGERT: Appended to Bruce's question I would like to ask whether it is necessary to have wet seed rather than dry seed to go into stratification?

HAROLD PELLETT: There is a definite benefit to having fully imbibed seeds before placing them in stratification since the

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[1] *Ed. Note – See paper by A. Newport, page 441*

dry seeds do not perceive the cold stimulus very well. With fully imbibed seed the treatment will be more uniform and will usually take a slightly less time. There is an advantage to having a medium mixed with the seed when they go into stratification in that the medium serves as a moisture reservoir to insure the seed against drying out. The amount of seed being stratified and the method of sowing after stratification is completed would probably determine whether a medium should be used or not.

AL FORDHAM: I feel that a moist medium is necessary. We did some work with *Chaenomeles* seed stored with and without medium and those stored without medium gave us no germination at all. We keep the volume of medium small and sow seed and medium together.

MODERATOR SHUGERT: I would comment at this point that if you are sowing the seed broadcast it need not be separated from the medium, but if you are drilling the seed with a planting machine, you must separate the medium from the seed or the medium will clog the equipment.

CHARLIE PARKERSON: Tom Pinney talked a lot about cost accounting and I would like to ask him what he does when he finds that a crop is not making money for him. Do you change the procedure, make a price list adjustment, or discontinue the crop?

TOM PINNEY: When we got our cost accounting system operating, we found that there were some items that had to be jumped 100% in price. My father and I agreed to do this over a 3 yr period; we are still in business and cost has not caused us to drop any item from our plant list; however some have been dropped for other reasons.

MODERATOR SHUGERT: We are out of time; it has been an excellent symposium and the audience has participated very well. I thank our speakers for a job well done.

(EDITORS NOTE: Mr. David Paterson was moderator for the second half of the Wednesday afternoon program).

MODERATOR PATERSON: A program on plant propagation would not be complete without some information being given about the use of growth regulators in plant propagation. At this time I would like to introduce Paul Read who will talk about slow-release growth regulators for rooting cuttings.

CONTROLLED RELEASE GROWTH REGULATORS FOR PLANT GROWTH CONTROL AND ROOTING OF CUTTINGS[1]

PAUL E. READ, VINCENT L. HERMAN, AND PAIBOOLYA GAVINLERTVATANA[2]

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University of Minnesota
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Abstract. "Controlled release" chlormequat (2-chloroethyltrimethylammonium chloride) has been demonstrated to effectively modify plant growth This encapsulated growth substance when incorporated into the growing medium, both effectively stimulated earlier flowering in tomatoes and petunias and retarded growth of tomatoes, petunias, snapdragons, marigolds, and other bedding plant species When utilized in a rooting medium, stimulation of early rooting occurred However, subsequent root initiation and development were greatly retarded in geranium cuttings

REVIEW OF LITERATURE

The growth, flowering and rooting of many flower crops, bedding plants and vegetable transplants have been successfully controlled with growth regulators to produce quality horticultural products (2, 3, 12, 13, 14). Growth regulating chemicals applied by various methods have successfully increased the yields of vegetable crops (7, 11), controlled plant size, retarded flower bud initiation, delayed flowering, stimulated earlier bloom, improved transplant quality, increased resistance to cold and other stresses, induced tuberization, improved root systems, and stimulated adventitious root production in cuttings (3, 4, 6, 7, 8, 9). In most cases these responses followed application of the chemicals as foliar sprays, drenches or dips. Often such applications cause a drastic initial reaction in the plant as opposed to a gradual uptake by the roots (7, 8, 10).

Carpenter and Carlson's work (1) along with the work of Read (8) indicated the potential for rooting cuttings with very low levels of chlormequat (Cycocel or 2-chloroethyltrimethylammonium chloride) in the rooting medium. In the latter research, presented at the 1968 I.P.P.S. meetings, we reported the

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[1] Scientific Journal Series Paper No 8550, Minnesota Agricultural Experiment Station

[2] Associate Professor, Research Assistant, and Graduate Student, Department of Horticultural Science

effect of SADH (succinic acid 2, 2-dimethyl hydrazide or B-Nine) and chlormequat on rooting of cuttings. In this research SADH stimulated rooting of cuttings while levels of 2000 ppm chlormequat retarded rooting. Both treatments increased tuberous root formation in dahlia; low levels of chlormequat were demonstrated to be stimulative to adventitious root formation in a number of herbaceous species.

In our current research we have emphasized growth control with an encapsulated formulation of chlormequat. A next logical step was to pursue the possibility of improving rooting of cuttings with this material incorporated in the rooting medium.

MATERIAL AND METHODS

Encapsulated chlormequat (3MCAP-CYC)[3] was incorporated into a peat-vermiculite medium for the growth studies and in either peat-vermiculite, or vermiculite alone, for the rooting experiments. Each capsule is composed of an aqueous solution of the active ingredient encased by a polymeric hydrocarbon shell (Fig. 1). The active ingredient is gradually released when the capsule comes in contact with water. Release is effected by

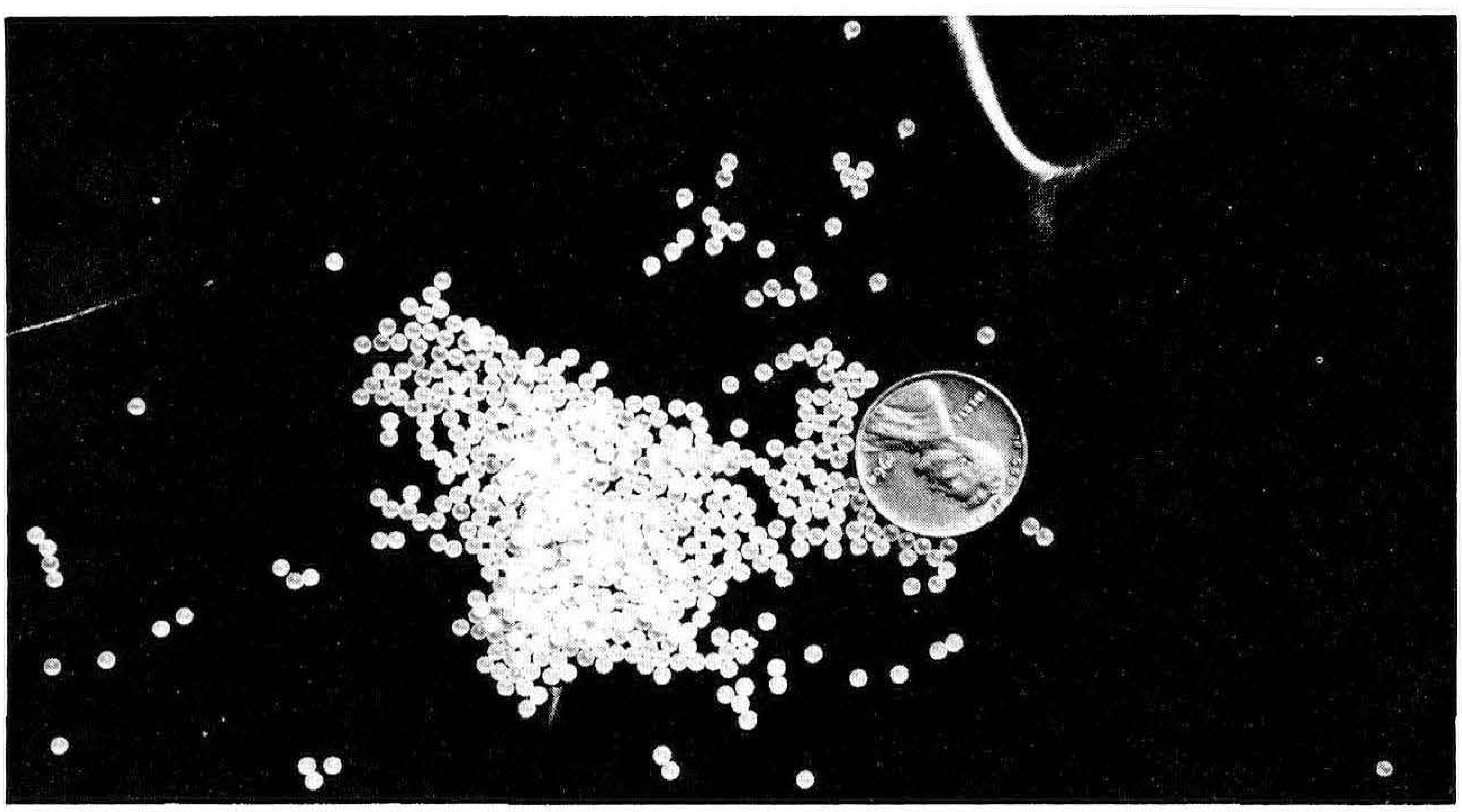

Figure 1. Capsules for encapsulated chlormequat (3MCAP-CYC). Note similarity to commercial controlled-release fertilizers.

[3] Supplied by New Business Ventures Division, 3M Company, St. Paul, Minnesota

equalization of the concentration differential between the capsule solution and the moisture content of the growing medium. The capsules do not physically rupture and the release rate can be controlled by varying the shell composition.

Capsules containing 4% chlormequat were used in these experiments and were mixed thoroughly in a nutrient-enriched peat-vermiculite medium and placed in 10 or 15 cm (4" or 6") polyethylene pots for the growth experiments and in vermiculite-filled flats, or peat and vermiculite-filled Forsyth pots, for rooting experiments. Non-treated plants were maintained as standard controls in all experiments and drenches and/or sprays of chlormequat at 1000 to 4000 ppm were utilized as additional controls for 'Rutgers' tomatoes. Petunia experiments also had the standard application of 2500 ppm SADH (B-Nine) spray. A randomized block design was employed and the experiments were conducted in an 18.5° - 24°C greenhouse (diurnal temperatures) with daily watering and fertilization weekly with 300 ppm N from 20-20-20 fertilizer for the growth studies. Approximately 30 cultivars of petunia and numerous other bedding plant species have been tested. Data and discussion reported here are for 'Red Cascade' and 'Happiness' petunia, 'Rutgers' tomatoes, 'Hot Jazz' salvia, 'Giant Rose Queen' cleome, 'Verns Delight' African violet, and 'Irene' geranium. Tomatoes and cleome were direct seeded, petunias and salvia transplanted at the first true leaf stage, and leaf petiole cuttings of African violet and terminal 4" cuttings of geranium were utilized in these studies. Cuttings of African violet were rooted in home propagating units (Forsyth pots) under cool white florescent lights, while geranium cuttings were rooted under intermittent mist, 15 seconds/7.5 min.

RESULTS AND DISCUSSION

Growth control with 3MCAP-CYC incorporated in the medium was excellent in all experiments with all species. Height control is illustrated in 'Rutgers' tomatoes (Table 1) where 3 to 12.5 grams/liter 4% 3MCAP-CYC incorporated in the medium provided height control similar to drenches or sprays of chlormequat; 25 grams/liter 3MCAP-CYC caused even greater height control, while all 3MCAP-CYC treatments reduced the number of nodes to the first inflorescence, thus providing earlier bloom by up to 2 weeks. Mean stem diameter was sharply increased by 3MCAP-CYC treatments suggesting that the plants are in a better nutritional and carbohydrate status that untreated or drenched controls.

Table 1. Comparison of effects of controlled-release, spray and drench forms of chlormequat on 'Rutgers' tomato plants. [z]

Treatment	Mean height (cm)	No. nodes to 1st inflorescence	Mean stem diam. (mm) [x]
3g 4% 3MCAP-CYC	25.60 c [y]	8.00 bc	8.57 abc
12.5g 4% 3MCAP-CYC	22.74 cd	7.57 c	8.71 ab
25g 4% 3MCAP-CYC	17.94 e	8.14 bc	7.86 a
1000ppm drench	22.79 cd	9.00 ab	7.86 bcde
4000ppm drench	22.92 cd	9.42 a	7.43 cde
2000ppm spray	36.47 b	9.86 a	7.14 de
Control	44.68 a	9.43 a	6.86 e

z/ Slow-release chlormequat (3MCAP-CYC) incorporated into peat-lite medium; sprays and drenches applied at 4th true leaf stage. Data 64 days after seeding.

x/ Measured midway between 1st and 2nd true leaf.

y/ Means in the same column followed by the same letter are not significantly different at the 5% level.

Petunia responses were similar although the enhancement of early bloom by low levels of 3MCAP-CYC was only 3-7 days as compared to the 2 weeks in tomatoes. Height control was again excellent when compared to the standard treatment commercially practiced by bedding plant producers (Fig. 2).

Figure 2. Height control in 'Happiness' petunias with controlled-release chlormequat vs. B-Nine sprays. *Above:* center plant grown in medium containing 3MCAP-CYC at 25g/1 with control plants on either side. *Below:* center plant sprayed with 2500 ppm B-Nine at silver dollar size with control plants on either side.

Pronounced height control in salvia and cleome are illustrated in Figures 3 and 4. It is readily apparent that plant producers can control plant height and size easily with 3MCAP-CYC incorporated in the growing medium. In many cases the control can be achieved concommittantly with enhanced earliness of bloom rather than the frequent delay achieved with standard commercial size-controlling techniques.

Levels of 6 grams or 12-1/2 grams/liter of peat-vermiculite medium stimulated rooting of 'Verns Delight' African violet cuttings. Root number was nearly doubled and the time at which cuttings were ready to be potted was advanced by 7 to 10 days. This preliminary information encouraged us to pursue further studies in rooting cuttings with controlled release chlormequat. In a series of experiments in which 'Irene' geraniums were rooted under intermittent mist, the early root number was increased by the 6 grams/liter rate, but by 15 days after sticking, the control cuttings were far superior in root number and root development of cuttings rooted in a 3MCAP-CYC-containing medium (Table 2)

Figure 3. Height control in 'Hot Jazz' salvia with controlled-release chlormequat. *Left to right:* 50, 25, 12.5g 3MCAP-CYC/1 peat-lite, and control.

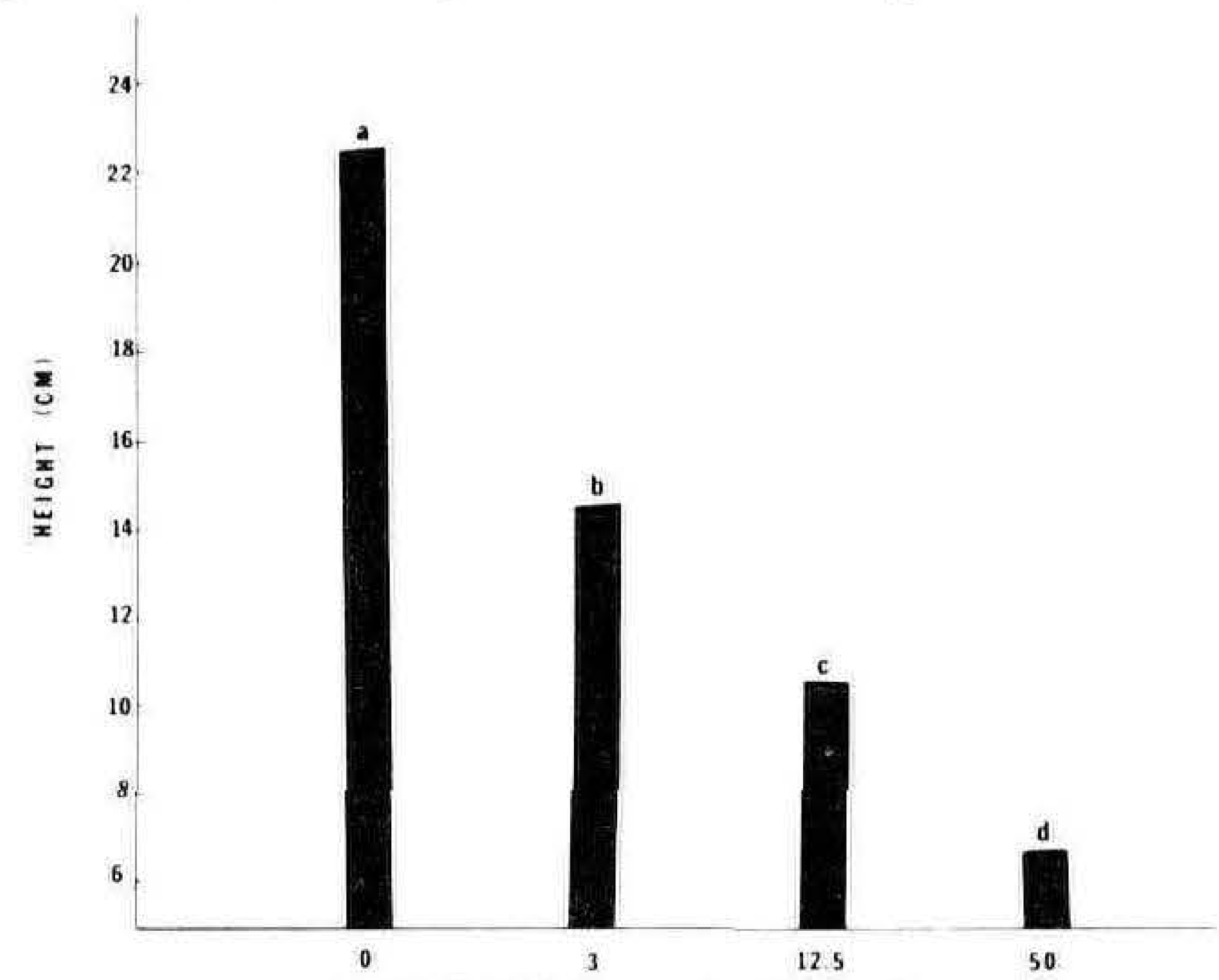

Figure 4. Height control in cleome 'Giant Rose Queen' with controlled-release chlormequat incorporated in the medium.

The results with geraniums suggest that although small levels of chlormequat can stimulate rooting of cuttings (1, 8) it is apparent that a continuing source of chlormequat in the rooting medium for geranium retards root development drastically. It is possible that release rates and application rates could, perhaps, be modified to solve this problem. However, it may be that the continuing source of growth-retarding chemical retards the growth of the plant too drastically and therefore will not be a satisfactory rooting stimulant. Further research is necessary to delineate the ramifications of use of 3MCAP-CYC for stimulating rooting of cuttings. It is also possible that other growth regulating compounds may be supplied to the base of the cutting through the encapsulation technique and possibly will be a more effective way of controlling rooting. Possible chemicals would include auxin-type materials and ethylene-releasing coumpounds, such as ethephon.

Table 2. Effect of controlled-release chlormequat on rooting of 'Irene' geranium.[z]

Grams 3MCAP-CYC/liter of medium	Root No. at 10 days	Root No. at 15 days
0	0	90
3	0	6
6	3	63
12	4	43
25	4	28

[z] Controlled-release chlormequat (4% formulation of 3MCAP-CYC) was incorporated into vermiculite rooting medium before sticking cuttings

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MODERATOR PATERSON: Thank you, Paul; we have time for a few questions.

JIM WELLS: Is this encapsulated CCC available?

PAUL READ: At this point it is experimental only; however there is a fair chance that it may be available within the next 3 to 5 yrs. Initially the material will probably be offered on the market as a component of pre-packaged media. The material seems to work best in non-soil containing media.

MIKE DODGE: Do you know of any work being done with encapsulated insecticides? This seems like it would be a very interesting area to investigate.

PAUL READ: I suggested this approach to the people who make our encapsulated cycocel but they have shied away from it primarily, I believe, because of the problems with clearance through E.P.A. It is a beautiful concept but with present regulations there would be considerable trouble getting approval for such a material.

MODERATOR PATERSON: Thank you very much Paul. Next we will hear from Dr. John McGuire concerning the difference in rate of uptake of IAA as influenced by the formulation.

EFFECT OF FORMULATION ON UPTAKE OF 3-INDOLEACETIC ACID IN CUTTINGS[1]

HEUNG, SHI-LUH, ROSA[2] and JOHN J. McGUIRE

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Abstract. Talc formulations of IAA prepared by dissolving the auxin in alcohol were superior to talc formulations prepared by grinding IAA crystals with talc Similar concentrations of IAA in aqueous solution were taken up faster and produced more roots per cutting Maximum uptake in aqueous solution took place in 24 hours but talc formulations required 72 hours

When talc and ethanol formulations were compared on the basis of adventitious root production in *Ilex* cuttings, it required four and a half times as much IAA in talc to get the same amount of roots as obtained in ethanol formulations

REVIEW OF LITERATURE

Research devoted to methods of application of root promoting chemicals to cuttings has been extensive. As a result, two methods of application have come into widespread use: the concentrated aqueous dip and the talc dust (1, 2, 3, 5, 6, 7, 8, 9, 14, 15). Plant response varies, some responding best to concentrated dips while others give best results with talc dust applications (14, 15). Little information is available on rate of uptake as it is influenced by formulation. It is known that the liquid formulation is taken up in the transpiration stream by diffusion (10, 11, 15, 17, 18). There is less information about talc formulations although there is some evidence that talc alone will stimulate some root initiation (16). It is also known that effectiveness of talc formulation is dependent on the fineness of the talc particles (14).

INTRODUCTION

Further information is needed if a complete understanding of the effect of the carrier or formulation is to be obtained. If a li-

[1] Rhode Island Agricultural Experiment Station Publication Number 1524

[2] Submitted as partial fulfillment of M S thesis University of Rhode Island, 1973

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quid formulation of IAA is more efficient than a talc, perhaps the explanation lies in rate of uptake or in the total efficiency of the uptake process. If the liquid formulation is the most efficient, then the question must be asked, why are talc formulations more effective for cuttings of some species? The following series of experiments were carried out to elucidate some of these questions.

PROCEDURES

Comparison of Two Talc Formulations. Grace (4) found a difference in rooting response in talc formulations when talc was mixed in different ways. These procedures were tested to determine the best method for preparing talc formulations of IAA. Two procedures were used, the grinding method described by Hitchcock, *et al.* (23), which consisted of grinding the auxin with talc in a mortar and pestle. The second method consisted of dissolving the prescribed weight of IAA crystals in sufficient 95% ethanol then pouring the solution over the prescribed weight of talc. After mixing to a slurry, the mixture was dried in a forced draft oven at 25°C. A 0.4% IAA mixture was prepared by each method and compared as rooting stimulants on cuttings of *Coleus blumei* Lour. Each cutting had two leaves and an almost identical leaf surface area. The basal 1/2 inch of the cutting was moistened in water and dipped in one of the talc formulations. Excess talc was removed by tapping the cutting gently. Cuttings were placed in a medium of sphagnum peatmoss and horticultural grade perlite (1:1 V/V) under intermittent mist at a minimum temperature of 20°C. After 10 days, individual roots per cutting were counted. Each treatment included five replications of five samples.

Determination of Quantity of Absorption or Adsorption. It is not possible to compare applications of talc to aqueous dips unless it is known how much of each material is either absorbed in the cutting or adsorbed to the outer surface.

Cuttings of *Ilex crenata* 'Convexa' were dipped in water and allowed to drain for 3 min, then dipped into talc to a depth of 1 inch. Excess talc was tapped off. Cuttings were dried for 3 days at 25°C so the talc could be brushed off. The talc was removed, first by brushing with an artist's brush, followed by washing in 95% ethanol. Ethanol was evaporated and the talc weighed. Five cuttings were treated at one time and the process repeated 65 times.

Mean talc adsorption was 13.62 mg ± 1.82 mg or approximately 2.72 mg/cutting. Uptake of ethanol was measured by dipping the basal inch of each cutting in 50 ml of 40% ethanol. The dilute ethanol was used since ethanolic formulations used to treat cuttings are in that range.

Each cutting was held in the solution exactly 10 sec, simulating the procedure used in applying, concentrated dips. Twenty cuttings were treated at a time and the volume of alcohol lost was measured in a buret. The average volume uptake per cutting was 0.82 ± 0.11 ml for 20 cuttings of approximately 0.04 ml per cutting. The coefficient of variability for replications was 12% for talc and 13% for the ethanol dips.

Determination of Rate of Uptake. IAA was used which contained 1% of the auxin labeled as IAA-2-^{14}C. This was mixed with nonradioactive IAA to make a final formulation of 0.6% IAA in 50% ethanol. This served as a concentrated dip. A talc formulation was prepared by dissolving the IAA in 95% ethanol and mixing with talc as previously described. The mixture contained 1% of the IAA as IAA-2-^{14}C with a total concentration of 0.6% IAA.

A talc treatment containing no IAA served as a check. Materials were applied to the lowest inch of 4-inch cuttings of *Ilex crenata* 'Convexa'. Excess talc was removed by tapping. Cuttings were placed at random in flats containing sphagnum peatmoss and horticultural grade perlite (1:1 V/V), then were placed under intermittent mist at 20^{0}C minimum in normal daylight. Each treatment had three replicates which included nine samples for each harvest date. Three samples were used for ^{14}C analysis, rooting response, and autoradiography. The samples were harvested after 1, 2, 3, 8, 16 and 32 days.

When cuttings were harvested, leaf blades were removed but petioles were retained. The uppermost leaf blade was retained on the ones to be used in autoradiography but all others were cut off.

The upper fourth of the cutting was rinsed in 95% ethanol and the lower three quarters was washed thoroughly in 95% ethanol and scrubbed with a soft bristle toothbrush. The wash process was repeated nine times using a different batch of ethanol each time. These wash solutions were assayed for radioactivity. After cuttings were washed, petioles were removed and the cutting was divided into four 1-inch segments. Segments of all samples in the replicate were pooled for extraction but remained segregated by position on the stem. Stem segments were homogenized in an ice bath in 15 ml of 95% ethanol in a Sorvall Omnimixer. The liquid extract was filtered from the residue and radioactivity of the insoluble portion measured in a Tracerlab planchet counter. Efficiency of the counter was 5%. Data were corrected for self absorption. Soluble extracts were evaporated in counting vials then 6 ml of scintillation solution were added. Samples were counted in a liquid scintillation counter, Nuclear

Chicago, Model 6860. Efficiency ranged from 50-60% depending on the samples.

Samples for auto-radiographic analysis were wrapped in cheesecloth and freeze-dried under a vacuum at -15°C. After all samples from all harvest dates had been obtained, they were re-humidified for 1-1/2 hours to facilitate handling. Cuttings were mounted on 10 x 12 inch sheets on 50% rag content paper with rubber cement. Mounts were pressed in a mechanical screw press to make the surface smooth. They were covered with Saran Wrap and exposed to Kodak Rp X-O-Mat X-Ray film. The film was developed by normal procedures (19).

Comparisons of Formulation at Varying Concentrations. In an attempt to equate the two formulations with actual root initiation of *Ilex* cuttings, comparisons were made of different concentrations of the concentrated dip and the talc formulation. Concentrations were prepared as before except that polyethylene glycol (Carbowax 400) was used as the solvent in the concentrated dips and cuttings were placed in the same environment described previously. Each formulation was made at the following range of concentrations: (given in percent) 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.6, 2.4, 2.8, 3.2. Three replicates of five samples were prepared as before and root counts per cutting were made after 46 days.

RESULTS

Comparison of Two Talc Formulations. The average number of roots per coleus cutting was significantly greater when the talc formulation was prepared by first dissolving the IAA in ethanol. (Table 1) This may be due to more thorough mixing.

Table 1. Number of roots on cuttings of *Coleus blumei* Lour 10 days after treatment

Formulation	Total [y]	$\bar{X}$
Talc IAA 0.4% (grinding)	1287	257.4 b [z]
Talc IAA 0.4% (ethanol)	2564	512,8 a
Talc (no IAA)	437	87.4 c
Control (no talc) (no IAA)	154	30.8 d

[y] Total of five replicates of five samples

[z] Means followed by different letters are significantly different (p 01)

Determination of Amount of IAA Applied to Cuttings. Based on the data obtained from the talc recovery tests and the volume of ethanol lost in the dipping tests it was determined that when a concentrate of 6000 ppm of IAA was used 1.6×10^{-2}mg of IAA in talc would adhere to the stem and 2.4×10^{-2}mg of IAA in ethanol would be taken up in the cutting in a concentrated dip treatment of the same concentration. The actual amount of IAA recovered as determined by calculating dpm and determining actual molecules of IAA were 3.2×10^{-1}mg in ethanol and 2.97×10^{-2}mg per cutting in talc.

Determination of Rate of Uptake. A summary of the data obtained by counting ^{14}C in soluble and insoluble fractions is shown in Table 2.

Table 2. Total radioactivity in cuttings of *Ilex crenata* 'Convexa' after application of IAA-2-^{14}C

Formulation	Time (days) 1	2	3 (dpm)	8	16	32
Ethanol						
Soluble	1516 5	1126.8	1129.1	1231.6	1238.6	1042 9
Insoluble	9285 1	7526 0	8649 1	9037 3	8581 3	6764 2
Total	10801 6	8652.8	9778.2	10268.9	9819.9	7807.1
Talc						
Soluble	48 9	92 8	78 8	85 8	49 2	43 2
Insoluble	454 0	644 9	921 8	564.1	388.1	473.9
Total	502 9	737 7	1000.6	649 9	437 3	517 1

Adsorption of the ethanol IAA was greatest within 24 hours after application. Uptake in cuttings treated with the talc formulation reached a maximum after 72 hours. Uptake from the talc formulation reached a maximum after 72 hours. Uptake from the talc formulation was always much less than that from the liquid formulation. The ratio of insoluble to soluble forms was greater in the talc formulation. This is not considered to be desirable. Adsorption and transport of ^{14}C can be observed in the autoradiographs as well (Fig. 1 & 2). The greatest amount of uptake is again in the cuttings treated with concentrated dips with the greatest concentration in the basal portion with smaller amounts transported to the apex. In all cases, concentrations were found at leaf scars and near the bark as had been reported previously by McGuire (12).

The variance in total uptake was also reflected in the rooting response Table 3.

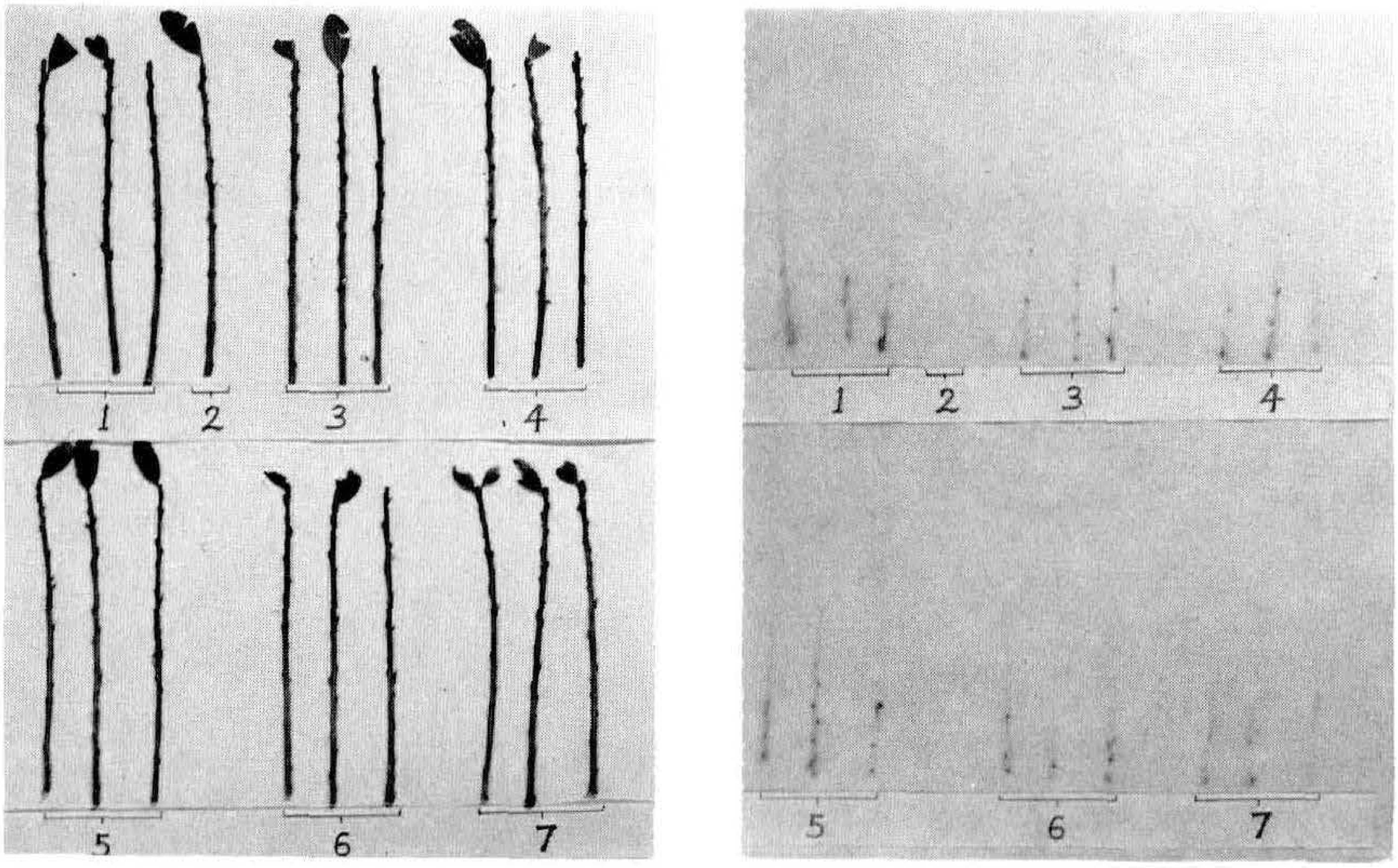

Figure 1. Distribution of radioactivity in cuttings of *Ilex crenata* 'Convexa' treated with 2-^{14}C-IAA in talc formulation. (Left) Original mount. (Right) Radioautograph. Left to right: (1) 24 hours after treatment; (2) untreated cutting; (3) 48 hours; (4) 3 days; (5) 8 days; (6) 16 days; (7) 32 days after treatment.

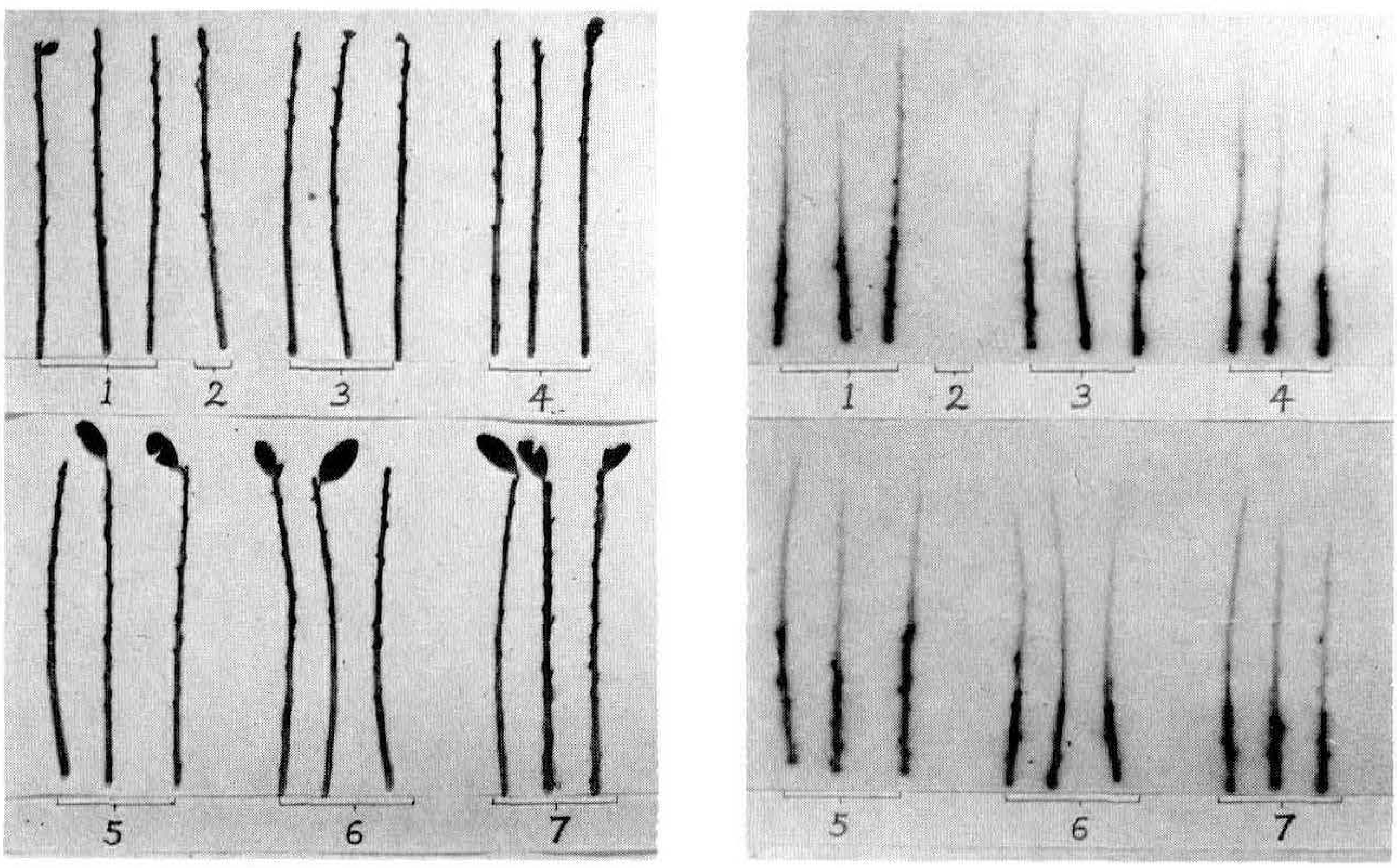

Figure 2. Distribution of radioactivity in cuttings of *Ilex crenata* 'Convexa' treated with 2-^{14}C-IAA in ethanol formulation. (Left) Original mount. (Right) Radioautograph. Left to right: (1) 24 hours after treatment; (2) untreated cutting; (3) 48 hours; (4) 3 days; (5) 8 days; (6) 16 days; (7) 32 days after treatment.

Table 3. Effect of formulation of IAA on rooting of cuttings of *Ilex crenata* 'Convexa' after 32 days

Formulation	Number of roots per replication 1	2	3	$\bar{X}$
IAA Ethanol 6000 ppm	305	277	334	305.3a
IAA Talc 6000 ppm	76	87	89	84.0 b
Talc	53	53	56	54.0 c

Means followed by different letters are significantly different (p .01).

When varying concentrations of IAA in each forumlation were compared it was found again that the liquid formulation was more effective (Fig. 3). When both formulations were used at 0.6% there were four roots per cutting on cuttings treated with the talc formulation and 14 roots per cutting at the same concentration when cuttings were treated with the concentrated dip. It *was necessary to use a concentration of 2.8% in talc to get that* number of roots.

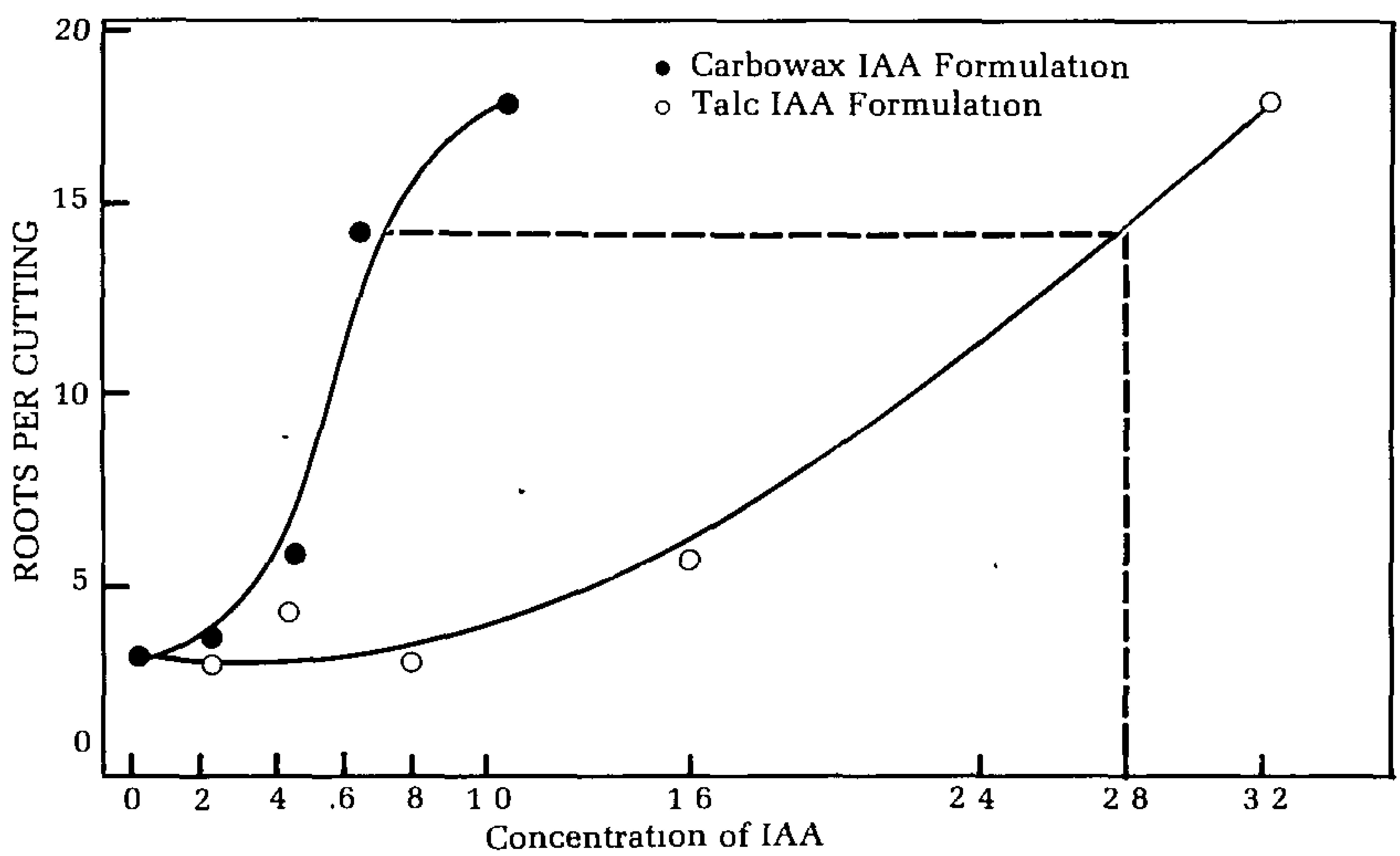

Figure 3. Comparison of relative efficiency of IAA concentrations in liquid (carbowax 400) and talc formulations on rooting cuttings of *Ilex crenata* 'Convexa' (growth period was from February 18 to March 31)

DISCUSSION

It is currently a practice of commercial propagators to use concentrated dips in the range of 10,000 ppm or less but talc formulations in excess of 4% or 40,000 ppm. The difference in relative rate of efficiency of the two formulations found in this study explains why they can be used at such different concentrations. There can be more to the problem however, since for certain plants a slow rate of uptake at low concentrations may be desirable and, though the talc formulation is less efficient, it may still be preferred for some plants.

Recently Shibaoka (13) found that an application of a dilute aqueous formulation of IAA applied the first day to cuttings of *Azukia angularis* had little effect on rooting, but it enhanced the effect of a similar concentration applied the second day. Treatment only on the second day promoted rooting by 70% and a combination of the two treatments promoted rooting by 200%. A similar phenomenon may occur in temperate woody plants. A slower rate of uptake may provide a suitable level of auxin at a time when endogenous materials are at an optimum level for root initiation.

SUMMARY

1. Dissolving IAA in ethanol prior to mixing with talc produced a superior talc formulation.
2. Concentrated dips were superior to talc formulations.
3. Uptake from the concentrated dip was at a maximum in 24 hours but maximum uptake required 3 days for talc.
4. Root formation was 3.6 to 1 when concentrated dip formulations were compared to talc formulations.
5. Distribution of ^{14}C in the cutting decreased with distance from the base. Much of the ^{14}C was immobile.
6. Though uptake from talc is slow and relatively inefficient, adequate rooting can be obtained if high concentrations are used.

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MODERATOR PATERSON: That was a very interesting and well done piece of research. Thank you for sharing it with us. This concludes this afternoon's program.

WEDNESDAY EVENING SESSION
December 5, 1973

The Twenty-third Annual Banquet was held in Salon Four of the Marriott Hotel, Chicago, Illinois. On behalf of the Society, Dr. John Wott presented a certificate of appreciation to Captain George Toop, captain of the IPPS 1973 charter flight to England, for his efforts in making the trip a memorable occasion.

The award for the best undergraduate paper was presented to Mr. Richard Randall of Virginia Polytechnic Institute.

Dr. William Snyder, Secretary of the International Board of Directors, made the following presentation:

DR. SNYDER: President Tukey, members of the Eastern Region and guests. Mr. Leslie Hancock, Chairman of the Award and Merit Committee, could not be with us this year and I have been asked to act in his stead to present the Award of Merit for 1973.

The recipient of the Award this year joined the Society in 1952 which missed by one year being an honorary charter member of the organization. At an early age, he indicated an interest in plant materials by identifying and labeling the plant materials on the campus of the academy, which was the equivalent of high school, that he was then attending. He served n the military in World War II and sbsequently received a Bachelor's degree and a Master's degree from Yale University. He is one of those individuals who could have pursued either the academic or the commercial field and been successful in whichever he chose. He chose to become a commercial nurseryman and is an excellent plantsman who has done a lot of selection and breeding and introduction of new plant materials, especially trees. He is the author of several books and numerous articles in the American Nurseryman and in our own Proceedings. He has received a number of awards: the Commercial Citation from the American Horticultural Society, the Thomas Roland Medal from the Massachusetts Horticultural Society, which is awarded for exceptional skill in the field of Horticulture. He is the past-President of the New Jersey Association of Nurserymen and is a past-President of A.A.N. He is the immediate past-President of our own Society — Mr. William Flemer.

The banquet speaker was Mr. William Valavanis, who spoke on "The Bonsai Art".

FRIDAY MORNING SESSION
December 7, 1973

DAVE PATTERSON: At this time I want to introduce you to Dr. Tom Fretz, who will be presenting the first paper this morning; he will also serve as moderator for the remainder of the program. Tom will present two papers on herbicides. The first will consider the causes of success or failure with herbicides and the second will be concerned with the use of herbicides for container nursery stock.

SUCCESS OR FAILURE WITH HERBICIDES?[1]

THOMAS A. FRETZ and ELTON M. SMITH[2]

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Wooster, Ohio 44691

Most herbicide failures we hear of are not herbicide failures. The conditions under which these materials have been used are usually responsible for the so-called "failures", so often quoted. When you consider all the external forces that can ultimately affect herbicidal action, it's a miracle they work at all.

The ultimate fate of an herbicide once introduced into the environment can be seen in Figure 1. Three major degradation processes and six transfer processes play a role in determining the fate of these chemicals. *Biological decomposition* or breakdown by living organisms; *chemical decomposition*, the breakdown by chemical processes in the absence of living organisms; and *photodecomposition*, the degradation by chemical processes involving radiant energy, are the three processes by which herbicides are degraded and their chemical composition changed.

The major transfer processes which affect herbicides in the environment include absorption by plants and animals, retention in vegetation and ultimate transference in the harvested product, adsorption by soil particles, movement through the air and into the atmosphere by volatilization, surface runoff into water sources and movement in soils, either as a liquid or a gas.

Not only are there numerous environmental factors which are involved in herbicidal action, but the chances for human

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[1] Published with the approval of the Director, Ohio Agricultural Research and Development Center, Wooster, Ohio, as Journal Article Number 148-73

[2] Mailing address — 2001 Fyffe Court, Columbus, Ohio 43210.

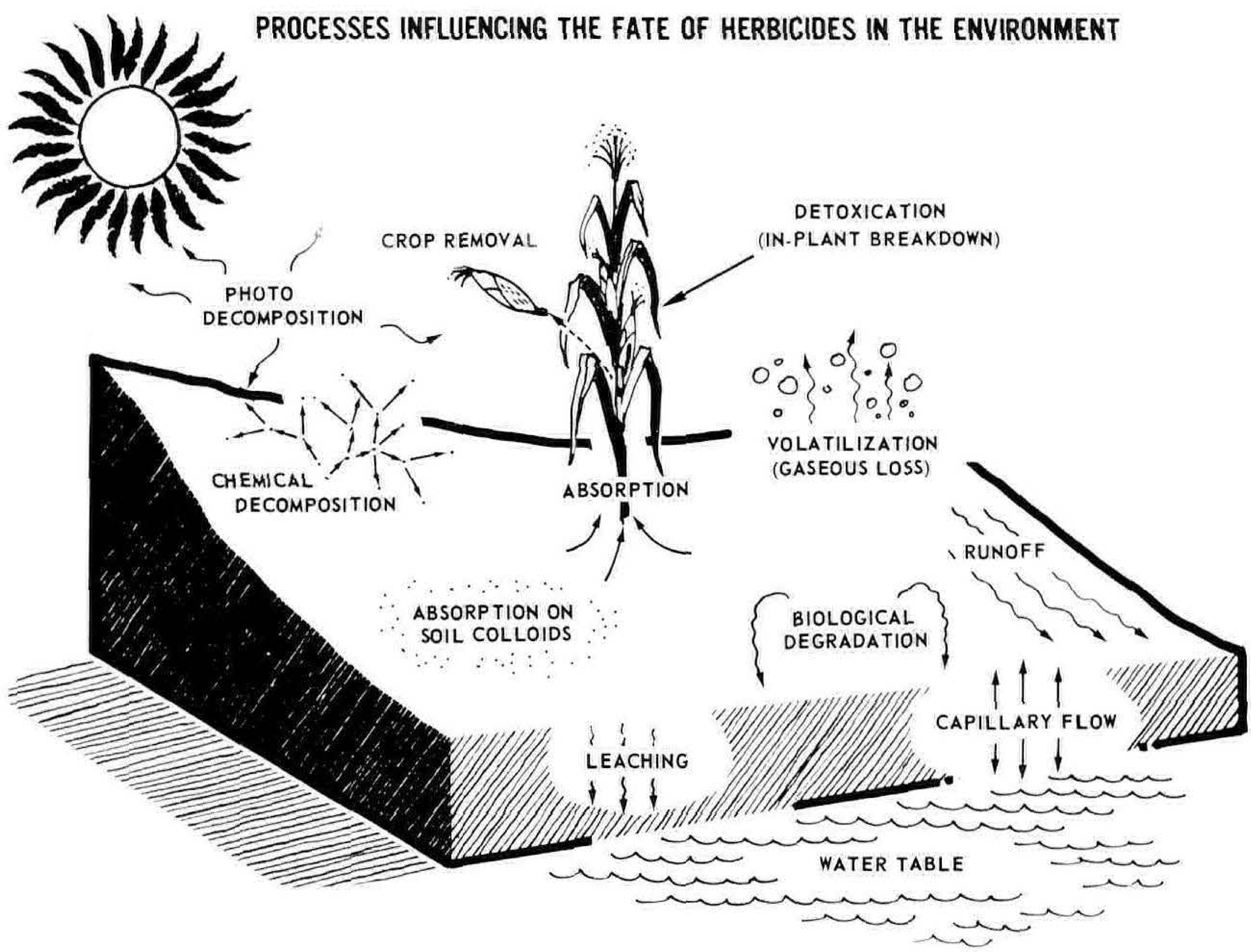

Figure 1. Processes influencing the fate of herbicides in the environment.

error are present from the inital steps of selection through application and crop management. The discussion which follows is not meant to be an excuse for past failures, but to draw attention to the variables so that future failures can be avoided.

THE WEEDS

Proper herbicide selection is extremely important in achieving a successful weed control program, be it corn or nursery crop production. It must always be remembered that herbicides are very selective, and while some control annual grass weeds, others control only annual broadleaf weeds. Still other herbicides have a relatively broad spectrum in terms of weeds controlled.

Knowing the weeds which are present in a particular situation will ultimately help in choosing the proper herbicide for the job. Table 1 is presented as a guide to the intelligent selection of herbicides for control of particular weed species. For example, selecting DCPA (Dacthal) for control of annual broadleaf weeds, almost certainly will result in erratic results.

In addition to considering the major weed species present in the nursery, one must think of increasing weed resistance follow-

Table 1. Weed species response to herbicides [1]

HERBICIDES Common Name and Trade Name	Amaranthaceae (Pigweed Family)	Chenopodiaceae (Goosefoot Family)	Compositae (Daisy Family)	Cruciferae (Mustard Family)	Gramineae (Grass Family)	Leguminosae (Pea Family)	Malvaceae (Mallow Family)	Solanaceae (Nightshade Family)	Euphorbiaceae (Spurge Family)	Polygonum aviculare (Smartweed)	Portulaca oleraceae (Purslane)	Stellaria media (Chickweed)	Convolvulus arevensis (Bindweed)	Cyperus sp (Nutsedge)
	Weed Groups													
Alachlor (Lasso)	*	0	0	0	*	0	0	*	X	0	*	?	0	X
Chlorpropham (CIPC)	*	*	X	*	*	*	X	*	0	*	*	*	0	0
DCPA (Dacthal)	X	*	0	0	*	0	0	X	*	X	*	X	0	0
Dichlobenil (Casaron)	*	*	*	X	X	X	*	*	X	*	*	*	*	*
Diphenamid (Dymid or Enide)	*	X	X	0	*	0	X	0	0	X	X	*	0	0
EPTC (Eptam)	*	X	X	0	*	0	0	*	*	*	*	X	0	*
Linuron (Lorox)	*	*	X	*	*	X	X	*	?	X	*	*	0	0
Simazine (Princep)	X	*	*	*	0	?	X	*	0	*	*	*	0	0
Trifluralin (Treflan)	*	*	0	0	*	0	0	0	X	*	X	*	X	0

[1] From — Lange, A H , 1971 *Agrichemical Age*, Vol 14(4) 5

Key 0 = not controlled, X = partial or erratic control
* = controlled

ing the continual application of a single herbicide. Nearly every nurseryman can cite examples of elimination of annual weeds only to be overrun with perennials. For this reason, the alternating of herbicides, development of an "Herbicide Program", and the use of combinations should be carefully considered.

THE CROP

An herbicide may effectively control weeds in one crop while severely damaging another crop. For example, dichlobenil (Casaron) may be used very effectively on juniper without injury but may cause severe damage on Japanese holly. The application of herbicides to various crops is by far the most exacting task the grower has to perform. The aim is to injure or kill one plant (the weed) while at the same time not injuring another plant (the crop).

Once a grower has decided on the herbicide which is specifically labelled for use on the crops and has an exact knowledge of the weed spectrum involved, he is ready to apply a material which is tailor made for the job.

INFLUENCE ON FOLLOWING CROPS

Some chemicals break down due to biological, chemical, or photodecomposition more readily than others. This may be either an advantage or disadvantage for the nurseryman depending on his cropping system. The advantage would be in terms of full season weed control while a disadvantage would result if either a crop rotation or winter cover drop is used in the nursery. Where a crop is to be removed at the end of the season and replanted, careful selection of the herbicide used in terms of the next crop must be considered. Perhaps where this type of a situation exists, growers should consider planting fields in terms of specific herbicide tolerant crops; for example, blocks of land where only *Taxus* or other simazine-tolerant crops will be planted.

If one uses a system of cover crops during the autumn and winter for winter protection of newly-planted nursery crops in the first or second growth years to prevent soil heaving, selection of the herbicide program must be carefully scrutinized in order to prevent herbicide damage to the cover crop.

TIME OF APPLICATION

Every herbicide has an optimum application time. Preplant herbicides such as trifluralin (Treflan), are applied prior to the planting of the crop, while preemergence herbicides, such as diphenamid (Dymid or Enide) are applied before the weeds emerge from the soil. With nursery crops we generally think of preemergence herbicides as being used on established crops prior to weed emergence. Postemergence herbicides are applied after the weeds have emerged from the soil.

Examples of correct time of application affecting herbicide performance should be familiar to all nurserymen. Dichlobenil, for example, must be applied at temperatures below 50°F (preferable during the winter) to achieve the desired weed control. In addition, we might cite chlorprophram (CIPC) as an herbicide from which a grower can suffer great losses due to wrong time of application. This material is labelled for use on dormant plants and if applied during active growth can cause severe injury.

Likewise, time of application in terms of weed seed germination can greatly affect the herbicide response. For example; simazine application during the winter after the emergence of the cool-season broadleaved weeds will be ineffective, but if applied in the early fall prior to their germination, successful control will generally result.

Thus using the herbicide in the proper manner, at the right rate, and at the proper time can help to insure the best results.

AMOUNT OF HERBICIDE USED

Herbicides often have a very narrow range of activity, between acceptable weed control and crop injury. Few herbicides can be used at excessive rates to insure weed control without causing undue hazard to cultivated crops. As an example, simazine may be used at rates of up to 25 to 30 lb. a.i./A on *Taxus* without injury but the same material at 4 lb. a.i./A will almost certainly injure deciduous species such as *Forsythia* and *Potentilla.*

SOIL TYPE

While herbicides are sold nationwide, no two soil types react exactly the same when it comes to herbicide performance; the triazine herbicides are more effective in clay type soils, while trifluralin and related herbicides are more effective in sandy soils.

In addition, control with the preemergent herbicides can be influenced by various soil surface conditions. For these materials to work best, not only is a weed-free soil surface necessary, but the soil should be freshly tilled or disked. Also of importance, particularly when granular materials are used, is for the soil surface to be relatively smooth in order to achieve a uniform distribution.

So, regardless of the claims made for a new herbicidal material, each grower should examine the material for 2 to 3 years on small areas to ascertain just what it will do under his soil conditions, which will vary in terms of soil organic matter, soil texture, weed spectrum, rainfall pattern, method of application, crop, and cultural practices.

SOIL ORGANIC MATTER

More than any other soil constituent, soil organic matter content determines the activity of herbicides in the soil. If soil organic matter is ignored, be prepared for erratic results from herbicides.

Table 2. Relative absorption of herbicides by soil organic matter [1]

None	—	Dalapon; Paraquat
Weak	—	CDAA (Randox); Propachlor (Ramrod), Chlorambem (Amiben)
Moderate	—	2, 4-D
Strong	—	Alachlor (Lasso); Diphenamid (Dymid or Enide), Dichlobenil (Casaron); EPTC (Eptam; Simazine (Princep), and Terbacil (Sinbar)
Very Strong	—	Diuron (Karmex), Linuron (Lorox), Chlorpropham (CIPC); DCPA (Dacthal), Trifluralin (Treflan)

[1] *From. Warren, G.F 1973 Action of herbicides in soil affected by organic* matter *Weeds Today* Vol 4 (2)·10-12

The importance of organic matter lies in its capacity to attract and hold a variety of molecules through the process of absorption or, more simply, the sticking of the chemical to the surface of the organic matter so that the molecule is not free to move in the soil solution and is thus less available to be taken up by plants.

The relative absorption of some common herbicides by organic matter is listed in Table 2. With nursery soils, especially those used in container production containing large quantities of organic matter, the weakly absorbed herbicides are largely in the solution phase and are readily leached out of the root zone, while the strongly absorbed herbicides give the longest period of weed control due to their strong attachment to the soil organic matter.

Often the strongly absorbed herbicides in these high organic matter soils work to the detriment of good weed control as application rates may be so high they either become uneconomical or exceed the legal limits suggested by the manufacturer. For example, trifluralin must be increased in its rate of application in order to achieve weed control in soils that have high amounts of organic matter (Table 3). In studies of container-grown nursery stock, trifluralin is often used in a range of 4 to 8 lb. a.i./A in order to achieve satisfactory weed control, primarily due to the large quantity of organic matter in the medium.

Table 3. Rate of trifluralin required to achieve desired weed control in soils of varying organic matter [1]

Percent Organic Matter in Soil	Trifluralin, required/A (lbs/Active)
1	1/4
2	1/2
3	3/4
4	1
6	1-1/2
8	2
16	4

[1] From Warren, G F., 1973 Action of herbicides in soil affected by organic matter *Weeds Today*. Vol. 4 (2) 10-12.

WEATHER CONDITIONS

Temperature and moisture have a great deal to do with the success or failure of an herbicide program. Once it is understood how these two factors can influence the killing action of an herbicide one can better decide the kind, amount and best time for application of herbicides.

Actually it is remarkable that weed control successes are as frequent as they are, if we stop to consider the great differences in weather conditions under which these chemicals are applied in the commercial nursery operation. Temperatures may vary from 40° to 100°F; soil moisture from air-dried to flooded; relative humidity from 10 to 100%; sunlight from 1,000 to 10,000 foot candles; and wind from 0 to 50 mph. Under these unpredictable weather conditions, we spray a few ounces of chemical on a half-million or more weeds per acre and the majority of time are rewarded with profitable weed control.

Many things must happen in order for a postemergent herbicide spray to kill weeds. The spray droplets must be caught and held by the leaf surface. Then the chemical must penetrate the leaf surface, often through a waxy surface barrier and move through the plant to the point where some killing action occurs. Temperature and moisture affect the herbicide and the plant, before, during and after the spray application.

TEMPERATURE

Postemergence herbicides generally perform best at warmer air temperatures. The major effect of temperature in this case is on the rate of uptake of the herbicide into the plant. This effect is offset to some extent by the increased rate of drying of the herbicide spray at higher temperatures, as once the spray dries, the penetration of the herbicide into the plant is reduced. Generally, since faster herbicide movement into the plant is favored by high temperatures, more favorable weed control can be obtained if the temperature is high at the time of application.

In addition, the thickness and chemical composition of the cuticle of the leaf surface can be influenced by temperature conditions ultimately affecting postemergence herbicide uptake. Cool night and moderate day temperatures often favor this increased cuticle thickness in some weed species, thereby reducing postemergent herbicide penetration.

Not only does temperature affect herbicide uptake, but temperature can have pronounced effects on the dissipation or losses of herbicides from soils through volatilization and degradation.

Likewise preemergence herbicides perform best at soil temperatures that favor weed seed germination and rapid growth. Cool soil temperatures that delay weed seed germination can reduce preemergent herbicide effectiveness markedly.

In addition, herbicides such as EPTC and trifluralin evaporate readily and their losses as vapors are quite rapid at high temperatures. Obviously such losses can reduce their weed controlling action. In the case of trifluralin and EPTC these volatilazation losses can be decreased by cultural practices, such as physically incorporating them into the soil. Apparently the quicker a volatile herbicide is incorporated into the soil after application, the better. From a practical standpoint, herbicides which must be incorporated into the soil to be effective have a limited application on established nursery stock. Since dichlobenil (Casaron) is so volatile at soil temperatures above 50°F, its use is limited to late fall and winter applications.

Soil temperature can also influence how quickly non-volatile herbicides become inactivated. Atrazine, for example, is rapidly converted by chemical reaction to hydroxyatrazine in moist soils above 75°F, while inactivation is very slow below this temperature. This helps to explain why atrazine residues are not as serious in the southern U.S. as they are in the more northern climates.

MOISTURE

Adequate soil moisture prior to the time of herbicide application stimulates uniform and vigorous growth of weeds. Application of preemergent herbicides under these conditions are thus more likely to succeed than when the soil has been dry at the time of treatment. Dry conditions cause uneven weed seed germination. As a result, proper timing of the preemergent spray application is difficult at best.

Humidity at the time of herbicide application also influences the ultimate weed control especially with postemergent materials. With high relative humidity more herbicide penetrates the leaves and more weeds are killed. Leaves in low relative humidity absorb less herbicide, thereby reducing the plant response.

Heavy rainfall shortly after a foliage application of herbicide may wash the chemical off the leaves before it can be absorbed. The most critical period for rainfall is probably within the first half hour after application.

For preemergence herbicides, rainfall is essential for satisfactory responses. Rain will carry most herbicides into the top 1/2 inch of the soil where the maximum number of weed seeds germinate. A delay in rainfall of more than a few days following application may reduce the degree of weed control. With irrigation systems this effect may be overcome rather easily. For many of the preemergent herbicides, a period of 10 to 14 days without rain following application often causes complete failure. During such a dry period, the herbicide may be destroyed by exposure to sunlight while it lies on the soil surface, or weeds may germinate and emerge without taking up the herbicide.

Heavy rainfall of several inches or more; soon after preemergent application can be detrimental. It may carry the herbicide beyond the depth of the weed seed or may be removed from the site of application by excessive runoff.

SUNLIGHT

Photodecomposition by exposure to ultraviolet light affects many herbicides. Some preemergent herbicides must be immediately incorporated into the soil to prevent this type of breakdown. At the other extreme, some preemergence type herbicides can be left on the soil surface until rainfall or irrigation carries them down to the zone of weed seed germination with no photodecomposition. Even shallow cultivation of these more or less stable herbicides apparently doesn't decrease their effectiveness.

HERBICIDE PROGRAMS

The ideas conveyed so far have dealt with the reasons for successes or failures with herbicides in the past. The key words which we should be using are "Herbicide Programs". Nurserymen should strive for a program of selected materials applied singly, or in combination, in order to achieve year-round weed control. The need in most nursery operations is for fall or early winter applications to remove the winter broadleaf weeds, followed by spring or early summer applications to remove annual and perennial weeds. Many nurserymen do nothing with herbicide programs during the summer months, using the excuse that they want to keep the labor force busy during a relatively slow period during the year. Robbing nursery stock of valuable water and nutrients as a result of unnecessary weed competition and thereby reducing overall growth, just to keep the help busy is certainly not a very valid justification.

In addition, it should be pointed out that observation is an important key to the use of herbicide programs. The nurseryman should not be looking for 100% year-round control with his program, which could result in eventual soil sterilization, but year-round control more in the range of 95%. Thus by carefully observing when weeds are beginning to reinfest a treated area, carefully timed reapplications can be planned.

SUMMARY

This discussion at least calls attention to the fact that herbicides are not perfect. Weather, soil texture, temperature, weed spectrum, soil organic matter, crop, and many other factors alone, and in combination, influence herbicide performance year after year. There may be seasons when, because of these factors, individual herbicide performance varies. But cultural control also varies year to year, so don't give up on herbicides just because of one bad experience.

HERBICIDE COMBINATIONS FOR WEED CONTROL IN CONTAINER NURSERY STOCK[1]

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Abstract. Herbicide combinations were effective in reducing weed growth in container-grown nursery stock. Trifluralin at 4 lb. ai/A and alachlor at 1.5 lb ai/A gave excellent grass weed control, but poor control of broadleaf weeds. Linuron at 1.0 lb, ai/A exhibited excellent broadleaf weed control but poor control of annual grass weeds. When linuron at 1.0 lb ai/A and trifluralin at 4.0 lb ai/A were applied in combination, excellent control of both annual broadleaf and grass weeds was observed.

INTRODUCTION

With the increased emphasis of growing nursery stock in containers, a viable program for weed control is essential. Over the past several years a great deal of information has been pub-

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lished comparing the effects of various individual preemergent herbicides for their ability to control weed growth in nursery containers (1, 2, 3, 5). Several effective herbicides are presently available and labeled for usage on field-grown nursery stock; however, at present there is no single herbicide that will give full season control over a wide range of grass and broadleaf weeds which are evident in container nursery stock production. In order to obtain full season weed control, without the expenditure of excessive manual labor, the use of herbicide combinations much like those presently employed in numerous agronomic crops may be necessary.

The objective of this study was to investigate the performance of several preemergence herbicides for their ability to control a broad spectrum of weeds in container-grown nursery stock, when employed in combination, in an attempt to develop a full season weed control system.

MATERIALS AND METHODS

The experiment was established on May 23, 1972. Uniformly rooted cuttings of *Ilex crenata* Thunb. cv. Helleri and *Rhododendron obtusum* Planc. var. *amoenum* Rehd. cv. Coral Bells were planted in 1 gal polyethylene nursery containers in a medium consisting of unsterilized weed infested loam soil, milled pine bark and builders sand (1:1:1 v/v/v). In addition to the natural weed seed population which was present in the unsterilized loam soil, large crabgrass [*Digitaria sanguinales* (L.) Scop.] and redrooted pigweed [*Amaranthus retroflexus* L.] seed were sown into the medium prior to the potting operation to insure an ample weed population.

The common, trade and chemical names of the preemergent herbicides employed in this study are presented in Table 1. Rates of application for the herbicides used in this study are given in Table 2.

Table 1. Nomenclature and formulations of herbicides utilized on container-grown nursery stock [1]

Common Name	Trade Name and Formulation	Chemical Name
Trifluralin	Treflan (4EC)	a, a, a-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine
Linuron	Lorox (50WP)	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
Alachlor	Lasso (4 EC)	2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide

[1] Common and chemical names accepted by the terminology committee of the Weed Science Society of America

The herbicides were applied with a 1 gal CO_2 constant pressure sprayer calibrated to deliver an 18 inch band at a volume of 40 gal/A. Immediately after treatment on May 24, 1972, all containers were irrigated with one inch of water in order to seal in the herbicides. All plants were then placed on 6 mil black polyethylene in a nursery area for the remainder of the experiment period, and received a standard nursery fertilization and maintenance program.

Weed control and phytotoxicity evaluations were recorded on September 6, 1972, 106 days after herbicide application. The rating system consisted of a 1 to 10 scale in which 1 represents no weed control or crop phytotoxicity and 10 represents complete kill of crops of weeds. On the basis of a previous study on weed competition effects on container-grown woody ornamentals (6), only a rating of 9.0 or greater was considered to be commercially acceptable.

The principal weed species encountered uniformly in all replicates of the experiment during the experimental period were: large crabgrass [*Digitaria sanguinalis* (L.) Scop.], goose grass [*Eleusine indica* (L.) Gaertn.]. crowsfootgrass [*Dactyloctenium aegyptium* (L.) Richter], redroot pigweed [*Amaranthus retroflexus* L.], dogfennel [*Eupatorium capillifolium* (Lam.) Small], and cutleaf eveningprimrose [*Oenothera laciniata* Hill].

Using a completely randomized design, the experiment included 4 replications of each treatment with 3 single plants per experimental unit. All data were subjected to analysis of variance and Duncan's Multiple Range Test (4) to delineate the treatment effects.

RESULTS AND DISCUSSION

Trifluralin, when employed as a single preemergent application at 2 lb.ai/A, gave poor broadleaf and grass weed control. Previous research (5) has shown that this response was expected when trifluralin was employed at a low rate on soils with high organic matter. When trifluralin was employed at 4 lb. ai/A, excellent control of grass weeds was evident; however, even at this rate, trifluralin exhibited poor overall broadleaf weed control (Table 2). Similar results were obtained when alachlor was employed at 1.5 lb. ai/A. Single applications of linuron gave excellent control of broadleaf weed species, but with little grass controlling ability (Table 2).

In regard to the various combination treatments employed in this study, trifluralin + alachlor combinations at both the 2.0 + 1.5 and 4.0 + 1.5 lb. ai/A rates gave excellent grass weed control, with both species of nursery crops employed in this test, but did not show a significant improvement in ability to control broadleaf weed growth when compared to either rate of trifluralin singly applied (Table 2).

The trifluralin + linuron combination, when employed at the 2.0 + 1.0 lb. ai/A rate, gave excellent grass weed control along with a significant improvement in broadleaf weed control when compared to a single application of trifluralin. When this same trifluralin + linuron combination was used at the 4.0 + 1.0 lb. ai/A rate, both grass and broadleaf weed control was significantly better than either of the materials when used singly (Table 2).

None of the herbicides alone, or in a combination, resulted in any visible phytotoxicity or injury to either of the container-grown test species used in this study (Table 2). While other combinations were not within the scope of this experiment, they should be explored in order to find materials which would give control to the broader spectrum of weed species which are presently indigenous to container nursery stock.

While this study is in no way inclusive, the results do indicate that herbicide combination treatments, such as the trifluralin + linuron at the 4.0 + 1.0 lb.ai/A rate, may provide a means to obtain weed control of a greater spectrum of weed species with no injury to container grown nursery stock. Similar studies using herbicide combinations were conducted during the summer of 1973, and the results appear to substantiate those reported from the 1972 growing season.

Table 2. Effect of various herbicides employed singly or in combination on weed growth and plant phytotoxicity in container-grown Coral Bells azalea and Helleri holly in 1972

Herbicide Treatment	Rate lb ai/A	Coral Bells azalea Weed Control[z] Broadleaf	Coral Bells azalea Weed Control Grass	Coral Bells azalea Injury	Helleri holly Weed Control Broadleaf	Helleri holly Weed Control Grass	Helleri holly Injury
Trifluralin	2.0	5 8 efg[y]	6 0 bc	1 0[ns x]	5 0 e	5 8 c	1.0[ns]
Trifluralin	4 0	5 8 efg	9 0 a	1 0	5 8 de	20 0 a	1 0
Alachlor	1 5	5 8 efg	9 5 a	1,0	7.5 bc	9.0 bc	1 0
Linuron	1 0	8 3 abcd	5.3 c	1 0	9 7 a	5.5 c	1 0
Trifluralin + Alachlor	2 0+1.5	7 0 cde	10 0 a	1 0	6 8 cd	10 0 a	1 0
Trifluralin + Linuron	2.0+1 0	7 5 bdc	8 5 ab	1 0	7 5 bc	9 3 a	1.0
Trifluralin + Alachlor	4 0+1 5	6 5 def	10 0 a	1 0	6 8 cd	10 0 a	1 0
Trifluralin + Linuron	4.0+1 0	9 0 ab	9 2 a	1 0	8 5 b	10 0 a	1 0
Non-Weeded Control	—	4 7 fg	1.8 d	1 0	6.5 cd	2 8 d	1 0
Hand Weeded Control	—	10 0 a	10 0 a	1 0	10 0 a	10.0 a	1 0

[z] Rating Scale 1 0 = no weed control and/or crop injury, 10 0 = complete kill of weeds and/or crop

[y] Means in a column followed by the same letter or letters are not significant at the 5% probability level

[x] Not significantly different at the 5% probability level

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MODERATOR FRETZ: Our next speaker is Charley Parkerson and Charley is going to do something a little different. He is going to show us a movie which he made concerning some of the work he has been doing.

CHEMICALS HELP CONTROL WEEDS IN CONTAINERS

CHARLES H. PARKERSON

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We, like all businessmen and — in particular — those that deal with nature, are faced with many problems — weather, labor, finances, and one universal bug-a-boo for the agricultural entrepreneur, WEEDS

Weeds are a problem because they affect plant growth, cause unsightliness of our nursery, and present a labor and financial burden. It is hard to say what single factor really pushed us to turn to the bags of chemicals that we had sitting in the back of the shed but never used. We had an experience with a herbicide about 5 years ago. Before the use of the herbicide, we had 50 weed species, and after its use we had 5 species of weeds present. These 5 together were more of a problem than the 50 we started with. I think the one thing that pushed us to the breaking point was our desire to use one of the slow-release fertilizers that cost somewhere around $15.00 per bag. We could not justify sending labor into the field to pull weeds and at the same time pull and eventually throw away this costly fertilizer.

Our nursery is similar to yours in most ways but vitally different in many respects. What I am about to say works for us, in our particular micro-climate. What I recommend may not work at your place, so check it out first. I am sure that most of you are in the same boat that we are in — everything that you have in the world is sitting out in those fields, so please run your own trials before throwing around a bunch of chemicals you have read or heard about. One other small point that I wish to make is that no herbicide will do you any good while it's still in the bag. I have told friends the success that we have had with a particular chemical, and they answer something like . . . "Yea, I've got some in the barn, but it has shown me nothing yet." Of course it hasn't. They only work when applied in an accurate and timely manner. In general, we use three chemicals, methyl bromide, Lasso and Casoron, to help us in controlling weeds in containers.

Methyl Bromide. Since our container mix contains 20% soil, our first effort at control starts by gassing the soil with methyl bromide at the rate of 1 lb/cu yd. This gives us control of existing weed seeds and gets us off to a fairly clean start.

Our real problems start after the containers have been in the field for about 5 to 6 weeks. Weed populations develop, and we have to start the costly task of hand weeding. I can't give you a dollar figure per plant or per acre of the cost involved in hand weeding. The only way I can judge it is that it took four women weeding all the time from March to November, plus additional help when things really got bad, to keep the weeds under control. Even then we really were not clean. We don't have a lot of plants to take care of, somewhere in the neighborhood of 250,00 1-gal and 50,000 5-gal cans. Many of you that have more containers use no herbicides and keep clean with less help. However, in our situation — thinking my employees are very conscientious and work pretty hard most of the time — we just could not keep up with the weeds.

We were crying the blues all over the place and asked for help from the local Virginia Truck and Ornamental Research Station. We supplied the plants, and research was done at our place by Dr. Henry Wilson, a vegetable man by trade. Research was conducted on a wide variety of plant material, using about 20 different herbicides, one of which was Lasso, a corn herbicide. On the basis of this research, Lasso 10 G was selected as a prime candidate for a closer look.

Lasso. After a little work on our own and a few mistakes, we decided to go with Lasso 10 G. I might add that sometimes mistakes can be your best friend. In a herbicide trial, I applied the small amount of chemical needed by use of a salt shaker. In one of my calculations for the Lasso plot, I let a decimal slip the wrong way and, in fact, applied the material at 10 times the suggested rate. Boy, I was mad at myself at first, but the plants showed no signs of being damaged, and a mistake turned into a real confidence builder.

The rate of Lasso 10 G that we use is 40 lbs/A as it comes from the bag. The frequency of application is not a hard and fast rule. Generally I wait until a block is planted and treat the entire block at one time. The first application is about 3 weeks after planting. I have gone in much sooner, but I prefer to wait. As a good rule of thumb, we apply the material every 8 weeks, starting in March and continuing until September. I try to put the material down on the entire farm in one pass, so to speak. If a planted block has received Lasso less than 5 weeks before, I do not re-apply to that block, and it will have to go an additional 8 weeks before it receives a second treatment. So in some cases, plants receive a treatment as close as 6 weeks and in others it may go 12 or 13 weeks.

Application is made to the plant beds using a broadcast rotary applicator. I caution you to calibrate your applicator prior to every use. Lasso is available in both granular and liquid formulations, but we prefer the granular formulation because it only takes one man to do the job, and it is easier than dragging hoses and working with nozzles and pumps. The only problem that we have is that Lasso 10 G is a very fine granular material and on windy days there is a problem in getting even distribution. We use it on most all our plants — all hollies, ligustrum, pines, white flowering dogwood, all junipers, yucca, magnolia, and cleyera.

Almost all of the plants that we propagate are started as cuttings taken from plants growing in our fields and have been treated with Lasso. We have not noticed any change in the rooting of plants treated with this chemical.

We have been more than pleased with the results so far. Now after 2 years of testing and 2 years of use, I am even more excited with the results than at first. We have not been able to eliminate all weeds, in particular the tough broadleaf ones such as clover. By elimination of most grasses, we have decreased our weeding activities to two women and they are not on weeding exclusively. From our experience, Lasso deserves a close look in your herbicide program. **Caution:** Lasso should not be used in greenhouses; severe damage has been reported from such use.

Lasso presents one big problem, however, that I would like to share with your. This material is not registered for use in ornamentals, and I am quite confident that it never will have a label for use on ornamentals. What I have just given may be against the law. Pesticide legislation is going to get worse before it gets better, and I am not sure how much longer we can use this material. Some official may come and close me down tomorrow, but if a few of you in this room try it and like it and you share it with a friend, then maybe someday our market for this material will be large enough to encourage the manufacturer to label this chemical for our use.

Casoron. We have been using this herbicide on *Pyracantha* spp. for the past 5 seasons. Once a year, as a general rule in late January or early February, we apply the granular form, using a broadcast application at the rate of 120 lb/A. We have had excellent results, requiring only touch-up weeding. I am happy to say we never weed firethorn.

Prior to last year, we were using a higher rate of Casoron and observed a yellow leaf margin. This yellowing did not hinder growth nor the rooting of cuttings taken from affected plants. The only real problem came from customers wondering if they had received a new special kind of pyracantha. This year at the 120 pound rate, I truly had to hunt for an example of plants with yellow leaf margins.

This leads me to another interesting point that I would like to make. Our using Casoron and practically eliminating weeds in pyracantha has proved to be a morale booster for my help. When your workers know that you realize what a terrible job weeding is, expecially in thorny or prickly plants and they can see that you care and are trying to help them, it is truly an indirect benefit to your business.

MODERATOR FRETZ: Thank you, Charley; your presentation is a first for this Society as far as I am aware of. I thought you did a good job of indicating the need for calibration of equipment used for application of herbicides. Our next speaker is Dr. Elton Smith who will talk about chemical weed control in lining-out beds.

CHEMICAL WEED CONTROL IN LINING-OUT BEDS

ELTON M. SMITH

The Ohio State University
Columbus, Ohio 43210

INTRODUCTION

Weed control in lining-out beds has always been expensive, since weeds have been controlled for the most part by manual labor. With beds usually composed of small plants, weeds must be removed frequently to reduce the competition primarily for light, but for moisture and nutrients as well. Although, women and teen-agers have been used extensively for weeding the labor costs have steadily increased to well over the $600/A/yr for weeding field stock as reported by Johnson in 1962 (1).

In recent years, pre-emergence herbicides have been used extensively by nurserymen in field stock but not in lining-out beds. Among the reasons for limited use in liner beds are: 1) fear of herbicide damage to small plants with a limited root system; 2) with large numbers of plants in a small area, concern that a mistake will eliminate a future crop; 3) often, lining-out beds contain numerous cultivars of plants and herbicide selection becomes more difficult; and 4) certain herbicides such as Treflan are not as effective in beds amended with peat or other organic materials.

Research workers have shown that herbicides can be safely used in lining-out beds (3, 4) with savings in labor of up to 70% (2). The objective of studies conducted in liner beds in commercial nurseries in Ohio for the past several years have been to determine those herbicides which will result in satisfactory weed control over an extended period of time with a minimum of plant injury.

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MATERIALS AND METHODS

The studies during the growing seasons of 1972-1973 were conducted in Fox silt loam soils with a pH range of 6.2 to 6.7. The herbicides were applied with 4 gal pressure-type tank sprayers or with rotary spreaders within 10 days following planting in April and May. All plots were irrigated immediately following treatment.

The predominant annual weed species encountered in most studies was galinsoga [*Galinsoga parviflora*] which is somewhat resistant to many herbicides. Other prevalent weed species included foxtail, crabgrass, lambsquarters, purslane, pigweed, and ragweed. The plant materials were a mixture of deciduous shrubs which had been rooted the previous summer and autumn.

RESULTS AND DISCUSSION

In the 1972 study the principal objective was to control galinsoga and the results, summarized in Table 1, indicate that Lasso, Princep, and Princep combinations were the most effective herbicides. In this study the plant materials were deciduous shrubs, most of which were susceptible to Princep, and injury was prevalent as shown in Table 2.

Table 1. Galinsoga control in lining-out stock

Treatment	Pounds a.i./A	% Galinsoga Control After 8 weeks
Check		0
Treflan	2.0	50
Dymid	8.0	70
Chloro IPC	10.0	80
Lasso	2.5	90
Princep	1.0	100
Princep + Lasso	1.0 + 4.0	100
Princep + Treflan	1.0 + 2.0	100

Since Lasso is not registered for nursery crop use, broad spectrum application would be limited to using Chloro IPC or possibly Dymid, although the latter in subsequent trials has not consistently controlled galinsoga.

In 1973, trials were conducted to evaluate control of both annual grasses and broadleaf weeds with new herbicides including some labelled herbicides for comparison. The results after 7 weeks (Table 3) indicate that Lasso and a numbered compound from Amchem (A-820), alone and in combination, were the most effective materials in controlling a mixture of weeds.

Table 2. Phytotoxicity to lining-out stock

Treatment	Pounds a.i./A	Injury Rating*			
		Spreading cotoneaster	Chenault viburnum	Bronxensis forsythia	Snowmound spirea
Check		0	0	0	0
Treflan	2 0	0	0	0	10
Dymid	8 0	10	0	0	20
Chloro IPC	10.0	0	20	40	30
Lasso	2 5	10	10	10	30
Princep	1.0	10	10	40	70
Princep + Lasso	1 0+4 0	10	10	60	70
Princep + Treflan	1.0+2.0	0	10	30	90

* 0 = No injury, 100 = Complete death Values above 30 are considered too injurious for use

Table 3. Annual grass and broadleaf weed control in lining-out stock.

Treatment	Pounds a.i./A	Percent Weed Control (7 Weeks)
Check		0
Lasso 4E	2.0	70
Lasso 4E	3.0	90
A-810 4E	3.0	70
A-820 + Dymid 4E + 80W	3.0 + 5.0	70
A-820 + Amiben 4E + 2E	3.0 + 2.0	80
A-820 4E	4.0	80
Treflan 4E	1.0	80
Dymid 80W	8.0	60
Amiben 2E	2.0	50
Betasan 3.6G	12.5	50

There was no appreciable injury associated with the ornamentals which included: flowering almond, regels privet, winged euonymus, bronxensis forsythia, vanhoutte spirea, and compact American cranberrybush viburnum.

SUMMARY

Based on these and other studies, herbicides for use in controlling weeds in liner beds must be selected on the basis of weed species anticipated, ornamentals present and soil type. In general, the safest labelled herbicides include Treflan, Dacthal, Chloro IPC, and diphenamid. These herbicides control weeds for only a few weeks and must be applied more than once a season. Princep and its combinations can be used with certain crops and will remain effective for 2 to 3 months or longer. Lasso and

A-820 show promise but are not currently registered for nursery use.

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1. Bingham, S.W. 1968. Economic evaluation for weed control in field-lined woody ornamental nursery crops. Proc. Amer. Soc. Hort. Sci. 92:704-712.
2. Bingham, S.W. 1968. Influence of herbicides on Japanese holly and hand labor for weed control. *Weed Science.* 15:478-481.
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4. Smith, E.M. 1972. Controlling galinsoga in lining-out stock. *Nursery Notes.* 5:4-5.

MODERATOR FRETZ: We are still running behind time and all questions will have to be deferred until this evening's program. Our next speaker is William Bennett who will speak on herbicides and combinations in field liners.

HERBICIDES AND COMBINATIONS IN FIELD LINERS

WILLIAM J. BENNETT

Cooperative Extension Service
West Springfield, Mass. 01089

Chemical weed control programs for nursery crops have been adopted at an increasing rate over the past several years. Effective herbicides have been developed and tested and nursery operators have shown cost reductions for weed control when compared to mechanical methods. Injury to nursery crops has been negligible when recommended herbicides are used at the correct time and at suggested rates of application.

Field trials of many herbicides and combinations of two or more chemicals have been conducted in Massachusetts by the Cooperative Extension Service for several years. Growers and chemical companies have been very cooperative in making these possible. In designing various field trials several considerations were basic to the decision making process. These are as follows:

1. The first flush of weed growth following transplanting is probably the most important to control effectively.
2. Granular formulations are much more practical for the smaller grower or the treatment of smaller blocks of similar plant material.

A-820 show promise but are not currently registered for nursery use.

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1. The first flush of weed growth following transplanting is probably the most important to control effectively.
2. Granular formulations are much more practical for the smaller grower or the treatment of smaller blocks of similar plant material.

3. Simazine is basic to any nursery herbicide program but it has limitations, e.g. weak on annual grass control.
4. Combinations of simazine at relatively low rates (1 lb. a.i./A) and one of several herbicides effective against annual grasses generally result in effective broad spectrum weed control and minimal plant injury.

SENSITIVITY OF NEWLY PLANTED NURSERY CROPS

Trials during 1965 and 1966 were designed to determine the toxicity of several herbicides and herbicide combinations to newly planted nursery psecies and were established in the three Extension regions of Massachusetts. Rooted cuttings were planted in May of each year, herbicides were applied, and a 1-inch irrigation followed. Trial plots ranged in size from 72 to 120 square feet. Plots were replicated two or three times at the various locations. Plant species were chosen which were known to be sensitive to the usual rates of simazine. These included *Euonymous alatus* 'Compactus,' *Forsythia* x *intermedia* and *Ligustrum ibolium* (privet). Soil types included sandy loam (Barnstable), medium loam (Hathorne), and silt loam (Amherst). Weed species existing in the trial areas included smartweed [*Polygonum scabrum*, Moench], galinsoga [*Galinsoga ciliata* (Raf.) Blake], purslane [*Portulaca oleraceae*], lambsquarters [Chenopodium *album* L.], foxtail [*Setaria viridis* (L.) Beauv.], barnyard grass [*Echinochloa crus-galli* (L) Beauv.], and crabgrass [*Digitaria sanguinalis* (L.) Scop].

Simazine, and combinations including simazine, resulted in severe injury in all plots in 1965 where wettable powder formulations were used. Plant injury in all cases appeared as yellowing and chlorosis of leaf margins usually recognized as simazine injury.

In 1966, when granular formulations were used, injury was also greatest in all simazine plots, although generally not as severe as with wettable powders. The 1965 results prompted the inclusion of trifluralin and a dacthal + diphenamid combination in 1966 trials.

Under the severe conditions of these trials the injury to nursery plants was much greater than could be tolerated in commercial practice. Results indicated however that effective weed control could be achieved with combinations of herbicides. Table 1 shows results of these trials. Trifluralin at 1 or 2 lbs. a.i./A in either liquid or granular form did not provide satisfactory weed control. Plant injury with these treatments was negligible. The combination of dacthal + diphenamid performed similarly to the trifluralin. Simazine at 2 lbs. a.i./A resulted in only slightly improved weed control while at the same time causing severe plant damage. The combinations of simazine 1 lb. a.i./A + diphenamid 4 lbs. a.i./A in both wettable powder and granular formulations provided increased weed control and a reduction in plant injury. This combination resulted in less plant injury in the granular formulation.

GRANULAR COMBINATIONS

For several years following these trials our intention has been to investigate the efficacy of newer grass herbicides as they became available and methods of application. These have been used in combination with simazine in all cases. At various times one or more major herbicide producer showed an interest in combinations of materials formulated on one granule. These were incorporated into the field trials during the years 1968-1970. Some of the combinations investigated during the time included:

simazine 1 lb. a.i.A	+	DCPA 10 lbs. a.i./A
"	+	diphenamid 4 lbs. a.i./A
"	+	trifluralin 2 lbs. a.i./A
"	+	alachlor 4 lbs. a.i./A

Table 1. Average weed control and plant injury ratings to newly set nursery crops

Treatments	Average Weed Control Ratings[1] (Amherst)	(Barnstable)	(Hathorne)	Average Plant Injury Ratings[2] (Privet)	(Forsythia)	(euonymous)
1 Treflan 1 lb Liquid	5.7	5.7	5.7	9.0	9.0	9.0
2 Treflan 2 lbs Liquid	6.7	5.7	6.7	9.0	9.0	8.3
3 Treflan 1 lb Gr	3.3	2.3	3.7	9.0	9.0	8.5
4 Treflan 2 lbs Gr	5.3	4.0	5.7	9.0	9.0	8.1
5 Dacthal 5 lbs Gr +Diphenamid 2 lbs. Gr	5.7	5.0	5.7	9.0	8.9	8.4
6 Simazine 2 lbs Gr	6.0	4.3	6.0	4.4	4.5	4.8
7 Simazine 1 lb Gr +Diphenamid 4 lbs Gr	6.3	6.0	6.7	5.7	6.5	5.9
8 Simazine 1 lb Gr.	7.3	3.7	7.7	6.1	6.5	6.3
9 Simazine 1 lb W P +Diphenamid 4 lbs W P	8.7	6.0	8.7	4.5	5.2	4.4
10 Check	1.0	1.0	1.0	9.0	9.0	9.0

[1] Weed Control Rating — 9.0 = perfect control, 7.0 = acceptable commercial control, 1.0 = no control

[2] Injury Rating — 9.0 = no injury; 1.0 = severe injury

Results with these combinations on a wide range of nursery species have been generally satisfactory in controlling annual weeds. They were applied following planting in May or June or immediately following a June clean-up of established nursery blocks. It was hoped that some of these combinations would be made available to the nursery trade, but this became less likely as time progressed. It appeared that unless both chemicals were products of the same company it was not realisitic to expect to see them on the market as one material. Many considerations such as registration procedures, liability determinations and others must be weighed in these policy determinations. Recent rulings by the Environmental Protection Agency now allow the mixing of registered chemicals to be applied as a tank-mix. This may encourage manufacturers to investigate the market potential of herbicide combinations.

FIELD MIXTURES OF GRANULAR HERBICIDES

During 1972 and 1973 field trials were established to determine the feasibility of blending or mixing commercially available granular herbicides prior to application to nursery stock. The mixing of two or more granules of dissimilar size and density has always been thought to result in uneven distribution. This could result in unsatisfactory weed control and/or plant injury.

Simazine (4% Gr) at 1 lb. a.i./A was field mixed with several grass killers in duplicated plots in three nurseries in June, 1972. Grass killers included the following: trifluralin (5% Gr) at 2 lbs. a.i./A; bensulide (3.6% Gr) at 8 lbs. a.i./A; alachlor (10% Gr) at 4 lbs. a.i./A; Amchem A 820 (2.3% Gr) at 4 lbs. a.i./A; Devrinol* (10% Gr) at 4 lbs. a.i./A; Geigy CG 10832 (2% Gr) at 2 lbs. a.i./A; and diphenamid (5% Gr) at 6 lbs. a.i./A. All materials were surface applied to weed-free soil with a hand applicator.

Predominant weed species included crabgrass, foxtail, pigweed, lambsquarters, and knawel [*Scleranthus annuus* L.]

All combinations except simazine 1 lbs. a.i./A + betasan 8 lbs. a.i./A and simazine 1 lb. a.i./A + diphenamid 6 lbs. a.i./A resulted in satisfactory weed control. Results are shown in Table 2.

Additional trials of the most promising of these combinations were conducted during the fall of 1972 and spring 1973. Fall treatments were applied in November and evaluations were made in May and June, 1973. All combinations resulted in satisfactory weed control under the conditions of these trials.

The 1973 trials were initiated in June and July at two nurseries. Plot size was increased from 200 to 250 sq ft in 1972 to 2200 to 2500 sq ft in 1973. This was an attempt to determine if distribution uniformity was satisfactory on larger areas. Evaluations in September and October showed satisfactory control of annual weeds. These trials included a rather large number of plant genera including *Taxus*, *Acer*, *Malus*, *Quercus*, *Sorbus*, *Gleditsia* and *Crataegus*.

* Trade Name

Table 2. Average weed control ratings with granular mixtures

Granular Mixture	Rate lbs a.i./A	Weed Control* Broadleaf	Grass
Simazine 4G + Trifluralin 5G	1 + 2	7.6	7 3
Simazine 4G + Bensulide 3 6G	1 + 8	6 6	5 6
Simazine 4G + Alachlor 10G	1 + 4	8 0	7.6
Simazine 4G + Amchem (A-820) 2 3G	1 + 4	8 0	7.6
Simazine 4G + Devrinol 10G	1 + 4	8 0	8 3
Simazine 4G + Geigy (CG-10832) 2G	1+ 2	8 3	7.0
Simazine 4G + Diphenamid 5G	1 + 6	7.0	6 3
Check		4 6	1.6

* Rating System: 1.0 = no control 9.0 = complete control

MODERATOR FRETZ: We have time for a couple of questions which can be directed to any of this morning's speakers.

JIM WELLS: I've always been rather dubious about using herbicides in a plastic house and I wonder what comments some of these speakers have along this line.

PHIL CARPENTER: I think Lasso is an excellent material for use in the field but if you use it inside a plastic house you're just asking for trouble. Two of our people in Indiana used it and they both had real problems.

HUGH STEAVENSON: We goofed and used Lasso in a house and I can guarantee that if you do it you will have trouble. You should not only not use an herbicide in a greenhouse but you should not even use it near a greenhouse where it could be sucked in by the fans.

FRANCIS GOUIN: We have had some drastic losses in Maryland from the use of Casoron in greenhouses. If you do get into trouble one thing which has alleviated some of the problem has been the use of activated charcoal at the rate of 1/2 pound per 100 sq ft and keep the area fairly moist.

MODERATOR FRETZ: This concludes this morning's session.

FRIDAY AFTERNOON SESSION
December 7, 1973

MODERATOR ZONDAG: The first paper of this afternoon's program will be presented by Dr. Paul Smeal who is going to tell us about efficiency in the nursery.

EFFICIENCY IN THE NURSERY

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Efficiency may be defined as the quality or degree of being efficient or, in production terms, a comparison of output with cost in energy, time, money, materials, labor, etc. Efficiency defined in its simplest term is to accomplish the task with the least amount of time and effort. Nursery efficiency and industrial management are similar in that both refer to the highly organized modern method of carrying on production of industrial operations.

As one looks at industrial management, the growth of manufacturing requires special supervision of machinery and the elimination of inefficiency. The first sustained effort in this direction was made in the 1880's by F.W. Taylor of the Midvale Steel Company. The motions of workers were studied to speed up production by cutting out excess movements. Such time and motion studies of the flow of materials through the plant became a major item of inquiry, as did product design. Relations with workers became the subject of industrial psychology. Soon after, much attention was given to improving worker morale by providing better facilities and new incentives, such as a chance for advancement and, occasionally, a voice in management. Other items that have come to be the concern of management include safety devices, better sanitation, rest, eating, and recreation facilities, health insurance, and pensions.

Efficiency should have top priority in any nursery, and it is vital to all personnel, from the owner to each individual employee. To help put efficiency into the proper perspective, it may be desirable to ask what, when, where, how and who is efficient in the nursery.

"What is efficiency", has previously been defined as accomplishing the given task or job with the least amount of time, materials, effort and expense.

When does efficiency take place? It should be taking place at all times. The question in the mind of the manager, foreman and every employee should be, "is there a more efficient way to accomplish the task?". All ideas should be given, received and tried. The employee generating good ideas should be rewarded, encouraging fellow employees to become interested in improving all phases of production. Have the foreman and the laborers develop goals and when these goals are met, reward them with an incentive. Set realistic goals that can be reached and, once reached, raise them slightly higher and make the incentive such that the employee will excel to reach these new goals.

Where does efficiency take place? In respect to management, is the efficient planning and execution of their responsibilities apparent? This could be anything from planning the production schedules, production practices, harvesting and marketing, to answering the correspondence promptly. Are the foremen organized and efficient in outlining the jobs and tasks to employees responsible to them? Are the tools, equipment and supplies readily available? Have the individuals become responsible for their tools and equipment? If you have been able to answer yes, then you are on the way to perfecting efficiency in your nursery.

How is efficiency accomplished? Someone in the management organization must be given the responsibility and authority to make changes to improve efficiency. It does little good to generate new ideas and then never try them or attempt to adopt them within the organization. The best way to improve efficiency is to tell yourself that there has to be a better, faster, less expensive way to accomplish the job. Then, utilizing the many resources available to you (your fellow nurserymen being one of the largest resources, as well as salesmen, university personnel, etc.), attack the problem at hand.

In conclusion, remember the five P's: Prior Planning Prevents Poor Performance. There will be efficiency if poor performance is eliminated.

MODERATOR ZONDAG: Thank you, Paul. Our next speaker is John Roller who will tell us about a program for growing crabapples.

PROGRAM FOR GROWING CRABAPPLES

JOHN B. ROLLER
Cartwright Nurseries
Collierville, Tennessee 38017

Our original method for production of crabapples was by budding. This program was dropped for two reasons; first, we had to rely on school boys who had no experience in budding and, since we rarely got the same boys back 2 years in succession, this meant continuous teaching of budders year after year. The second reason was the percentage of "dog-legs" that we got from budded trees. Many of them seemed to grow straight out — then up; at best they were second-rate trees.

The poor stands from inexperienced budders and the percentage of "dog-legs", plus the fact that cutting off the understocks came at a time when we were very busy with other work, combined to make this a poor method of producing crabapples, so it was discontinued. Then for two seasons we bought crabapple whips from outside sources. This solved all of our problems except the "dog-legs," as our source budded their trees and we still had "dog-leg" trees.

We decided to go back to the old-fashioned method of whip grafting, using salaried personnel and doing the grafting when the weather was too bad to work outside. However this was not satisfactory because most of the men had other duties that kept interrupting the grafting. During this time the grafts were made and packed in spaghnum moss, sawdust, etc., then placed in cold storage until planting time. This necessitated going through them periodically, checking to see if they were too wet or too dry and throwing away the bad ones. It didn't take long to see we were fighting a losing battle.

After this we did what we should have done all along. We made the apple grafting the responsibility of the propagating department and developed the following program: As soon as we complete our juniper grafting — usually late January to mid-February, we make the apple grafts. We prepare whip grafts, wrapped with waxed string. The completed grafts are counted and put in 3x9x18 inch plastic poultry bags tied at the top. These are placed in wooden crates or cardboard boxes and put into cold storage until planting time. The natural condensation seems to provide the right amount of moisture to hold them until planting time. To check them, all we do is pick up a sack and look at it. This eliminated the laborious task of unpacking and repacking to see if the grafts were too dry to too wet and throwing away the bad ones. In the plastic bags they will keep for 3 months, if necessary, without any loss and without excessive callus formation.

Our percentage of good trees jumped to 95% in the field. The only critical thing is that they must be planted deeply enough so that the graft union is well below the ground level. If it is allowed to dry out it is a dead graft. Our grafts are normally planted in the field the first week in March but any time in March will do. We use our regular planter and plant at our regular spacing.

Following this program we are able to get excellent stands and, as for growth, grafts planted in early to mid-March will give us whips that are from 2 to 5 ft, lightly branched; about 70% are 3 to 4 ft; about 17% are 2 to 3 ft; and 12% are 4 to 5 ft, if grown in good soil. These are good straight whips. However, there are always exceptions. For instance, last year was an exceptional year almost all over the United States; it began to rain excessively in Tennessee in late October and continued into the spring. We were unable to complete our regular field plantings until June. Due to these adverse weather conditions we were not able to adhere to our time table. We had completed our juniper grafting earlier than usual and optomistically went ahead with our apple grafting. This was completed in January but we were unable to plant them until May 10; consequently our percentage of live trees dropped to 75 to 80%. This reduction in percentage of live grafts, we think, was caused by dry, windy weather immediately after planting The loss of 60 days growing time reduced the growth of our trees in proportion and our heaviest ones were only 3 to 4 ft in height. I have often wondered what the results would have been if they had been packed in wood shavings or sawdust and held from January until May.

Now, which is more economical, budding or grafting? Usually budding is the cheaper method of producing most fruit and some ornamental trees but I am firmly convinced that, in crabapple production, grafting is the most economical method. The actual labor cost of the grafting operation is about 2-1/2 cents; the cost of plastic, $7.50 per thousand; the cost of wrapping twine, $2.00 for a 6 inch tube that will wrap 2000 to 2500 grafts; add the cost of the roots and the total cost comes to about 5 cents per graft. Balance this against the cost of budding, budding strips, suckering costs, the number of plants too crooked to be usable, plus land rent for 1 to 2 years before transplanting, the transplanting costs, and you can make your own cost comparison.

The grafting method has worked out exceedingly well for us. It is true that northern growers with a shorter growing season can not plant their grafts as early as we normally do and therefore could not get the growth that we get in a normal season. We believe this is the best method of producing crabapples in our area and we are going to stick with it.

MODERATOR ZONDAG: I'm sure there are many questions but because we are running late we will continue with the program and if there is time at the end of the program we will handle questions then. Our next speaker is Wayne Mezitt, who will tell us about his methods of grafting unusual shapes and forms.

GRAFTING TO OBTAIN UNUSUAL SHAPES AND FORMS

R. WAYNE MEZITT

Weston Nurseries, Inc.
Hopkinton, Mass. 01748

INTRODUCTION

The types of plants I graft are usually dwarf or weeping cultivars of the various species on which they are grafted as rootstocks. The unusual shapes and forms are the result of the subsequent growth of the grafted plant. Most of the plants are top-grafted, from 1 to 6 ft. high although some are grafted in tiers, using side grafts, depending upon the effect desired. Most propagators are familiar with simple top-grafting techniques. Those who have toured nurseries have undoubtedly seen *Cotoneaster* cultivars, *Acer palmatum* 'Dissectum,' and *Syringa velutina (s. palibiniana)* as well as other plants grafted on standard rootstocks. My report is an extension of these procedures, drawing from my experience over the past few years.

REASONS FOR GRAFTING

An important reason for top-grafting is to provide interesting and unusual plants for use in landscaping. Such plants become more important as the people who use plants become more sophisticated and look for something different. Also most of these are slow growing and require very little maintenance. Their relatively small size allows them to be planted in pots or tubs and moved whenever desired.

Another reason is to create "mature" specimens faster than by conventional techniques. A 5 or 6 yr old *Chamaecyparis obtusa* 'nana Gracilis' that is created by multi-grafting to a 3 ft tall understock would take 25 years or more to grow from a conventional graft or cuttings.

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A third reason that is closely related to the previous one is seed formation. In some cases it is possible to cause a dwarf plant to produce seed by top grafting it. This is especially interesting in the case of witches brooms or dwarf plants that seed only when mature, because the progeny from the seed are often as unusual as the parent in growth characteristics. We have produced early seeding on cultivars of *Pinus strobus*, *Tsuga canadensis* and *Cornus florida*.

A fourth reason is one of necessity. Occasionally a uniform branching height or straight or interesting stem is necessary and grafting techniques provide the simplest method of accomplishing it with some plants.

PROCEDURES

Most of the understock we use is grown in the field until it reaches suitable size. In the fall of the year, we dig and wrap understock plants in plastic burlap (or pot them), then prune branches according to how they will be grafted, then store the plants in an area where they experience a normal winter until we are ready to graft. We usually graft in February so, depending on the species, we allow several days to several weeks in a warm house to start the understock growing. Standard grafting techniques are employed, but after-care is crucial because of the size and age of the understock. We try to maintain very high humidity and light intensity for every plant and, depending on the species, and cultivar, we wax or paint the graft union, or wrap it in sphagnum, then bury it in peat moss or shade it from the sun. The percentage success is largely dependent on the species and the condition of the understock and scion. The aftercare encompassing the next 2 weeks to 2 months determines the maximum or minimum survival percentage. For example, large *Picea* grafts are in the 25 to 50% success range, *Euonymus* in the 75 to 90% range, and *Pinus strobus* in the 90 to 100% range, according to our experience.

Depending on the species, the understock is cut back partially or wholly during the next 3 to 4 months. Most of the new plants are moved outdoors in June and planted in the field in July. There are some losses over the summer and winter depending on the species and individual plants. Partial losses of one or more grafts on each plant occur so we try to compensate by putting extra scions into the stock when we graft.

The plants are ready for landscape use in as little as 2 years in the case of *Syringa velutina* and *Cotoneaster adpressa* var. *praecox* or as much as 5 or more years in the case of very slow growing scions, such as *Pinus strobus* 'Nana' and *Tsuga canadensis* 'Hussii.'

CULTIVARS TRIED

We have tried many cultivars grafted on a large number of understock species with varying success. Table 1 lists the successful combinations we have tried. To be in this list the scions must have survived at least one winter outdoors. While some will never have good landscape applications, many are noteworthy and unique new forms.

Table 1. Successful graft combinations

UNDERSTOCK	SCION
Abies fraseri	*Abies koreana* 'Prostrate Beauty' (Prostrata, *A. lasiocarpa* 'Compacta,' *A procera (A nobilis)* 'Glauca', *A. pinsapo* 'Glauca'
Acer palmatum	*Acer japonicum* 'Aconitifolium,' *A. j* 'Filicifolius ('Aconitifolium'), *A palmatum* 'Dissectum,' *A p.* 'Ornatum' ('Dissectum Atropurpureum'), *A p* 'Crimson Queen', *A. p.* 'Sangokaku,' *A p* 'Crispum' ('Shishigashura')
A. saccharum	*Acer saccharum* 'Globosum'
Betula papyrifera *B (Verrucosa (B) pendula,* B. alba)	*Betula verrulosa*, 'purpurea,' *B V* 'Tristic,' *B V* 'Youngii'
Caragana arborescens	*Caragana arborescens* 'Pendula,' *C A* 'Lorbergii'
Cornus alba 'Siberica' *Cornus sanguinea*	*Cornus alba* 'Argenteomarginata,' *C A* 'Gouchaultii,' *C* A ba 'Kesselringii,' *C a* 'Spaethii'
C. florida	*Cornus florida* 'Hohman's Golden,' C. *f.* 'Pendula,' C F. 'Welchii'
Crataegus phaenopyrum	*Cotoneaster adpressa* var. *praecos*, C. 'Lowfast,' *Crataegus monogyna* 'Compacta,' *Chaenomeles* 'Cameo'
Euonymus europaeus	*Euonymus fortunei* 'Gracilis' ('Argenteomarginatus'), *E f* 'Andy,' E. *f.* 'Kewensis,' E F. 'Longwood,' E. F 'Vegetus'
Fagus sylvatica	*Fagus sylvatica* 'Purpurea Pendula,' F. s. 'Tortuosa'
Forsythia (in variety)	*Forsythia viridissima* 'Bronxensis'
Ginkgo biloba	*Ginkgo biloba* (male, in variety), *G b.* 'Pendula'
Juniperus virginiana	*Juniperus chinensis* var. *sargentii*, *J communis* 'Hornibrookii', *J horizontalis* 'Bar Harbor', *J h* 'Blue Mat,' *J h* 'Wiltonii,' *J. procumbens* 'Nana,' *J squamata* 'Prostrata,' *J. virginiana* 'Globosa,' *J v* 'Pendula'
Laburnum x *watereri* Vossii	*Laburnum alpinum* 'Pendulum'
Larix Leptolepis	*Larix* x *pendula*, *Larix gmelinii*
Ligustrum amurense *L. ibolium*	*Ligustrum vulgare* 'Iodense,' *Syringa velutina (S palibiniana)*
Malus sargentii	*Malus* 'Barbara Ann,' M. 'Edna Mullins,' M. 'Red Jade', M 'Van Eseltine', M 'Winter Gold', *M zumi* var *calocarpa*, *Chaenomeles japonica (C. lagenaria)* 'Appleblossom'

Morus alba var. *tatarica*	*Morus alba* 'Pendula'
Picea abies *P. glauca* *P pungens*	*Picea abies* 'Maxwellii' *P. a.* 'Pendula', *P glauca* (dwarf), *P pungens* 'Koster' ('Glauca Compacta'), *P p* 'Globosa', *P p* 'Montgomery', *P. p* 'Glauca Pendula'
Pinus resinosa	*Pinus densiflora* 'Prostrata', *P. d* 'Umbraculifera', *P. mugo* var. *mughus*, *P. resinosa* (dwarf)
P strobus	*Pinus strobus* 'Nana', (*P* is 'Radiata' or 'Umbraculifera'?), *P s.* 'Pendula', *P. s.* (witches broom, in variety), *P. s.* 'Globosa' (?), *P parviflora* 'Glauca'
P sylvestris	*Pinus sylvestris* 'Repens' (?), *P thunbergiana* (dwarf)
Prunus tomentosa	Apricot (in variety), cherry (in variety), nectarine (in variety), peach (in variety), plum (in variety)
P. serrula *P serrulata* 'Kwanzan'	*Prunus* x 'Hally Jolivette', *P. subhirtella* var *pendula*, *P yedoensis* 'Yoshino Schidarki' (Shidare-yoshino?)
Pseudotsuga menziesii	*Pseudotsuga menziesii* 'Pendula'
Rhodendron carolinianum	*Rhododendron* 'Balta', *R* 'Laurie', rhododendrons in variety
Rhodendron obtusum var *kaempferi*	*Rhodendron Kiuianum*, *R. yedoense* var. *poukhanenses*, azaleas in variety
Salix caprea	*Salix caprea* 'Pendula'
Sophora japonica	*Sophora japonica* 'Pendula'
Sorbus aucuparia	(contorted), *Sorbus aucuparia*
Syringa japonica	*Ligustrum* *Syringa vetutina*,
Taxodium distichum	'Pendula' *Taxodium distichum*
Taxus cuspitdata *T* x *media* 'Hicksii'	*Taxus baccata* 'Fowle' *Taxus b* 'Repandens', *T b* 'Silver Green', *T. B.* 'Washingtonii,' *T cuspidata* 'Nana,' *T. c.* (los spreading), *T.* x *media* 'Nigra'
Thuja occidentalis 'Douglasi Pyramidalis' *T. occidentalis* 'Nigra'	*Thuja occidentalis* 'Pumila', *T o* 'Hetz' Midget', *T o* 'Rhendiana', *Chamaecyparis lawsoniana* 'Minima Glauca', *C. obtusa* 'Nana Gracilis' ('Nana Compacta'), *C. o.* 'Crippsii', *C o* 'Filicoides', *C o.* 'Gracilis Minima' (='Minima'?), *C o C o.* 'Lycopodioides', *C. o.* 'Ericoides', *C. pisifera* 'Filifera Auera,
Tusga canadensis	*Tsuga canadensis* (dwarf in variety) *T c.* 'Hussii', *T. c* 'Pendula', *T. c* 'Prostrata' ('Cole's Prostrate'), *T c* (witches broom in variety)
Viburnum opulus 'Roseum'	*Viburnum carlesii* 'Compactum'

MODERATOR ZONDAG: Some of the plant shapes and forms Wayne showed in his slides are those which landscape architects are frequently looking for. I'm sure his paper will encourage some of us to try grafting to produce some of these unusual forms.

Our next speaker is Dick Wolff who will be discussing successes and failures in grafting Japanese maples.

SUCCESSES AND FAILURES IN GRAFTING JAPANESE MAPLES

RICHARD P. WOLFF

Red Maple Nurseries
Media, Pennsylvania 19063

The title translated means — I have some good news and some bad news. Although I lack much formal training most of my training came from the trial and error method of doing and reading; failing; regrouping and failing again — and when limited and ultimate success did come — as Gleason would say — "How sweet it is". I could spend all of my allotted time speaking of failures, but any success is replete with failures so let us look on the bright and positive side.

I will define the term "grafting" to bring this talk into sharper focus. Grafting is the art of joining parts of a plant together in such a manner than they will unite and continue to grow as one plant. In the plant industry, grafting must be fast, efficient and precise if good economy is to be effected. Our end result should produce a vigorously healthy tree of superior quality.

Briefly, let me review with you the pre-grafting, grafting and post-grafting procedures and, along the way, I will discuss specific points that have a direct bearing on the success or failure in the grafting process. I invite you to relax and come with me on an exciting adventure into the world of grafting the beautiful maples of Japan.

ROOTSTOCK

Let us begin by examining the rootstock or understock. In our operation, *Acer palmatum* 'Littleleaf' is used exclusively for the production of rootstock seed. Most commercial grafters of Japanese maples in the U.S. use this tree. Its qualities are indeed magnificent when analyzed. It is fast growing and has a superb root system. It has a high degree of compatibility with all known cultivars of *A. palmatum*, *A. p.* 'Dissectum' and *A. japonicum* — and incidentally, it is a beautiful tree in its own right. In addition to using seed taken from *Acer palmatum* 'Littleleaf', we have instituted a program of rooting cuttings taken from this cultivar. Such rooted cuttings are potted and become an extremely valuable source of graftable understocks, thereby reducing our complete dependency on importing seed from Japan.

For the past 10 years we have systematically removed the 25 fastest growing understocks from batches of thousands of seedlings. These have been carefully tagged and set aside and now form the basic stock trees from which high quality cuttings are taken for rooting and expressly grown as understocks for grafting. Seedlings are graded and approximately 25% are rejected as being below par in quality for grafting. These rejects are ideal for bonzai, however, and are sold for that purpose.

An extremely wide range of growth characteristics have been observed in young 'Littleleaf' seedlings. For example, after a 4 year period, some seedlings grown from seed taken from the same tree will show a minimum terminal growth of 2 to 3 inches while others show a maximum shoot growth of 4 ft. These measurements have been taken over the past several years. I like to think of grafting on rootstocks of this superior understock as plugging into a top power source or hooking a booster rocket to a wagon. In short, something is going to move and move they do!

Rooted cuttings are often grafted with excellent results after just one growing season, but by waiting a second year, a stronger plant emerges from the greenhouse in the spring. Seedlings and cuttings are potted up in 2-1/2 and 2-1/4 inch rose clay pots — the latter giving more grafts per square foot of bench space. Understocks are grown in a (hopefully) rabbit-free fenced-in compound. We have suffered untold losses to Bugs Bunny and his pals, he is enemy No. 1 to the Japanese maple. Entire crops have been cut down by this ambitious fellow who finds the texture of the wood so inviting for sharpening his teeth; indeed, it can look like a rotary mower was run through the seedling area.

POTTING MIX

Several years ago, in conjunction with Dr. Craig Oliver of Penn State University, we ran a series of tests for potting mixes expressly designed for container-growing of Japanese maples. The results were interesting and the mix that did the job for us was 3 parts good garden loam (pH-6); 3 parts sphagnum peat moss; 3 parts horticultural perlite (medium); 1 part dehydrated cow manure plus 1/2 lb. ground dolomite limestone per cubic yard of mix.

In December the young understocks must be brought in to an unheated cool house or well ventilated greenhouse. Do not make the mistake of leaving the potted understocks in the frames and then hopefully get them as you need them. You may wait too long and a severe freeze will lock them in as if they were set in a block of concrete. You will then wait around and day by day watching your grafting program go down the drain. We experienced this and it severely affected our grafting program. In the cool house the understocks are kept on the dry side but not to a point of dessication.

TIMING

The orderly progression of transferring batches of flats into the greenhouse to awaken the sleeping plants begins about Christmas time. Batches are color coded with plastic tape to prevent possible mixup with other batches or flats that may not be ready for grafting. The greenhouse is run at 60 to 65°F and approximately 15 to 20 days later, the understocks may be showing signs of growth activity. When you see the new white tips just forming on the roots, this is the ideal time to start grafting. A word of caution — don't allow the understocks to remain in the greenhouse too long past this point or they will come into leaf, the timing will be off and it will be too late to graft. Control of timing the admission into the greenhouse of batches of flats is tricky. A scientific approach must be devised or you will surely wind up with no trees to graft, or too many to graft, and a very erratic work flow schedule. The trick is to know your grafting production capacity. How many technicians are grafting? How many trees can they graft per day? How many trees do you plan to graft? A safe rule to follow is to allow 60 working days before the warming March air arrives. With these precautions, you can plan your grafting program.

Keeping charts on production has proved to be invaluable for subsequent grafting seasons. The chart is also used to keep notations on greenhouse temperatures in relations to the time the understocks take to break dormancy.

GRAFTING ROOM

I like to think of the grafting room as the surgery room where thousands of operations are performed and the technician as a surgeon very proficient in the art of grafting. The grafting room should be a comfortable and well lighted area. The technician should be comfortably seated with attention being paid to adequate lighting. We use a series of overhead flood lamps so as to eliminate shadows plus a small, high-intensity spotlight to cover the operating area. White oilcloth is used on the grafting table to aid in reflecting light and to make an easier job of cleaning up at the close of each day's activities.

SCIONS

There are over 230 different cultivars of *Acer palmatum*, *A.p.* 'Dissectum' and *A. japonicum*. We are grafting about 100 of these cultivars. The selection and collection of scionwood from the many trees can be a job in itself. Strict adherence to identification tags is mandatory during this process and, indeed, from here on until the tree goes to the ultimate purchaser. The gathering of the scions is done a week or so before they are needed. They are immediately wrapped in a wet cloth and stored in a refrigerator at 35°F. In selecting scionwood, I prefer straight wood from the current year's growth. The old rumor that scions of Japanese maples can not be taken in freezing weather is absolutely not true. However, special precautions must be observed when taking wood at below freezing temperatures. The wood should be wrapped outside and put immediately in the refrigerator at 35°F so that it will thaw slowly.

GRAFTING

We use two types of grafts — the side tongue graft and the wedge graft, as shown in Figure 1. In both of these grafts, a high degree of success has been noted for the last 4 years — at least 97%. Both methods of grafting are fast and dependable with a good amount of cambial surfaces coming in contact and should take a good technician approximately one minute to complete on a production basis. Every effort is made to match the size and diameter of the understock to that of the scion but, in reality, our scions run slightly smaller than the understock at the point of union.

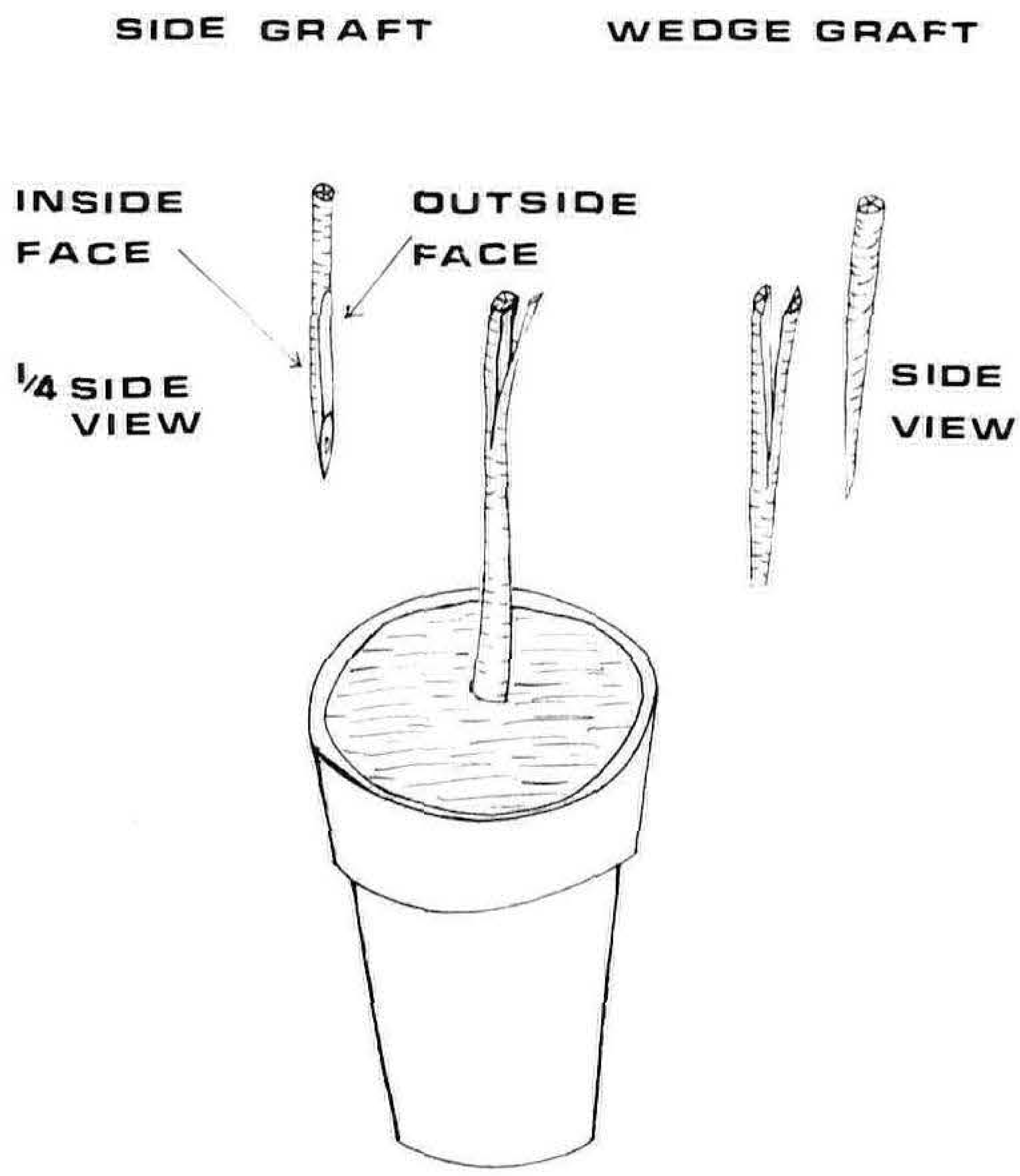

Figure 1. Side and wedge grafts used in propagating Japanese maple. Note slanting cut made at the base of the scion used in the side graft.

The side tongue graft is made by cutting the top off the understock at a point approximately 3 inches above the soil line. We use a linoleum knife, or grafting knife, if preferred. A 1-1/4 inch cut is made on the understock and extreme care is taken not to cut too deeply into the understock. The cut should go no deeper than 1/5 to 1/4 of the diameter.

The scion is selected and, in all cases, a small portion on the end to be grafted is cut off and discarded. A small wedge is fashioned by making cuts on both sides and the tip is cut off on a 45^0 angle. The lower buds are removed with a sharp downward brush of the thumb; however, at least two sets of buds are left remaining on the scion. Scion length ranges from a few inches to 6 to 8 inches on some of the larger grafts, particularly on *A. japonicum*. On many *A. p.* 'Dissectum' or cutleaf varieties, the graft is made 5 to 8 inches high on the understock. The reason for this is the great amount of lateral growth produced by the cutleaf cultivars. It gets the new growth off the ground, so to speak.

The wedge graft is made with a center cut directly down into the center of the understock, cutting down to a depth of 1-1/2 inches. The scion is fashioned by selecting wood approximately the same diamenter and, as in the side tongue graft, discarding a small portion on the base. A perfect wedge is made with the cut approximately 1-1/4 inches long. With both types of grafts wedges are inserted firmly in the understock with maximum care being taken to align the cambium layers.

BINDING

Binding is done with rubber grafting strips 5 inches long and 3/16 inches wide. Other nurseries use string to bind the union with equally good results. Binding is from top down, keeping the rubber strip flat to prevent cutting into the soft bark of the Japanese maple. Do not bind too tightly nor too loosely, but the union must be firmly held together.

WAXING

The new graft is dipped in paraffin wax to seal the union from the air. Wax temperature is maintained exactly at 140^{0}F by a thermostatically controlled electric heating element. The wax dip should be quick and should cover the entire union. We have never found evidence to prove that the 140^0 temperature was injurious to buds or woody tissue of the scion. New lower melting point waxes are equally as efficient but more costly.

SANITATION

Sanitation will determine success or failure from here on. In late fall, the greenhouse should be drenched with malathion, benlate and daconil. True, we have an overkill situation here, but we want to start with and maintain a sanitary environment for the young maple grafts.

Medium grade horticultural perlite is used on the benches and the pots are plunged to the mid-point. As soon as the pots are placed on the bench, a spray of daconil fungicide is applied.

TEMPERATURE CONTROL

Temperature control is now acute. Every effort must be made to maintain a temperature of 60 to 65°F. If the temperature should push upwards to between 80 and 90°F — most certainly bleeding from the understock will occur and virtually "drown" the graft, and there you are, with a beautiful failure on your hands. Cool Ray liquid glass shading has proved entirely satisfactory on both plastic and glass greenhouses. Adequate ventilation goes hand in hand with maintaining temperature and good sanitary conditions. Fans are left running continuously.

WATERING

In several weeks the union of the graft has taken; new growth is pushing and the requirements for water are increasing. Do not hesitate to water now. We have lost young trees at this point because of failure to water properly. Temperature of the greenhouse should still be kept in the 65° range.

REMOVING GRAFTED TREES FROM GREENHOUSE

By mid-May, you may be anxious to bring your new grafts out of the greenhouse, but a word of caution is in order. Five years ago, on May 15th, we removed several thousand new grafts from the greenhouse. That night we encountered a light frost which froze much of the tender new foliage. This resulted in the loss of several hundred trees which could not make new leaves. Our trees do not leave the greenhouse now until June 1st, at which time all danger of frost is past. Most young grafts can stand full sunlight but some light shade is beneficial before the transition to full sunlight.

By mid-July the graft unions are strong enough so the grafting rubbers may be removed; this step coincides with repotting the grafted plants to one quart containers.

A BRIEF REVIEW OF THE 12 REASONS FOR POSSIBLE FAILURES ARE AS FOLLOWS:

1. Failure to use or select proper understock.
2. Failure to protect young understocks from rabbits.
3. Failure in not bringing understocks in soon enough to prevent their freezing solid in the frame.
4. Failure in poor procedures for taking scions below freezing.
5. Failure to observe good sanitary conditions in the greenhouse and on the grafting bench.
6. Failure in matching and sizing scions to understocks.
7. Failure in binding the grafts too tightly or too loosely.

8. Failure by grafting too early or too late (in short — poor timing).
9. Failure to dip the grafts in wax so as to completely cover the union.
10. Failure to maintain proper ventilation and air movement in the greenhouse.
11. Failure to water properly, especially after grafting.
12. Failure by bringing the young grafts out of the greenhouse too soon and subjecting them to frost.

Now you know the causes of failure — eliminate them and you will have **SUCCESS.**

MODERATOR ZONDAG: Our next paper is entitled, "Growing Crapemyrtles in a Marginal Climate", by Ben Davis and Lonnie Lankford.

GROWING CRAPEMYRTLES IN A MARGINAL CLIMATE

BEN DAVIS II and LONNIE LANKFORD

Ozark Nurseries Company
Tahlequah, Oklahoma 74464

Ozark Nurseries is located in the Cookson Hills (a part of the Ozark Mountain range) in northeastern Oklahoma. This places us in USDA plant hardiness zone 7a. Although the average minimum temperature for this zone is given as 0 to 10°F, we nearly always experience 2 or 3 days of -5°F or lower at sometime during the winter.

This climate makes it difficult to grow crapemyrtle [*Lagerstroemia indica*] by the conventional method of propagating from unrooted hardwood cuttings lined out directly in the field. Because of the cold winter temperatures, cuttings lined out before mid-April are many times freeze-damaged. Late planted cuttings do not make enough growth in one season for most of the plants to reach salable size. It is very risky to leave them in the field 2 years because in most years the 1 year old plants will nearly all be winter-killed. We have tried digging all of the plants at 1 year, before extremely cold weather, grading out the plants large enough to sell, and lining back out the smaller plants. As a rule this did not work well because, while the plants were too small to see, they were too large to transplant easily through our transplanting machines. This practice usually resulted in poor stands from these re-lined out plants.

8. Failure by grafting too early or too late (in short — poor timing).
9. Failure to dip the grafts in wax so as to completely cover the union.
10. Failure to maintain proper ventilation and air movement in the greenhouse.
11. Failure to water properly, especially after grafting.
12. Failure by bringing the young grafts out of the greenhouse too soon and subjecting them to frost.

Now you know the causes of failure — eliminate them and you will have **SUCCESS.**

MODERATOR ZONDAG: Our next paper is entitled, "Growing Crapemyrtles in a Marginal Climate", by Ben Davis and Lonnie Lankford.

GROWING CRAPEMYRTLES IN A MARGINAL CLIMATE

BEN DAVIS II and LONNIE LANKFORD

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For the previously mentioned reasons we formerly purchased most of our crapemyrtle plants from growers who were located further south. However, economic conditions gradually changed, making this alternative no longer feasible. Some of our former suppliers went out of business. The others raised prices to that it was no longer possible to buy crapemyrtle and be able to re-wholesale them at a competitive price. Also, the supply of colors other than red was often short and unreliable.

These conditions caused us to consider the possibility of propagating crapemyrtle from softwood cuttings. We felt it would be possible to root the cuttings in outdoor mist beds, dig them as soon as we had a light frost to loosen the foliage, and pack them to be held in cold storage until it was safe to plant them in the spring. We also felt that by lining out a rooted cutting, it would be possible to grow most of the plants to salable size in one growing season, provided that they were fertilized heavily.

In the summer of 1971 we stuck our first batch of cuttings to try out our theory. Cuttings were taken during a period between July 15 and August 27. Cuttings were made 6 inches long, and the lower 1-1/2 inches were stripped as they were taken. Cuttings were then dipped in a solution of 1 tbs Captan per gal water. The basal ends of the cuttings were then dipped for 5 seconds in a solution of 0.25% IBA prepared as follows. Five grams of IBA were dissolved in 500 ml isopropyl alcohol, making a 1% base solution. Then 100 ml of the base solution was added to 100 ml of alcohol and 200 ml of water to make the 0.25% solution. Cuttings were stuck in outdoor mist beds in a medium of soil which had peat moss and sand added and stirred in with a rotary tiller.

The cuttings rooted in about 10 to 14 days. Unfortunately, they were stuck too late in the summer and the resulting liners were very weak and spindly. Partly because of this and partly because they were packed too wet, about 50% of the liners rotted in the storage during the winter. In spite of this setback the remaining liners, when lined out, made enough growth in one season to live up to our expectations.

In the summer of 1972 we stuck most of our cuttings earlier; from about June 20 to July 5. As soon as they were rooted, we began fertilizing them moderately. It was necessary to shear the cuttings to keep them about 12 inches tall to prevent them from shading out the slower growing cuttings in the bed. By digging time in the fall we had very heavy liners which stored well and transplanted well the following spring (1973). The cuttings rooted well enough to produce about 80% heavy liners. These plants, after lining out, grew well enough to be about 95% salable size by the fall of 1973.

At the present market price of crapemyrtle we feel that our propagation and production program is an economically sound one. This is a good example of the way in which changing economic conditions can make a change in propagation and production methods not only possible, but necessary.

MODERATOR ZONDAG: Thank you, Lonnie. Our next paper is by Joe Cesarini and is entitled, "Rooting of *Betula alba* clones."[1]

MODERATOR ZONDAG: Our next paper is on propagation of rhodendron cuttings and will be presented by Mike Medeiros.

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[1] EDITOR'S NOTE Mr Cesarini discussed his methods of rooting selected clones of *Betula alba* and Roger Coggeshall spoke on propagating own-rooted lilacs

ALL YEAR PROPAGATION OF RHODODENDRONS BY CUTTINGS

MICHAEL J. MEDEIROS

Plane View Nursery
Middletown, R.I. 02840

Most nurseries which propagate rhododendrons take the cuttings when a new flush of growth matures. In my area this is in early July and in September. Although these times generally produce the optimum rooting, it is possible to root rhododendrons very successfully at other times of the year.

If you propagate rhododendrons almost exclusively, as we do, after the fall crop is rooted you will have an empty cutting house. Starting another crop at this time spreads out the work load and keeps our facilities operating year round.

Before giving a month-by-month accounting of our cutting activity, I would like to describe our propagating structures and materials.

Our propagating house is a Quonset-type structure covered with polyethylene. It has a bench on either side with a path in the middle. Each bench is constructed to support three rows of flats. The bench is a pipe structure covered by a length of copper naphthenate-treated snow fence. This allows the bottom of the flats to be heated by a hot air poly duct which runs the length of each bench. The sides of the bench are enclosed with poly to keep the hot air under the flats.

A mist line is suspended over each bench where it will not

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A mist line is suspended over each bench where it will not interfere with flat handling. Flora-Mist fogging nozzles supply the mist which is controlled by a balance screen.

Cedar flats measuring 14 x 20 x 3 inches hold the cuttings. They are treated with copper naphthenate before filling with the medium. The use of a flat to hold the cuttings is very important in our operation. It allows us to remove the flats as the cuttings root and replace them with newly-filled flats. If flats are not used and the bench is filled with medium, it would be necessary to transplant the cuttings when they are removed. With flats, transplanting can be done at another time. In our case, they will stay in this original flat until they are sold as rooted cuttings or transplanted directly into outdoor beds.

The use of individual containers also tends to prevent the spread of disease organism within the bench since there is no lateral flow of water between them. If a disease is detected in a flat, the flat can be removed without disturbing other flats.

Our rooting medium is vermiculite; it is sterile, lightweight, readily available and of a consistent quality from year to year. We use the insulation grade which has a larger particle size than the horticultural grade. Before placing it in the flats it is screened with a 1/8 inch square mesh screen to remove the fine particles. This gives a medium with a high air volume, thus eliminating any tendency toward sogginess.

One of vermiculite's greatest advantages is that the cuttings can be left in the flat for as long as a year after rooting and it will still be easy to separate the cuttings without damaging the roots. This permits us to stick a cutting in July, let it root that summer, store it in a cool house and plant it in outdoor beds as late as November without having to make an intermediate transplanting.

Due to the high air volume of vermiculite, it does have the disadvantage of drying out rather quickly and requires more watering than other media.

Hormones are applied in liquid form using the quick-dip method. We prepare our own hormone solution consisting of 0.5% indolebutyric acid, 0.5% naphthaleneacetic acid and a trace of boron. To prepare this, the hormone powders are dissolved with Carbowax 400 and then mixed with an equal volume of water to make our basic solution. To this basic solution, we then add different amounts of water to vary the strength. This will range from 1/2 water, 1/2 basic solution for the harder cuttings to 1 part basic solution, 9 parts water for the most tender cuttings.

In preparing the cuttings we remove all but the top 4 leaves and cut off the outer 1/3 of these leaves. The cutting is then cut to a length of about 2-1/2 inches. Next, it is given two side wounds by either cutting or scraping, Then it is dipped in the hormone solution. Scaly-leaved cuttings are treated in the same of harvesting and production of large numbers of rootstocks. It is a new technique and it is very exciting.

One of our Western Region members brought back some slides from their meetings in Hawaii to show us how they propagate som plants in Hawaii without any medium.

BRUCE BRIGGS: These are cuttings of a groundcover which is easy to root. They are laid 200 to 300 per pan without any medium and placed under the mist to root. Because there are so many in each pan you can't let the roots get too long or they tangle badly and are difficult to separate, but they do often take these right from the rooting bench out to the jobs and plant them barerooted.

MODERATOR CARVILLE: Thank you, Bruce. We have one more slide presentation and then we will adjourn. Bob Fitzgerald wants to show us some work he has been doing on overwintering plants in Massachusetts.

EDITOR'S NOTE: Bob Fitzgerald showed slides of a winter storage method used inside Quonset structures. Sheets of polyethylene 1-1/2 mil thick were stretched over plants and tucked in around plants laying on their side in Quonset structures. An attempt was made to approach the 1 to 1 ratio discussed by Frank Gouin. Some damage occurred to plants near the perimeter of the Quonset structure and in the second year insulation was used on the outside edges of the plants under the poly with no damage resulting. Temperature graphs showed the temperature beneath the poly remained fairly constant although very cold and fluctuating air temperatures occurred both outside and inside the Quonset structure.

MODERATOR CARVILLE: With this presentation we will adjourn the meeting and hope to see all of you in Tulsa, Oklahoma, next year.

[This page move to after p. 302]

way except that the leaves are not cut. Benlate is applied to the newly stuck cuttings and the application is repeated about every 6 weeks.

Production consists primarily of the hardier cultivars such as 'Catawbiense Album', 'C. Boursault', 'C. Grandiflorum', 'Roseum Elegans', 'English Roseum', 'Nova Zembla', 'America' 'Ignatious Sargent' and 'Peter J. Mezitt'.

Now I would like to run through the 12 months, starting with January, to tell you which months we have found it possible to take cuttings successfully.

January and February are good months for taking cuttings. At this time of year we use a hormone concentration of 1/2 basic solution and 1/2 water. This same concentration is used on all cuttings taken after the first frost.

We have found this is a good time to take 'Peter J. Mezitt' cuttings. As soon as they root, they will put on a flush of growth. Rooting them at this time of year eliminates the dormancy problem sometimes associated with the fall rooting of this cultivar. When March arrives, it becomes more difficult to root rhododendrons successfully. At this time of year all of the rhododendrons are ready to grow and the sunnier days will force growth in the warm greenhouse. Cuttings taken in March will need more room in the flats to accommodate the new foliage if overcrowding is to be avoided.

After March, no more outdoor cuttings will be taken until the new spring growth matures in early July.

July cuttings are treated with our basic hormone solution diluted with water from 50 to 80%. The concentration depends upon the maturity of the cutting and the particular cultivar being treated.

After we have made the cuttings from this first flush of growth, we wait until the next flush matures before starting cuttings again. This is sometime in September.

October, November and December cuttings are treated as described previously for the months of January and February.

Cutting material may be taken from either liner beds, permanent mother blocks or from field stock. By properly selecting cuttings from liner beds you can promote desired branching in the plants. However, if you take cuttings from this source it will be necessary to leave the plants in the bed one more growing season to develop the necessary size for lining out.

Although we make cuttings many times during the year, we generally do not take them from any one plant more than once in that year. Removing repeated flushes of growth from a rhododendron can be harmful to the plant.

In conclusion, it is possible to root rhododendrons successfully over an extended period of time and doing so may allow you to use your labor and facilities more efficiently.

MODERATOR ZONDAG: One paper has been added to our program this afternoon and is entitled, "Observations on the Rooting of Rhododendrons", by Arie Radder.

OBSERVATIONS ON THE ROOTING OF RHODENDRONS

ARIE RADDER

Imperial Nurseries
Bloomfield, Connecticut 06002

At Imperial Nurseries we have switched from field growing of rhododendrons to 100% container growing. In our Connecticut winter climate we have to protect the containers; this is done by placing them in plastic hoop houses where we stack them together in November and leave them under plastic protection until the end of March.

About the third week of March we start to remove the plants from the hoop houses and space them on black plastic in the growing area so that we can put some good growth on them without any further spacing during the season. At the same time we will shape up all the plants to obtain compact, full rhododendrons. In the past we threw the clippings on the compost heap, but I noticed that there was a considerable amount of nice propagating wood among the clippings so we decided to try to root them. We had space open in our propagating houses and on April 4, 1973 we placed cuttings of four cultivars of rhododendrons in our cutting benches. The rooting medium consisted of 60% Canadian peatmoss and 40% coarse horticultural grade perlite.

On April 10, 1973 we stuck 2500 'Nova Zembla', 2200 'Catawbiense Boursault', 500 'Catawbiense Album' and 150 'Roseum Elegans'. The cuttings were treated with 2% IBA in talc with 12-1/2% Dichlone active and 50 ppm boric acid added. Additional dates and treatments were as follows:

4/10/73 Immediately after insertion all material was drenched with a solution of 8 oz Dexon and 6 oz Benlate per 100 gal of water.
4/20/73 Cuttings were sprayed with Dithane M 45, 2lb/100 gal.
5/8/73 Repeat of Dexon and Benlate drench.
5/15/73 Repeated Dithane spray.

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5/8/73 Repeat of Dexon and Benlate drench.

5/15/73 Repeated Dithane spray.

5/27/73 All cuttings were sprayed with a solution of 12 oz Captan WP and 1 pt of 20% Malathion per 100 gal.

6/18/73 Repeated Dithane spray.

7/2/73 Repeated Dexon-Benlate drench.

Temperature of the rooting medium was maintained at 67°F during the first 2 weeks and raised to 70°F afterwards. The intermittent mist was operated from 9:30 a.m. to 4:30 p.m. except on cloudy days when we misted manually about 2 sec every hour.

Root initiation was observed after about 3 weeks. Plants were lifted and potted on July 16, 1973. (They could have been lifted earlier but because of other priorities they were not). The results were as follows:

Variety	No. stuck	No. rooted	Percent rooted
'Nova Zembla'	2500	1740	70
'Catawbiense Boursault'	2200	2100	96
'Catawbiense Album'	500	420	84
'Roseum Elegans'	150	120	80

Very few of the unrooted cuttings had died, so most were re-stuck, rooted and potted up. We found these results quite gratifying and intend to repeat the tests in 1974 with greater quantities and all varieties that we have in cultivation.

ROOTING UNDER MIST IN OUTDOOR BEDS

We have several outdoor mistbeds which were originally tobacco seedbeds. They are 6 ft wide and 100 ft long with ends and sides made of 2 x 12" planks set on edge. On both sides and about 3 inches below the top of the plank runs a 1 inch galvanized waterpipe with small nozzles 3 ft apart which throw a fine fan-like spray. We put these on time clocks and grow our softwood shrub and evergreen cuttings in these outdoor mistbeds. Early in June, I decided to try to propagate rhododendron cuttings in these mistbeds. We emptied out some of the sand and put in a 4 inch layer of 60% Canadian peatmoss and 40% coarse perlite.

Cuttings were taken from 1 year old container plants on June 28, 1973. All cuttings were washed first in a solution of Captan and then treated with No. 3 Hormodin powder with 12-1/2% Dichlone active and 50 ppm boric acid added. Our mist clocks operated on sunny days from 7:30 a.m. to 6:30 p.m. but were shut off on cloudy or rainy days and operated manually if necessary.

The timers are set for 30 sec of mist every 5 min. We surround the mistbeds with 4 ft high snowfence covered with clear plastic to prevent wind from changing our mist pattern. Cuttings are in full sun without any protection. The results are shown below:

Variety	No. stuck	No. rooted	Percent rooted
'PJM'[1]	980	911	93
'Roseum Elegans'	1000	800	80
'Catawbiense Boursault'	500	450	90
'Catawbiense Grandiflorum'	900	750	83

[1] The 'PJM' cuttings were potted 8/6/73 while others were potted 9/19/73

We have also tried rooting in outdoor mistbeds in pots placed on a 6-inch layer of coarse concrete sand. We used the Slim Line pot (Nursery Supplies, East Patterson, N.J.). It is a smooth white plastic pot 7 inches deep. It has three 1/2 inch holes about 3/16 inch up from the bottom and has six rows of 1/16 inch holes (8 holes per row) with rows 3/4 inch apart.

These pots were loosely filled to about 1/2 inch from the top with our rooting medium and 522 *Rhododendron* 'Roseum Elegans' were stuck in them in our outdoor mistbeds on July 11, 1973. They were left out until approximately October 1, 1973 and are now in one of our propagating houses to over-winter. Root initiation was good and from testing at various times I would guess we have about 100% rooting.

We intend to use both methods on a larger scale next year.

MODERATOR ZONDAG: Thank you Arie; that completes this portion of the program and I will now turn the podium over to Al Fordham for his new plant forum.

AL FORDHAM: To begin this portion of the program we have James Jozwiak who will describe some unusual conifer selections which they have made.[1]

AL FORDHAM: Virgil Drake has a red maple which he would like to tell us about.

VIRGIL DRAKE: We have propagated this tree by budding for the past 5 years. The tree has green leaves until about August 1 when it changes color three times between August 1 and October 15. At the first change the outside edge of the leaves become purple and the inside remains green, then about September 15 the purple turns red and the inside remains green and, at the last change, the outside remains red while the inside turns yellow. Trees will be available as soon as the patent application is completed.

AL FORDHAM: Elwin Orton has two new dwarf hollies which will be described by Dick Zimmerman.

DICK ZIMMERMAN: Two dwarf selections, *Ilex crenata* 'Dwarf Pagoda' (female) and *Ilex crenata* 'Green Dragon' (male) have been made. These selections came from a population of 850 seedlings resulting from a cross of *Ilex crenata* 'Mariesi' x *Ilex crenata* 'John Nosal' made in June, 1965. The original plants are 12 to 15" tall and have been maintained in 2 gal containers for the last 4 years. These plants were selected for their dwarf habit, dark green glossy foliage and unusual or artistic habit of growth. The plants propagate readily from stem cuttings 1/4" in length or longer. The plants average 2" of growth per year.

These two clones are being introduced as speciality items for use in rock gardens, as indoor bonzai or potted plants, and in terrariums. Propagation material is available to commercial propagators from Dr. Elwin R. Orton, Jr., Rutgers University.

AL FORDHAM: Joe McDaniel has some hybrid oaks and a pond bald cypress he would like to tell us about.

JOE McDANIEL: The English have been more active than American nurserymen so far in propagating hybrid oak cultivars, but we, with our greater array of native species, have a choice of more naturally occurring hybrids, several of which are now being investigated as material for propagation. Most hybrid oaks I have observed are fertile and their acorns will yield hybrid seedlings though, of course, they do not reproduce the parent exactly. There are hybrids in the Midwest that combine the European *Quercus robur* with such American species as *Q. alba*, *Q. prinus*, *Q. macrocarpa* and *Q. muhlenbergii*. In several cases such hybrids, in addition to the greater vigor associated with interspecific hybridity, have shown much greater resistance to mildew than pure *Q. robur*.

My first picture, taken at Kew Gardens, shows a massive old specimen of Turner's oak, *Q.* x *turneri*, which originated in England before 1785 as a cross between *Q. robur* and the introduced Mediterranean evergreen, *Q. ilex* or Holm oak, which is related to our own *Q. virginiana*, the live oak of the Southern states. There is a variety *Q. pseudoturneri* which, according to Rehder, is better known in cultivation than the type. He says it is a shrubby

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[1] EDITOR'S NOTE. Mr Jozwiak showed slides of *Picea glauca* and *Pinus resinosa* compact forms which they have developed through their breeding program He indicated that scions and cuttings are available to nurserymen requesting them through established USDA procedures.

tree with handsome dark green leaves retained in milder climates until spring.

Q. x *bebbiana*, shown in the next two pictures, is the name for all hybrids between Q. *macrocarpa* and Q. *alba*. First reported near Chicago, it is known from other locations, and may be looked for in most areas where both parent species occur. The Cully Nursery at Jacksonville, Illinois has an F_1 tree which has given F_2 seedlings, some of which color as well as any white oak. The tree in the pictures is a massive old specimen in Harrodsburg, Kentucky, southwest of Lexington, which may be the national champion for this hybrid species. It is in a yard in the east side of town, south of the east-west highway.

My final slide, also taken at Kew Gardens in September, shows a tree of what is perhaps the oldest named cultivar in Taxodium: *T. ascendens* 'Nutans', named first by Aiton in his 1789 publication, *Hortus Kewensis*. It is still propagated in European nurseries, but I do not know of a specimen in the U.S., where *T. ascendens* or Pond Baldcypress is native. (The Kew label mistakenly attributes it to Mexico.)

Some botanists now unite all pondcypresses under T. distichum as *T. d.* var. *nutans*, but even if we accept this species lumping (which I do not), the distinctive 'Nutans' clone with its pendulous branchlets hanging from near-horizontal main branches, is one which deserves to be retained as a cultivar by grafting. It is different from other *T. ascendens* trees, including the newly patented *T. a.* 'Prairie Sentinel' which was selected in Illinois.

Taxodium ascendens, in general, is distinguished from the more common *T. distichum* by usually being a smaller tree, with foliage appressed to the twigs, which make it look more like a deciduous juniper. On its own roots, it usually does not have the "cypress knees" associated with *T. distichum* on wet sites, but these should develop on *T. ascendends/T. distichum* grafts; I have seen them on some Florida native trees that otherwise would classify as *T. ascendens*. There probably has been some hybridization where both species occur. Experience in the Midwest shows that both are hardy well north of their native range and, except for natural seed reproduction, they are by no means confined to swampy sites. With the introduction of uniform grafted cultivars, I predict a much wider use of *Taxodium* (both species) in the near future.

AL FORDHAM: *Joe Cesarini has an azalea he would like* tell us about.

JOE CESARINI: *Azalea 'Kaempo' is an outstanding plant. It* is a hybrid between *Rhododendron obtusum* var. *kaempferi* and

R. yedoense var. *poukhanense*. The cross was made to increase the hardiness of *R. y.* var. *poukhanense;* it blooms about 2 weeks later than anything else. It is hardy and is grown in Rhode Island; we sent some to Alabama and it stands the heat there. I sent some to the West Coast and have heard very favorable comments from there. I entered it in the New York Azalea Show 2 years and both times it won first prize.

AL FORDHAM: Joerg Leiss has a plant he would like to describe.

JOERGE LEISS: This is a weeping form of *Cercidiphyllum japonicum*; and only other one I know of was found in a temple garden in Japan and has been described in the literature. This one has been grafted on a 6 ft stem of the normal Katsura tree. It grafts quite readily as long as you do not trim the stems up too quickly; otherwise the stem will die back.

FRIDAY EVENING SESSION

December 7, 1973

PROPAGATORS' POTPOURRI

The Friday evening session convened at 8:05 p.m. Larry Carville served as moderator.

MODERATOR CARVILLE: The Potpourri is a little different concept than our usual Question Box in that I've asked two of our members to begin this evening's program with slide presentations showing some new and innovative methods and techniques. Some of these new ideas you saw last night when the tour leaders were discussing the different tours which we went on in England. Some of you were not able to go with us on the "Propagator's Tour of a Lifetime" and I felt it would be a good idea to try to show you some of the things they are doing over there. I've asked Hugh Steavenson to lead off this evening's program by showing you some slides of a new technique that we saw on the tour in England.

EDITOR'S NOTE: Mr. Steavenson showed slides and discussed a jacketed cold storage unit for nursery stock; conifer seedlings and transplants can be stored in these units for as long as 18 months and then taken out to the field and planted with as much as 98% survival. Their soil fumigation procedures are much like ours except that they do not use methyl bromide because a licensed applicator must be hired to do this and it is too expensive. Planting boards of a specific width and notched to indicate where the plants are to be set are used at one nursery and

R. yedoense var. *poukhanense*. The cross was made to increase the hardiness of *R. y.* var. *poukhanense;* it blooms about 2 weeks later than anything else. It is hardy and is grown in Rhode Island; we sent some to Alabama and it stands the heat there. I sent some to the West Coast and have heard very favorable comments from there. I entered it in the New York Azalea Show 2 years and both times it won first prize.

AL FORDHAM: Joerg Leiss has a plant he would like to describe.

JOERGE LEISS: This is a weeping form of *Cercidiphyllum japonicum*; and only other one I know of was found in a temple garden in Japan and has been described in the literature. This one has been grafted on a 6 ft stem of the normal Katsura tree. It grafts quite readily as long as you do not trim the stems up too quickly; otherwise the stem will die back.

FRIDAY EVENING SESSION

December 7, 1973

PROPAGATORS' POTPOURRI

The Friday evening session convened at 8:05 p.m. Larry Carville served as moderator.

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MODERATOR CARVILLE: The jacketed cold storage unit was discussed in several of the papers from GB&I in Volume 20 of the Proceedings. The main concept we wanted to present to you is the growing of seedlings essentially in a shipping container.

Another new concept which we want to present to you tonight is controlling the environment for liners in northern Michigan. Rich Brolick of Zalenka's Nursery will show you what they have been doing in this regard.

EDITOR'S NOTE: Mr. Brolick showed slides and discussed the construction of two structures each 114 ft wide by 1911 ft long. The two structures provide about 10 acres under lath. The structures are domed with 12 ft sidewalls and are about 23 ft high at the center. It is constructed of zinc-plated steel tubing 1-1/2 to 2 inches in diameter all bolted together with galvanized fittings and was covered with 3600 rolls of snow fence. The central portion of the structures are open and of sufficient height so that trucks, tractors, planters and other field equipment could be used inside without impairing their operation. The cost of the structure was given as 42 cents/sq ft of useable area though estimated cost on a new structure to cover another 5 acres is estimated to be 60 cents/sq ft of useable area. The present structures have withstood winds up to 65 mph without any damage.

MODERATOR CARVILLE: In their area it is necessary to have a structure which snow can freely pass through and so they have used snow fence. I'm sure many of us will be keeping an eye on these structures to see how well they work for you.

We will now begin with questions for this evening's program. The first one is for Arie Radder. How critical is the depth of inserting rhododendron cuttings into the medium. One article said that it was important not to insert the cuttings any deeper than needed to keep them upright?

ARIE RADDER: We have never been too fussy about this, but we insert the cuttings about 1 to 1-1/4 inches deep into the medium.

MODERATOR CARVILLE: Another question for you Arie; in your talk you said you discontinued using Benlate in your hormone mixture for rhododendrons but you drenched the cuttings at least twice with 50% Benlate after they are in the bench. Please explain.

ARIE RADDER: Dr. Hoitinck still thinks Benlate is necessary, but when we were using it in our hormone mix we were getting stubby roots and slow rooting on some varieties so we went back to Phygon and got much quicker rooting.

MODERATOR CARVILLE: Does anyone else wish to comment on the use of Benlate in the hormone mix?

JOHN SPARMANN: We tested Benlate in several combinations with IBA for rhododendrons in Florida and we find that Phygon is much superior.

MODERATOR CARVILLE: Does paraquat have any bad effects when used around tree stems, specifically birch and *Tillia*, in nursery rows?

ELTON SMITH: Paraquat will kill any green tissue and I have seen some problems where green tree stems were hit by this material. Caution is needed when you are using paraquat around any tissue which is green.

MODERATOR CARVILLE: Is there a winter control for crabgrass that will last into the summer?

ELTON SMITH: Simazine will control crabgrass but whether or not it will last into the summer depends on many factors. I have had it last into the summer from a fall application at 3 pounds active material per acre but at low rates it will not control it.

MODERATOR CARVILLE: Elton, were any trials made using herbicides on seedbeds?

ELTON SMITH: No, they were not.

FRANCES GOUIN: A couple of years ago I applied herbicides to pine and spruce beds immediately after seeding and topped with a mixture of half sand and half sawdust. This was a fall seeding and CIPC was applied at 8 pounds per acre and then the beds were covered with straw for winter protection. I had very good seed germination and no mustard or chickweed in the CIPC treated plots, but the untreated plots were badly infested with these two weeds. This was only one year's work and I intend to repeat it.

RALPH SHUGERT: I have used dacthal on seed beds of conifers, most woody ornamentals, and many perennials and have only killed one plant with it. I want to caution that anyone using this material should be sure that the seedlings have their true leaves formed before the material is applied. If the seedlings are still in the cotyledonary stage it will kill them. I applied the material at the rate of 12 pounds per acre as it comes from the bag.

MODERATOR CARVILLE: Can *Syringa amurensis* var. *japonica* seed be germinated earlier by warm treatment?

BILL CUMMING: Based on our work at Morden, seed stratified for 2 months at 40°F followed by 2 months at 70°F and planted out in May will hasten the germination by about 6 weeks.

RALPH SHUGERT: In Nebraska I sowed the seed in the fall and got about 60 to 65% germination in the spring. This was with no prior stratification.

MODERATOR CARVILLE: What is a cheap product to color seed coats for ease of seeing in seeding operations?

HUGH STEAVENSON: Venetian red should do it.

MODERATOR CARVILLE: At this point I want to ask Frank Gouin to show us slides on some work he has been doing with respect to depth of sticking of cuttings.

FRANK GOUIN: Nursery practices are constantly evolving and sometimes these new practices can get us into trouble. In Maryland, some of our growers have been experiencing increased losses up to as much as 90% in the rooting of rhododendrons and azaleas. In an attempt to determine the cause of this, I observed that the rooting medium depth has evolved from 5 to 6 inches or deeper in a bed down to 2 to 3 inches in a flat and in one instance about 1 to 1-1/2 inches deep in a plastic tray. So what has happened? The media have remained the same, the depth of sticking has remained the same, but the water table has been gradually moved up closer to the surface of the medium. I believe that oxygen is needed for the rooting of ericaceous plant materials especially and, as you go deeper in the medium, you have less oxygen and more water. I set up a small test to demonstrate the effect of depth of sticking on the rooting in flats. The results were quite dramatic. On those cuttings stuck deep the base rotted off and sent out roots in the upper portion of the medium; on the cuttings stuck only 1/2 inch into the medium, we stuck 250 cuttings and got 250 with good root balls. The cuttings were treated similarly in both instances except for the depth of sticking. These are the results of only a one year study and we intend to repeat it next year in a more elaborate fashion but I offer this information to you as something you may also want to consider.

MODERATOR CARVILLE: Those of us who have had the experience of sticking cuttings in 6 inches of medium then going down to a 4 inch depth and possibly changing again to 3 inches of medium because you're going into some sort of a pot operation and rooting percentages have decreased along with these changes because you have not considered this correlation may well want to look into this depth-of-sticking in more detail.

JOHN ROLLER: I'd like to ask Dr. Gouin if he has ever worked with pine sawdust as a rooting medium. I've been a big advocate of this material for a long time because it is almost impossible to overwater.

FRANCES GOUIN: When I was in New Hampshire we did use it for the rooting of lilacs, but I have not used it since I've been in Maryland.

MODERATOR CARVILLE: Jim Wells, I have two questions for you. (1) Does Aqua-gro cause higher salt accumulation and, (2) what is a good water pressure for misting plants to avoid droplets?

JIM WELLS: No — and 800 psi in that order.

MODERATOR CARVILLE: Jim is being very cautious tonight; he had dinner with Tour A.

I have some questions for Dick Wolff; would you explain the side grafting technique you use on Japanese maples and the need for waxing?

DICK WOLFF: I have drawings of this technique and will submit them for insertion in my paper. The need for waxing arises because if that graft is not tight, air will get in, the cut surfaces will dessicate and the graft will not take.

MODERATOR CARVILLE: Do you cover the graft area with perlite and do you leave the top of the bench open?

DICK WOLFF: The graft area is not covered with perlite; it is used only to keep the base of the pot moist so it is not pushed into the perlite very deeply. The tops of the benches are left open.

MODERATOR CARVILLE: Do you graft red on red seedlings or red on green seedlings or is there no difference in graft takes?

DICK WOLFF: All of our grafting is done on *Acer palmatum* 'Littleleaf' which is the green Japanese maple. If you graft on the red seedlings you just don't get the growth out of them. Years ago we did do some grafting on red seedlings but in an attempt to standardize and make our product more uniform we've gone entirely to the 'Littleleaf' understock.

CASE HOOGENDOORN: Were your percentage of takes as good on the red understocks as on the green understocks?

DICK WOLFF: I can't really answer that because that was a number of years ago and I was not as skilled at grafting then as I am now; as my grafting skill has increased over the years, so have the percentage of "takes." I really can't make a fair comparison.

MODERATOR CARVILLE: Joe Cesarini, would you explain your procedure for rooting dormant cuttings of *Acer palmatum* cultivars?

JOE CESARINI: Sometime in February, depending upon the weather, we go out and select stems and bring them in and cut them into pieces, cutting just above each set of nodes. The cuttings are wounded slightly and treated with 1% IBA in talc. These are stuck in a mixture of peatmoss and perlite which is very dry; if you can squeeze water out of it it is way too wet. The cuttings are stuck close together in the flats and are kept cold on the top with perhaps just a little bottom heat. The cuttings are left in the flats outside all during the next growing season. In February, they are brought in and potted in 3-inch pots and pinched to fill them out. These are later transferred to 3-gallon cans.

DICK WOLFF: I took some of the green dormant tops which we were cutting off from our grafts and made cuttings of these. They were dipped in 1.2% IBA with some fungicide added and stuck in a very dry peat-perlite mixture, just as Joe has described, and these were well rooted in 40 days. About 95% of them rooted; and they were potted up and grew just fine.

I tried rooting some completely dormant 'Littleleaf' taken a month earlier and they rooted but they were a lot slower. I also tried rooting some of the red varieities such as 'Bloodgood' and although the rooting was only about 60% I believe this method is economically feasible.

We're experiencing a lot of bark explosion on the base of these cuttings during the first or second year after they are set outside. I was wondering if Joe is having any of this problem?

JOE CESARINI: We don't have much of that though occasionally a few cuttings turn black on the bottom but I don't know what causes it.

MODERATOR CARVILLE: Is there a material to remove sooty mildew from plant material in a closed greenhouse?

ARIE RADDER: Botran should do it.

MODERATOR CARVILLE: We now have another brief slide presentation which covers a new technique for storage of plants for growing on. This will be presented by Case Hoogendoorn.

CASE HOOGENDOORN: I copied this idea from Bald Hill Nurseries. They had a storage house 5 or 6 years ago in which they used to store their red Japanese maple and pink dogwood cuttings. This is not a greenhouse but rather a storage house; I call it my "big deep hole". It is set 6 feet deep in the ground with a roof of corrugated fiberglass over the top. The idea behind this is that when we have a severe winter the frost may go down as much as 3 feet but, because we are below the frost line, the temperature will only go down to 37°F — at least this is what they tell me. Now we can rely on the temperature of the soil to prevent freezing of the materials we store in it yet we get sufficient cold to overcome the dormancy and it will be uniform — which will prevent splitting. I can't tell you anything about how this storage performs yet since this will be our first winter to use it, but I thought I could show you my "big hole in the ground".

MODERATOR CARVILLE: Case didn't mention it, but perhaps you noticed the fans and vents which are on automatic controls to ventilate heat from the structure on bright sunny days. Hopefully Case will be able to tell us more about this structure next year.

Another new technique which we saw in England involved apple production and I've asked Chiko Haramaki to show you some slides on what they're doing over there.

CHIKO HARAMAKI: With this new method of apple production they are planting 30,000 to 50,000 trees per acre. After the first year of growth the shoots are sprayed with B-Nine or Alar at 2500 ppm. This induces the whips to produce flower buds the next year and each whip will bear 5 to 6 apples. By this method they can get between 1,000 and 1,500 bushels of apples per acre. After the bearing year, the stems are cut off close to the ground and a new whip is allowed to form the next year but no apples are formed that year. In other words, with this method you get apples only every other year but the yields are fantastic.

One of the problems they're working on is the cost of propagating these trees. With 50,000 trees per acre the cost of planting material is quite expensive. They estimate that with current methods it cost them 75 cents per tree but they hope to bring it down to 25 cents per tree which will make this method economically possible. They are also looking at different methods of growing the trees such as trellising, different regulators to control flowering and fruiting, methods of harvesting and many other things related to this method of growing. It has stimulated a lot of thinking and trying of new things and even if the method itself proves to be impractical there should be many new exciting ideas come out of this work.

MODERATOR CARVILLE: This method has not been used in this country, it is still being developed in England. It does still have many problems associated with it but it does have the possibilities for studying all kinds of new practices such as methods

See p. 344

INAUGURAL SESSION

September 26, 1972

HAMILTON, NEW ZEALAND

An account of the inaugural meeting of the International Plant Propagators' Society, New Zealand Chapter-at-Large. Tuesday, September 26, 1972.

A gathering of plant propagators was held at the University of Waikato, Hamilton, to discuss the formation of a Chapter of the Society here in New Zealand.

The move to start a chapter here was initiated by Mr. J. S. Wells of Redbank, New Jersey, in correspondence with Mr. Ellaby Martin of Martin's Nurseries, Hamilton. Although this was not the first time the development had been considered, Mr. Martin felt that the time was right for exploring the possibilities in greater depth. He contacted Mr. R. E. Lycette of the University of Waikato and other horticulturists he knew to have an interest in plant propagation as well as some of the existing members of the society living in New Zealand.

The preparation for the inaugural meeting was carried out largely by Ellaby Martin and Ron Lycette and the date was fixed to coincide with Mr. Jim Wells' visit to Hamilton. The horticulturists were contacted through their connections with the New Zealand Nurserymen's Association, Institute of Parks and Recreation Administration, and other professional horticultural groups.

Mr. Martin opened the inaugural meeting by welcoming all those present, particularly those who had travelled a considerable distance. He apologized for the relatively short notice everyone had had, but in view of the good attendance this had not stopped people from travelling from as far as Levin, New Plymouth, and Kaikohe. He extended a special welcome to Mr. Jim Wells and described him as a keen member with a wish to extend the benefits of the IPPS around the world. He said that it was Mr. Wells' presence in New Zealand which had been the stimulus for the start of a group here.

It was then decided that Mr. Martin and Mr. Lycette, as convening officers, retain the positions of President and Secretary for the meeting. Mr. Martin outlined the proposed programme for the afternoon and evening. He said that there would firstly be a series of seven short papers given by prominent horticulturists and that at the end of the afternoon Mr. Jim Wells would give a talk on the IPPS. The meeting would then adjourn for a meal and reconvene in the evening to discuss the formation of a group in New Zealand. If it was decided to form a group there would need to be an election of officers and a short business meeting.

The meeting was then addressed by the following speakers:

Mr. F. Schuurman, Sunbeam Roses, Auckland
"Propagation of Roses by Cuttings"

Mr. A. Palmer, Palmers' Nurseries, Auckland:
"Grafting of Tropical Hibiscus"

Mr. E. E. Toleman, Horticultural Advisor
Dept. of Agriculture, Hamilton:
"Propagation of Nymphaea"

Miss P. Bates, Ruakura Research Station, Hamilton
"Application of Overseas Research to Local Conditions"

Mr. B. Haggo, Dawn Nurseries, Auckland
"Propagation and Production of Daphne"

Mr. R. M. C. Scott, University of Waikato:
"Propagation by Leafbud Cuttings"

Mr. R. E. Lycette, University of Waikato:
"Aspects of Fern Propagation"

The first half of the meeting concluded with Mr. Martin thanking all the speakers for the trouble they had taken in preparing such interesting papers. The standard of the papers should have proved to everyone present the value of the society. Mr. Martin extended his gratitude to the University of Waikato for the provision of facilities and to Mr. Lycette for his assistance in arranging the meeting and his help in preparing the publicity.

After a short meal break the meeting reconvened. Mr. Martin welcomed back the assembly and extended a welcome to those who had not been present during the earlier part of the day.

An open discussion took place with many people expressing their appreciation of the afternoon's programme and how it could be regarded as a forerunner of many such programmes should an I.P.P.S. Chapter be formed here in New Zealand. Everyone was obviously keen to set up a Chapter and it was formally moved by Mr. George Smith and seconded by Mr. Ivor Harvey that a branch of the International Plant Propagators' Society be set up in New Zealand. This motion was carried unanimously. Mr. Martin then vacated the chair and Mr. Jim Wells acted in the capacity of chairman for the election of a president. Mr. Martin was elected as the Foundation President of the Chapter in New Zealand, with Mr. G. B. Smith as Vice-President. The position of Secretary-Treasurer was filled by Mr. R. E. Lycette and members of the executive committee were Miss N. Parr, and Mr. B. Haggo.

A number of matters of business were then discussed regarding subscription rates and entrance fees. It was decided that the pattern as set by both the American Regions should be followed as nearly as possible. The business part of the meeting concluded with the executive committee being instructed to take the necessary action to set up a constitution and the structure of the Chapter. With no further business Mr. Martin thanked everyone present for their enthusiasm and support and promised that the efforts of both himself and the executive committee would be directed at setting the Chapter on a firm foundation, so that it could grow from strength to strength.

At the conclusion of the general business meeting Mr. Jim Wells outlined further the history and objects of the I.P.P.S. He described briefly the formation of the Society from its inception in 1951 until the present day. He told how Mr. E. Scanlan, Commissioner for Shade Trees, City of Cleveland, had been the instigator, bringing together the original members, and that it eventually fell on Mr. Wells to become the first President. He emphasized that the general purpose of the organization was to provide for the dissemination of knowledge through the proper channels, providing helpful guidance and assistance to plant propagators through its meetings and publications.

Mr. Wells then showed some slides of tunnel houses and some methods of propagation he thought would be of interest to New Zealanders. It was obvious from the enthusiasm and interest shown by those gathered that Mr. Wells keenness had spread to everyone and the newly-formed executive committee felt spurred on to establish the framework for a branch of the Society in New Zealand.

TECHNICAL SESSION

Tuesday Afternoon, September 26, 1972

A METHOD FOR THE VEGETATIVE PROPAGATION OF HARDY WATER LILIES [*NYMPHAEA*]

E. E. TOLEMAN

Ministry of Agriculture & Fisheries
Hamilton, New Zealand

In this case the term "hardy" refers to those *Nymphaea* which grow in temperate zones but not necessarily to those known generally as tender or tropical. The technique to be described was evolved to meet the requirements for several hundreds of small plants of a standard size and age. In this case the cultivar, Gonnere (syn. Crystal White), was used as sufficient material of it was readily available.

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Normally, when only a few plants are required, side shoots from the main rootstock are removed but natural increase thus is very slow. It has long been known that *Nymphaea* will survive in wet soil only with no water above the rootstock but in such cases smaller leaves and far more growing shoots are produced. It was also known that a dormant shoot bud is present on the rootstock at the axil of it and the leaf stem, even if the latter is no longer present. With this knowledge, the rootstocks were placed in containers and grown in water 30 centimetres deep. This water depth was decreased over a period of eight weeks so that finally the rootstocks had no water over them but were in wet soil only. By the end of the first season, over a growing period of six months, an average of one shoot suitable for removal had been produced every 10 centimetres. This was done whilst they were dormant with no foliage present. The soil was kept wet but with no water over the rootstocks. Before growth was expected to commence in the spring, the rootstocks were incised along the centre line to a depth of 2/3. Cuts across the rootstock to the same depth were made every 5 centimetres. As a control, uncut rootstocks were used, some covered with 30 centimeters of water and some in wet soil only. In all cases the terminal and existing side shoots were removed. To encourage earlier growth the plants were placed in a glasshouse where the temperature did not fall below 10°C. A moist atmosphere was maintained by frequent sprinkling controlled by a time switch.

Growth thus encouraged was quick and shoots started to grow from the majority of the sections. These were removed when sufficiently large and a small second crop subsequently developed during that season. In all, by the end of the season, an average of one plant per 2 centimetres length of rootstock resulted. This compared with one plant per 10 centimetres by natural propagation in water and one plant per 6 centimetres in wet soil only with no cuts.

More shoots were produced on the younger part of the rootstock and had only this material been used the plant production rate per length of rootstock would have undoubtedly been increased. The rootstocks were allowed to become dormant in their natural season and the process repeated in the following growing season, but no further incisions were made or needed. From these, one plant per 5 centimetres was produced. This decrease was probably due in part to the cutting of the rootstock and the treatment already received in the previous year.

An alternative system was also used where the rootstocks were cut into complete sections 3 centimetres wide. Although in almost every case a plant resulted, it took a complete season to grow and obviously all the rootstock was used. Subsequently, in another season the cross incisions into the rootstock were made every 2.5 centimetres and this resulted in an average production of one plant per 1.5 centimetres on rootstock per season.

The use of growth stimulants could also be considered. Although perhaps the need to propagate in large numbers plants such as that described does not arise often, the technique used shows what can be done if necessary. The method was evolved knowing the plant's habit and behaviour and applying to these a basic knowledge of plant propagation and culture.

J. WELLS: I am not clear whether you used the 5 cm segments with the shoots attached or took the shoots off as cuttings.

E. TOLEMAN: No, the shoots only were used; after they made 3 or 4 cms of growth, they normally produced a few adventitious roots and then we cut the shoots off.

J. WELLS: Would the cut-up rootstock produce further shoots?

E. TOLEMAN: Yes. In the year the work was started, one lot of segments produced two crops and some even three. The work was done in the northern Hemisphere and was done under glass between February and September. However, with the onset of autumn they went into a state of dormancy even when the heat was turned on in the glasshouse.

J. WELLS: What did you do with the shoots after cutting?

E. TOLEMAN: They were put in 3" clay pots with 'silver sand', no soil — because of the possibility of bacterial rot.

E. J. MARTIN: Where were the root segments placed?

E. TOLEMAN: In shallow galvanised trays.

F. SCHUURMAN: Were the plants fertilized in any way?

E. TOLEMAN: No, not at the rooting and first potting stage.

ASPECTS OF FERN PROPAGATION

R. E. LYCETTE

Cambridge, Waikato
New Zealand

The most general plan of propagation of ferns is by spores but with many species it is difficult and with some it seems impossible. In a country where ferns form a dominant part of the vegetation and the range of species is considerable there is often little inducement to plant propagators to widen the range of ferns available. Many private citizens and too often nurserymen also 'raid the bush' to obtain stocks of ferns — their method of propagation in this case is roots or rhizomes dug bodily from the soil. Too often this ends in tragedy with the whole fern dying. Exotic species and cultivars are often propagated asexually from the divisions or rhizomes from the nurseryman's own stocks.

The purpose of this paper is. very briefly, to discuss the success we have had here at the University of Waikato with the propagation of ferns from spores.

The fern species we have tried are chiefly exotic, many of them subtropical. Although more elaborate techniques have been tried we have finally settled on this method for all our propagation. It is simple, and when carried out with cleanliness and punctuality on receipt of the spores the rate of success is very high.

Briefly, before I describe the technique, I will remind you of the stages in the fern life-cycle so as to refresh your memories.

1. *Sporophyte generation*

2., 3. The sori distributed along the sporophyll

4. Indusium and receptacle
5. Sporangium
6. Spore
7. Gametophyte generation — prothallis
8. Antheridia
9. Archaegonia
10. Sporophyte generation emerging from prothallis.

The spore is generally received either as a brown powder or attached to a remnant of the sporophyll. The packets containing the spore are separated out immediately and kept in such a way as to reduce risks of contamination. All the labelling and recording is carried out at this stage without anyone opening the packets.

Ordinary 2-liter glass jars are taken and thoroughly washed and sterilized in dry air beginning at 450^{0}F and running down overnight to a handling temperature by morning. At the same time trays of teased sphagnum moss are given the same very high temperature treatment.

In the morning the moss is added to the jars and watered with de-ionised rainwater so that the level of wet moss is just below halfway up the jar. The water is kept to a level just below the surface of the moss.

At this stage the spore is tipped over the surface of the moss and previously hot water sterilized vacuum seals are slipped on. The seals are held firmly and need to be kept down and untouched for about 10 days. The whole jar is partly submerged in the propagating pit for the development stage of the prothalli at a temperature of 75° F. Sterilized water may be added carefully if the jars dry down.

By about 10 days the first signs of life will appear — the moss will show a green staining to be followed by a haze of little green dots. These grow at a variety of rates into the prothalli which can be allowed to become quite tightly packed. They are then very carefully moved out into trays of sieved sphagnum, kept in moist heat for two weeks and then taken out of heat as the first few fronds appear. From then on they will steadily grow to become sizeable plants in twelve months; many will in fact bear sori by that time.

F. SCHUURMAN: What length of time is needed from spore sowing until a commercial grade of plant is obtained?

R. LYCETTE: A lot will depend upon the growing medium and environment but 12 months should provide a good-sized plant.

COMMENT: We are getting very good germination of many species using this method but I have no idea how much it is due to the spore being fresh and the easiness of different species to grow.

A. PALMER: What effect does light have on germination?

R. LYCETTE: Diffused light is available in the house and reduced even more by the container's lid and the embedding of the jar in the soil.

P. BATES: What mixture do you pot-on into?

R. LYCETTE: We place them initially in sieved sphagnum moss and 'flood in' clay and leafmould over a period of time, increasing the heaviness of the medium gradually.

To carry this one stage further, for our specialist purposes it is our practice to place horizons in the pot — clay below the potting medium. This has been based on the recognition that ferns usually grow in a layer of humus-rich soil over clay.

LEAF-BUD CUTTINGS

R. M. C. SCOTT

University of Waikato
Hamilton, New Zealand

Why leaf-bud cuttings? The main purpose of leaf-bud cuttings is to produce as many new plants as possible from a limited stock material. They are slower than stem tip cuttings in that they take longer to produce a mature plant but they can be produced in large numbers.

A leaf-bud cutting, as its name suggests, consists of a leaf blade, petiole or leaf stem, an axillary bud plus a small portion of the stem. In actual fact a leaf-bud cutting is a miniature softwood cutting.

It is important when taking these cuttings, as with any cuttings, to select healthy disease-free stock plants. A cutting from a poor quality stock plant will produce an inferior quality new plant. It is also important to select mature tissue, i.e. leaves and petioles which have a mature axillary bud or axillary shoot primordia capable of producing shoots in a relatively short time. However, although they should be mature, the cuttings should be made from relatively young, healthy growth, as cuttings from old growth will take longer to develop roots and the axillary bud may die before the roots develop.

In the actual taking of the cutting the amount of stem retained is usually quite small depending on the subject being propagated. The stem section can be left whole or it can be cut longitudinally which, if the leaf arrangement is opposite, will produce two cuttings from one node. Even if the leaf arrangement is alternate the stem section can still be cut in the same manner exposing more of the root-producing tissue to the rooting medium.

After leaf-bud cuttings have been made they are subject to the same environmental conditions for rooting as stem cuttings. They should be treated with a rooting aid, "Seradix B I," and set in a medium consisting of 1 part peat and 2 parts fine pumice.

We have found from our own experience that this mix is very satisfactory. The medium should be placed in a small tray or container and then placed in a propagating frame with bottom heat which should be set at between 75°-80° F. As our propagating frame does not have a mist system we syringe the cuttings overhead frequently. Adequate moisture while the cuttings develop roots is very important.

A selection of plants that can be propagated in this manner includes:

Aphelandra squarrosa
Fatshedera lizei

Fatshedera lizei 'Variegata'
Philodendron sp.
Peperomia sp.
Codiaeum (crotons)
Rhaphidophora aurea [*Scindapsus aureus*]
Ficus elastica 'Decora' (plus other species and varieties)
Cissus (kangaroo vine)
Rhoicissus (grape ivy)

It should be noted that most of the above plants can be propagated by tip cuttings but to obtain the maximum number of cuttings from the minimum amount of stock, propagation by leaf-bud cuttings is practised.

J. WELLS: In one New Zealand nursery I visited I saw leaf-bud scions being placed onto an easily-rooting cuttings, treated with hormone, put into the propagator and rooted. The subject was *Rhododendron* and the idea was to build up stock rapidly.

P. BATES: Was the old bud cut out or rubbed out of the *Rhododendron*?

J. WELLS: Cut out with a slicing action.

P. BATES: On camellias, with leaf-bud cuttings you get beautifully shaped plants.

E. J. MARTIN: In using hormones do you take precautions to avoid getting it on the bud?

R. SCOTT: Yes, I endeavour to keep it limited to the cut surfaces of the cutting.

PROPAGATION OF DAPHNES

B. HAGGO

Dawn Nurseries
Auckland, New Zealand

In the R.H.S. Dictionary over 35 species of *Daphne*, both evergreen and deciduous are described. I will concentrate my remarks on one of these species; in fact, to a cultivar known as *Daphne odora* 'Rubra.'

Stock Plants — I consider the key to *D. odora* 'Rubra' production is healthy vigorous stock. Selected plants are set out in the best piece of nursery land and grown for two years before being used for cuttings. These stocks are maintained from 5 to 7 years before removal and replacement by fresh plants. Below a soil pH of 6, growth is restricted. Good results are achieved with a pH of between 6 and 6.4. A balanced fertilizer applied in early spring and again after the cuttings are removed (late summer) maintains growth.

Fatshedera lizei 'Variegata'
Philodendron sp.
Peperomia sp.
Codiaeum (crotons)
Rhaphidophora aurea [*Scindapsus aureus*]
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A semi-shaded position is ideal but not essential. The shade holds the green colour in the leaf during the hot summer, otherwise yellowing occurs. The shade is particularly valuable if there is delay in taking the cuttings, as yellowish cuttings take longer to root and can defoliate.

Insects which may weaken and damage cutting growth are mealy bug and green aphis. These are controlled by using summer oil and nicotine sulphate. Harder to control is Blast, or bacterial spot (*Pseudonomas synisintae*). Raised black spots on the underside of leaves turn them yellow, causing defoliation. Regular Bordeaux sprays, particularly in the autumn will give good control. The virus known as Cucumber Mosaic is a well-known problem in Daphnes. We find if suspect plants are removed and burnt immediately a healthy line can be maintained.

Cuttings: Timing will depend on fitting in with other subjects being grown. In the Southern Hemisphere, February-March, even through April, for taking cuttings allows wood to be firm and tips to terminate. Tip cuttings only are used, preferably terminated. Stems may be browning but are still green. Lengths are not used because after looking sound the leaves can yellow and defoliate. Cuttings are usually made by women with sharp secateurs. The lower leaves are stripped by hand (not cut). Wounding or hormone treatments have not given sufficiently better results to warrant using.

The rooting medium used is 3 parts Mercer sand and 1 part shredded Hauraki peat. Cuttings are inserted in wooden trays, placed in a glass house pit, using bottom heat of 75^0 with intermittent misting. Rooting takes about ten weeks. An average tray of 100 cuttings would give:

70% strongly-rooted, which are potted
10% weak-rooted, which are potted
15% not rooted and replaced
5% thrown out — rotted or poor leaves.

Over-Wintering: This period we find difficult as the damp cool conditions favour root rots, especially *Pythium*. Potted cuttings are held under polythene frames and kept as dry as practicable. When flowers develop these are removed. On bright, sunny days (September), planting or potting can commence.

R. SCHUURMAN: Is it economical to put unrooted cuttings back into the propagator?

B. HAGGO: If the cutting material is 'in short supply'? Yes. But if we could always be assured of enough we would make extra cuttings to cope with estimated losses.

A. PALMER: Do the cuttings you put back produce a weaker plant?

B. HAGGO: No. Strangely, they come out a stronger plant and the reason seems to be that they are less subject to *Pythium* infection.

GRAFTING TROPICAL HIBISCUS

A. W. PALMER

Palmer's Nurseries
Auckland, New Zealand

Tropical hibiscus are generally from Hawaii, differing vastly from the Fijian varieties in that they tend to have larger flowers, be more frost tender, have a more 'sprawly' growing habit, and will not stand winds of any force. Hence they must be grafted and in turn this produces:

1. A stronger root system which will handle stronger winds.
2. A more vigorous plant, flowering earlier and better, with longer life.
3. A hardier scion variety in reference to frost.
4. A saleable plant in approximately 6 months.
5. A larger quantity when stocks are limited.

Grafting. Spring seems to be a successful time, and plants grafted at this time can be retailed in February (late summer). If grafted in late summer and wintered in a glasshouse they produce good saleable plants for early spring.

Method 1: Grafted onto a growing stock — in a tube — is ideal. The stock must be vigorous, hardy and produce roots very quickly. Some good examples are 'Suva Queen,' 'Simmond's Red', 'Fiji Flame', 'Agnes Gault'. If hardwood cuttings are prepared in late summer and tubed as soon as they are rooted, they produce excellent stock for grafting in the spring. A whip and tongue graft is best, producing a good neat strong union. Cleft grafting is probably practised more often for several reasons: (1) quicker; (2) possible to use machine to cut scions which is easier for unskilled labour.

The scion is prepared with two nodes and of recent growth. The leaves will need reducing in size slightly. If the scion is prepared with leaves left on it is advisable to place the graft under mist; this isn't necessary if the leaves are removed.

Method 2: The scion is grafted directly onto an unrooted, hardwood cutting. Take a cutting of a suitable stock, as described above — 3½" to 4" long, ¼"-½" thick. Cut to a node at the base, and to an internode at the top on an angle. Hibiscus being somewhat susceptible to rot, it must be ensured that a clean cut is made. The scion should be prepared the same as for

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3. A hardier scion variety in reference to frost.
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Method 1. The stock has to be split with a knife and have the scion inserted for the cleft graft. Tie very tightly with plastic, and coat with grafting wax or with a stretchy type of rubber which seals and waterproofs. If the scion is inserted flush with one side of the stock the cambiums will be matching — (the cambium of hibiscus is very wide). The best graft matches on both sides. Dip the stock in Seradix 2 with 5% Benlate and put it in a tube of 1 part peat, 2 parts sand. Put on bottom heat at 80° F, and use mist if the leaves are left on the scion. These will root in 5 to 6 weeks and the scion will start to shoot. Liquid fertilizer can be applied weekly as soon as cuttings are well rooted.

Once the scion has sufficient top growth the ties can be cut and the grafts can be potted into a larger size. If the stock shoots at any time they should be cut off.

J. WELLS: Am I correct in assuming that the method was to graft on an unrooted cutting?

A. W. PALMER: Yes, using an easily-rooted cultivar which will root in the same time the graft takes to form a union.

J. WELLS: Do you ever use a side graft?

A. W. PALMER: No, because it is not as quick as a cleft and speed is essential. The machine is only capable of making a cleft graft.

P. BATES: Do you have the stock dormant and the scion forced on to get the growth when you require it?

A. W. PALMER: No, you can have a dormant stock or scion with no leaves on either.

F. SCHUURMAN: With conditions right how many could you graft in a day?

A. W. PALMER: Two men doing the complete operation between them, including potting into tubes, did 100 per hour with ease. This output increases with experience.

G. B. SMITH: Do you try to disbud the stock to avoid suckering?

A. W. PALMER: No, it may be worthwhile — but they do not shoot normally.

E. J. MARTIN: Is the graft potted above the soil level?

A. W. PALMER: Definitely above soil level — to avoid, at all costs, problems with rot.

E. J. MARTIN: Do you find it unnecessary to wax the graft?

A. W. PALMER: The rubber obtained locally for the purpose will spread over the union completely.

SUMMARY OF NEW PLYMOUTH FIELD DAY FEBRUARY 24, 1973

JUDITH COWAN

Duncan and Davies
New Plymouth, New Zealand

Duncan & Davies: A tour of the *Research and Development Department* was first on the agenda, with Mr. Trevor Davies (Managing Director) outlining the conception and function of this area which is to grow new introductions (both local cultivars and imports) to a stage where their merits in this locality can be ascertained as to hardiness, merits of flower, foliage or growth habit, etc. Stock is thus built up allowing immediate propagation of worthwhile subjects.

Propagation Department: The emphasis here was that all visitors be allowed to wander about as they pleased, migrating to the area of particular interest to the individual. Static displays were mounted of heating equipment (kindly loaned by the local City Council), mist nozzles and ancillary equipment, and these stimulated much discussion and exchange of ideas. Much doubt was expressed about the types of misting nozzles at present available.

Media trial work on rhododendron and magnolia cultivars was displayed in chart form with samples of the media used. The inclusion of sawdust was somewhat startling to many people and the four grades of perlite caused considerable comment. The standard rooting media used by the nursery for the last ten years consists of 3 parts sawdust, 1 part peat, and 1 part sand. This again aroused comment but the results were self-evident on inspection of material in the glasshouses.

Further charts showing the rooting hormones and potting composts used were made available and obviated the repetitive answering of questions. A brief outline (with examples) was given of the recording system used throughout the nursery. Based on code system whereby each crop is given a code number which remains with it from inception to sale.

Considerable interest was shown in the Quonset type glasshouses, mainly in relation to the material used throughout.

Trial beds of open ground cuttings in a nearby sheltered valley brought back memories of "the old days" for some, and raised the doubt about the expense of indoor mist propagation. Of particular interest were the results of wisteria cultivars, and Golden Elm — the "Control" of which were superior in numbers rooted.

Following a salad lunch at *Pukekura Park*, members were introduced to Mr. George Fuller (Curator) who gave a conducted tour of the glasshouses, then up to the *City Council Nursery* where he had mounted a display of orchid propagation methods.

A brief survey was then made of *R. A. Duncan's Propagating Department*. Members noted with interest the use of simple low tunnel structures for mist propagation.

On to Duncan & Davies container and field division at Brixton where considerable interest was shown in the new paddle mixer which turns out ½ cubic yard in three minutes. The newly laid out container area of 12 acres stimulated discussion on methods of surfacing and materials used.

Seaview Plant Farm just out of Waitara was next on the agenda and here the owner, Mr. O. Gibson, had a very attentive audience as he displayed his method of open ground propagation of *Protea* and related species.

The final call for the day was paid at the home of *Mr. Howard Theobald*, a keen young nurseryman, specializing in a wide range of rare perennials, bulbs and cacti.

PROPAGATION OF PROTEACEAE BY CUTTINGS

B. L. McKENZIE

Topline Nurseries
Auckland

Cuttings of *Protea*, *Leucadendron* and *Leucospermum* are taken from mid-summer to early winter. These are approximately 4-5" in length (depending a little on the cultivar) and the lower two thirds is stripped of leaves. Cuttings are then treated with IBA 0.3%, quick dip, this giving better results than the Seradix No. 2 powder, formerly used.

The rooting medium I use consists of peat and sand, 1:1 and, as our nursery produces liner crops only, 90% of the plants are rooted directly in tubes. This also reduces root disturbance which is particularly important with Proteaceus plants. Certain small-leaved cultivars are rooted in small tubes and, when rooted, transferred into larger tubes. The potting mix here comprises 2 parts soil, 1 part peat, and 1 part sand, sterilized with M.B.C. and contains the following fertilizer per cubic yard: lb. Uramite, ¾ lb. superphosphate, 1 oz. potassium nitrate, 1 oz. potassium sulfate. No lime is used but supplementary liquid feeding is given.

Our aim throughout rooting and growing on is to have a maximum airflow with a minimum of water. We achieve this by placing the cuttings in outdoor frames using P.V.C. cover as a rain shield over which heavy shade is placed during the brightest part of the day (9 a.m. to 4 p.m.). Water is applied by hand 2-3 times a day under hot conditions but only when absolutely necessary. As rooting commences both shade and watering are progressively reduced.

GRAFTING ORNAMENTAL CEDARS

N. PARR

Lyndale Nurseries
Auckland

I would like to speak of my experience with the grafting of three cedar cultivars — *Cedrus deodara* 'Aurea', *C. atlantica* 'Glauca' and *C. atlantica* 'Aurea'.

The understock used is *C. deodara* seedlings about 18 months old and grown in small containers where a vigorous root growth is maintained through liquid feeding. The plants are brought into the glasshouse for several weeks prior to grafting to stimulate root activity. This is usually about mid-March (early autumn) or when the scion wood is considered mature.

Figure 2. *Cedrus deodara* 'Aurea' one year from grafting.

PROPAGATION OF DWARF ORNAMENTAL CONIFERS

B. BLACKMAN

Blackman's Nurseries
Te Kuiti

Annual production in our nursery is in excess of 30,000 dwarf conifers in containers.. I consider, by specialisation, we have been able to concentrate all our efforts on aspects of production and problems associated with the various species and cultivars.

I have been told that dwarf conifers are nature's freaks and it would appear, by the inability of most forms to set seed, that nature tends to conserve her species. We have found on rare occasions when a dwarf conifer does produce cones, the resulting seed is usually not viable or, if viable, plants true-to-type cannot be produced, e.g. *Pinus mugo* and *Thuja orientalis* 'Aurea Nana'.

Having observed the results of imported grafted dwarf conifers, I am convinced that grafting should not be practised unless cultivars are impossible to propagate economically by cuttings. In the same way an apple tree will respond to rootstock vigour, a dwarf conifer grafted onto a strong-growing seedling will lose its character.

All of our conifer cuttings are propagated under glass. We have an all-purpose house with heating cables on all benches which run at a temperature of 21°C. (70°F). We also have intermittent mist on half the benches.

We use a standard propagating medium of 2/3 pumice and 1/3 Irish peat. This gives us adequate drainage under mist conditions and sufficient water retention elsewhere. We have attempted to reduce the cost of our medium by introducing different types of sawdust in varying proportions but have found it too water-retentive over the long period it takes cuttings of some conifers to root.

While many propagators advocate large cuttings, in my opinion small cuttings ensure that the dwarf character of the plant is retained. Over several seasons we observed that by taking large cuttings from stock plants of *Chamaecyparis lawsoniana* 'Forsteckensis' any growth made the next season was progressively smaller and more different to propagate, but where smaller cuttings had been taken from different plants the annual growth rate was better and we had an appreciably better take. Since our discovery that many conifers are affected in this way we have, wherever possible, used the nursery row as a source of material.

Propagation commences in late summer starting with the more easily rooted cultivars. Where possible we try to make all our cuttings of wood that is somewhere between semi-mature and mature but the type of wood tends to vary depending on the species being taken. For example we have successfully taken very soft cuttings of *Juniperus communis* 'Depressa Aurea' but correspondingly soft cuttings of *Juniperus chinensis* 'Blaauw', due to the nature of the species, have been equally unsuccessful.

All of our cuttings are wounded and Seradix 3 (IBA 0.8%) is used on all cultivars regardless of the type of wood used.

As most of our material is collected from the nursery row, it is relatively free from disease but all of our cuttings receive one application of Benlate fungicide after they have been set in trays.

In my experience, it is difficult to get two propagators who agree on the benefits of using mist on conifers. This, I feel, is mainly because for too long we have considered conifers as plants that, in the process of propagation, cannot be hurried. For many years I subscribed to that theory and we used bottom heat and manual misting usually once or twice a day. Since installing mist we have found the time taken for rooting has been greatly reduced. Some forms, however, cannot be hurried.

We tube our cuttings straight from the bench into a 1:1 mixture of soil and used propagating mix.

In summary I should like to say that I have been deliberately vague as to the specific time in which to take any particular dwarf conifer cuttings because I believe that climate and the particular state of one's stock plants, along with the method used, are more important in most cases. Timing is of paramount importance with *J. chinensis* [*J.* x *media*] forms and *Chamaecyparis ob-*

tusa forms. Here I feel, through unsuccessful experiences of attempting to emulate other propagator's timing, that a variation in climate from area to area is, perhaps, the key.

PEAT/SAWDUST MIXTURE AS A PROPAGATING MEDIUM

JUDITH M. COWAN

Duncan & Davies, Ltd.
New Plymouth

While the properties of peat have been well researched and are known to all nurserymen, sawdust as a propagating medium has received surprisingly little attention. As far as I can ascertain the only New Zealand literature on the subject was produced by Mr. Charles Challenger of Lincoln College some ten years ago. I find it amazing that a material so readily available and with such obvious potential should have escaped critical analysis.

History. At Duncan and Davies we have been using sawdust as an integral part of the propagating medium for the last 14 years during which time a change was made from "pit" to "container" propagation. Sawdust was considered suitable because it had the following advantages:

(1) *Availability* – Most materials had to be imported from outside the Taranaki region, e.g. sand and pumice from the Waikato area. Sawdust was available from a number of local mills and a regular supply could be maintained.

(2) *Cost* – For a medium which is being used once only, it becomes important to keep the cost at a relatively low level. The extreme cheapness of sawdust, coupled with the excellent results achieved, led to increased trials and usage.

Earlier our mix was comprised of sand/pumice or peat/sand and, with the change-over to plixi trays as containers, these orthodox mixes appeared to be too wet. Trial work done with sawdust showed that here was a material worthy of further investigation. Some problems had to be resolved — whether plants grown in a sawdust mix would transplant into soil, and drainage problems with the container — not to mention the elusive rooting percentage!

Results continued to be highly successful and eventually led to the adoption of a *standard medium* consisting of: 3 parts sawdust, 1 part peat, and 1 part sand (or pumice). This mix has been in use up to the present day and is used on an extremely wide range of plant material.

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Ingredients.

(1) *Sawdust.* The type of sawdust we use is generally from *Pinus radiata* trees, but sometimes that from *Cupressus macrocarpa*, and occasionally *Dacrydium cupressinum* (Rimu) is used, although this is generally mixed with the pine sawdust. The sawdust is untreated, coming straight from the breaking-down saws at the mill and may be up to three months old. It is of a coarse chip grade due to the large set on the saws.

(2) *Peat.* The peat used is imported from Ireland. The cost of New Zealand peat is comparative but the Irish peat moss is consistently of a better structure and grade.

(3) *Sand.* This is brought in from the Waikato area, the reason being that our local product is very heavy, the supply has been inconsistent, and it had been difficult to obtain within a given envelope. We are thus faced with a very high freight charge.

(4) *Pumice.* Pumice has recently replaced sand in our medium — mainly for purposes of standardization throughout the nursery, and due to our increasing export trade, where sand is often considered unsuitable.

In common with many other nurseries we are always anxious to improve our techniques and the availability of materials such as *perlite* in differing grades and *polystyrene* has led us to some interesting trials. Keeping in mind our standard mix as a basis for comparison, a number of trials have been done within the production line.

Table 1. Results achieved in media trials within the production line, showing the percentage of rooting in each case

Plant	Std Mix	Peat-Sawdust, 1:1	Peat-Perlite, 1:1	Peat-Polystyrene, 1:1	Peat Only
Rhododendron 'President Roosevelt'	70%	82%	57%	87%	30%
x*Soulangeana Magnolia* 'San Jose'	90	80	100	—	—
Boronia megastigma	87	95	83	37	79
Phebalium 'Illumination'	88	100	88	—	—

Results to date seem to indicate the following points about a 50/50 peat-sawdust rooting medium:

(1) In most cases it is as good as, or better than our standard medium.

(2) Rooting occurs more quickly.

(3) Root quality also appears to have improved.

The largest trial to date of this medium has been on an easily rooted subject, *Phebalium squameum* grown as a contract crop.

Of the 10,000 required 8,000 were set in a 50/50 peat-sawdust and a much superior rooting system was apparent.

Another interesting fact emerging from trial work such as this is that where the pumice fraction is reduced (or rexoved altogether) there appears to be a marked increase in rooting percentage. In line with this, from the results with the peat-sawdust mix, and new soil mixing facilities at the nursery, we have recently changed to a 3:2:1 medium (3 parts sawdust, 2 parts peat and 1 part pumice) and the results appear to be very promising.

Where do we go from here? It is obvious that a lot more research has to be done into the materials available as propagating media, including those as commonplace (in New Zealand, anyway) as sawdust.

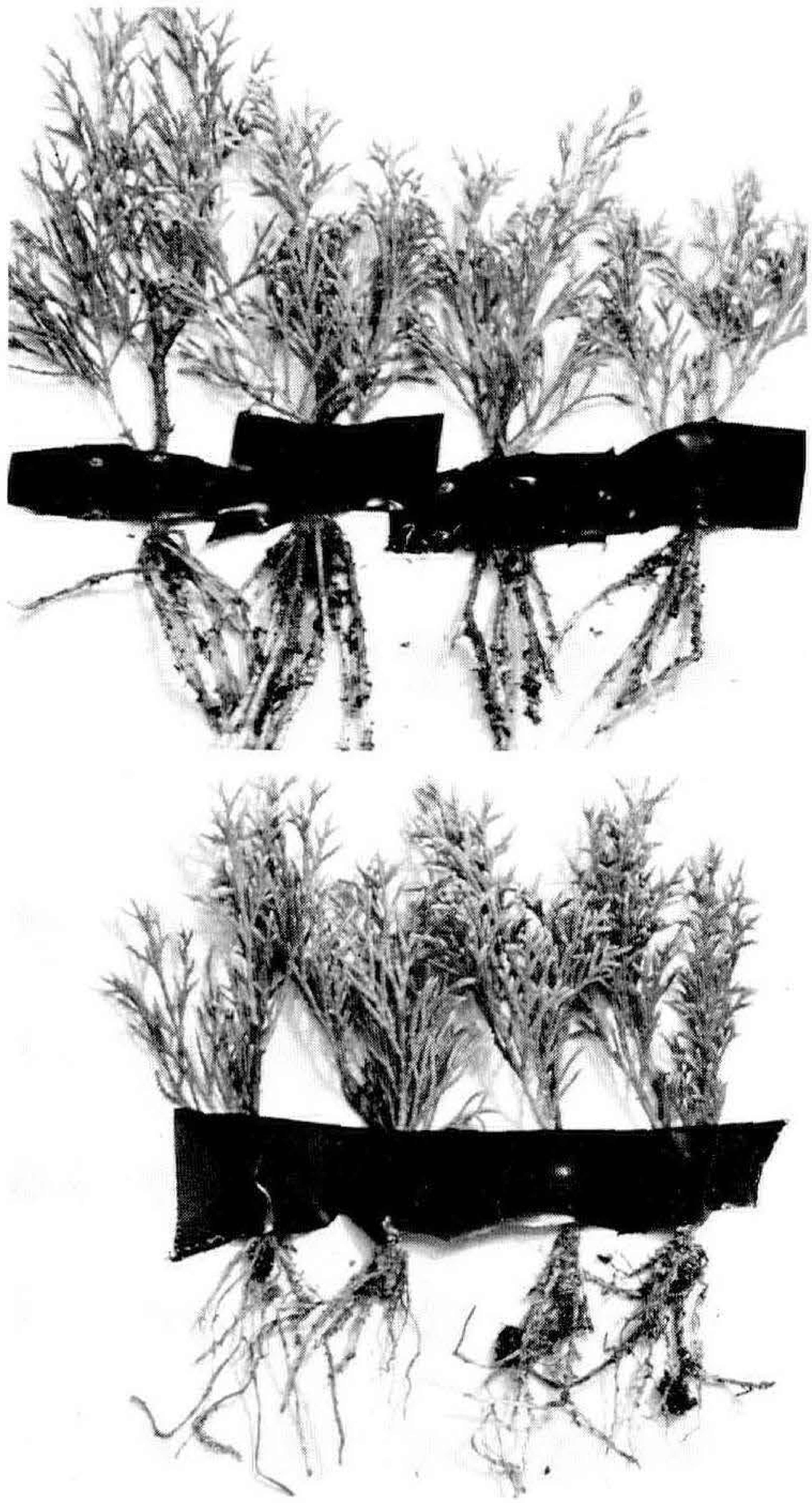

Figure 1. Comparison of root quality in *Cupressus sempervirens* 'Swane's Gold' cuttings. *Above.* Peat-sawdust, 1:1. *Below.* Standard medium; sawdust-peat-sand. 3:1:1. Reset September 14, 1973. Lifted November 1, 1973.

Figure 2. Comparison of root quality in *Photinia* X 'Red Robin' cuttings using a peat-sawdust, 1:1 medium *(above)* vs. standard medium: sawdust-peat-sand, 3:1:1 *(below)*. Set September 24, 1973. Lifted November 1, 1973.

PROPAGATION AND CULTURE OF RAOULIAS

T. HATCH

Joy Plants,
Auckland

These ground cover plants are, as far as I know, endemic to New Zealand and some are still awaiting identification. On the whole they are riverbed or high mountain plants and they grow in very exposed and poor conditions. The majority are mat plants some extending to six or eight feet across. Most are grey in colour and felty in texture owing to the fine hair covering. They can be divided into two types: one, the "Vegetable Sheep" type, comes from the mountainous regions, mainly in the South Island. These grow in big silvery hummocks, hence the name, but are somewhat difficult to grow in the North Island owing to climatic variation. The second type, known as "scabweeds", inhabit riverbeds down to sea level and are thus more suitable for growing in the North Island. Two of the most popular types are the silvery-coloured, *Raoulia hookeri*, and *R. eximia*, which is grown extensively overseas. In New Zealand most cultivars are still treated as collector's items, with the exception of those already mentioned.

The "Vegetable Sheep" type are difficult to propagate and there are only two or three people in the North Island growing them. All cultivars can be grown from cuttings taken *in situ* from plants in their native habitat or from plants which have become "acclimatised" to the northern conditions. Remove the dead leaves at the base of the cuttings and insert in coarse sand and place in shade outside. They will not stand close humid conditions inside and take about three months to root.

The more easily rooted cultivars can be grown simply by division which is best done in the autumn, the pieces being set in a tray of pumice-sand, placed under cover for a week and then shifted outside. Harden in stages then shift out into full sun for a further six weeks when a nice compact root system is formed. Sand appears to be essential for this first period but they can then be potted up into a 50/50 peat-sand mix with 8 lbs. MagAmp and 4 lbs. lime added per yard.

Raoulias can also be grown from seed but this is a rather long process.

Most cultivars are relatively slow growing but are becoming popular for rockeries and will stand tremendous traffic (e.g. those planted around some of the hydro-electricity stations). Very few pests seem to attack them apart from a small leaf-roller caterpillar which can be easily controlled with Malathion.

PHYSIOLOGY OF ROOT INITIATION

B. T. BULLOCH

Biological Sciences, University of Waikato
Waikato

A botanist's approach to plant propagation is fundamentally one of rueful diffidence. An eminent plant physiologist confessed that, despite his erudition on the mechanics of plant function, he found it impossible to persuade plants to function in his backyard vegetable garden. It's no mystery really for in large part botany consists of taking something the plant does without any trouble and making it seem difficult — in fact, to make it seem impossible is a major break-through. Perhaps it's the difference between science and technology, or if you like, the difference between science and reality.

Biological science today has two prime backdrops: the interaction of organisms with their environment, including other organisms — that is the broad field of ecology; and how organisms function — that is the broad field of physiology.

In the course of their practical work at this University, botany students investigate common hormone-mediated plant responses. For example, a property of GIBBERELLINS is to induce dwarf cultivars of peas, beans and maize to grow to full size. Gibberellins (GA) promote a proportionally much smaller extension of full-sized cultivars, but at increasing concentrations, rapidly become inhibitory and eventually fatal. With a modified mung bean test we demonstrated AUXIN's promotion of adventitious root initiation on French bean cuttings. Using ivy cuttings we showed the enhancement of root initiation and development by the presence of juvenile leaves.

In this latter case one may postulate that the leaves are a source of photosynthate, or phenols which protect auxin from being enzymatically oxidised, or a site of protein synthesis. A mixture of sugar and amino acids only partially substitutes for juvenile leaves, leading some workers to search (unsuccessfully) for a specific rooting hormone, although a synergistic interaction of known growth regulators is more likely.

When this lecture was first mooted I suggested (carelessly) that plant propagation consisted of promoting what was going to happen anyhow.. Let's look at what happens. Notice that the roots induced on the French bean cutting by immersion in auxin solution are in lateral rows directly referable to the anatomy of the stem vasculature. Roots are initiated in the primary rays just outside the vascular cambium. The meristematic activity of the vascular cambium, cutting off derivatives that become phloem towards the outside and xylem towards the inside, produces the secondary thickening of dicotyledonous stems.

Consider willow, a so-called easy rooting subject, which has latent root primordia at its nodes. These latent root primordia are released from suppression by wounding or high humidity to grow out as adventitious roots. Initially the primordia are just undifferentiated groups of cells, but by nine years they may have a well-organised root cap and vascular system. Rapid vascular differentiation is a feature of the release of latent adventitious roots. How do we study the environmental influences *on the cell* that cause cells in such close juxtaposition to differentiate as phloem, xylem, and cambium?

Wetmore & Rier (1) found that if a bud was grafted on to the top of a block of *Syringa* callus in sterile culture, nodules of vascular tissue differentiated in the callus at a precise distance back from the bud, suggesting a critical point in a gradient. Moreover, physiological concentrations of sucrose and IAA (indole-acetic acid) could be substituted for the bud, and when ratios were varied, high IAA favoured xylem differentiation and high sucrose favoured phloem.

Vascular differentiation can also be studied in wounded *Coleus* stems, where physiological concentrations of both exogenous auxin (2) and CYTOKININ enhance the differentiation of WVM's (wound-vessel members), a kind of xylem element. Cambial activity may be studied in segments of *Coleus* stems on sterile media, here auxin favouring xylem production (3) and gibberellin favouring phloem.

Let's consider an experiment with brittle willow, *Salix fragilis*, consisting of applying a ring of TIBA (tri-iodobenzoic acid) between the second and third nodes (numbering from the stem apex) (4). TIBA blocks the transport of IAA, in this case reducing the levels of extractable auxin below the ring by 50 %. Cambial activity was reduced by 25 %, the number of root primordia initiated during the experiment by 50 %, and their cell numbers per primordium by 75 %. The reduction in primordia well-developed at the beginning of the experiment was much less though their cell numbers were also reduced by 50 %. The effects of surgical removal of expanding leaves and buds are similar to a TIBA blockage.

Presumably the reduction in intra-primordial cell divisions and the reduction in cambial activity reflect the same response to auxin depletion, but has the reduction in primordia actually initiated a direct auxin effect or an indirect effect through the depression of cambial activity? This was investigated using exogenous gibberellin to stimulate cambial activity (4). At rates of GA that increased cambial activity by more than 75 %, well-developed primordia were reduced over 95 % in number, whilst primordia initiated during the course of the experiment were less sensitive, being reduced by only 60 % in number.

Hence it may be concluded that auxin does have a direct effect on root initiation in brittle willow, but only if the concentrations of auxin are sufficient to sustain a given level of cambial activity. Further, GA depresses rooting by affecting an auxin-mediated process after the actual initiation.

The varying levels during the year of hormones such as GA and auxin, and the other growth regulators with which they interact, could account for the seasonal variation in the rooting ability of cuttings of many species, as well as the differences among the species themselves.

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CHEMICALS AND THE REGULATION OF PLANT GROWTH

A. S. EDMONDS

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Many chemical substances are now used in horticulture and agriculture to affect the growth and development of flowering plants. Some of these substances are very familiar, for example:

2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid

These chemical substances intervene and exert recognisable effects on plant growth and development but in a characteristic, non-nutrient way. Small amounts are effective, and these quantities are not incorporated into the substance of the plant.

Among the many regulatory substances in common use are the two above-named selective herbicides which kill plants of broadleaved species but not of grasses. As well there are total-kill primordia initiated during the course of the experiment were less sensitive, being reduced by only 60 % in number.

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Among the many regulatory substances in common use are the two above-named selective herbicides which kill plants of broadleaved species but not of grasses. As well there are total-kill herbicides, e.g. CMU, 3-p-chlorphenyl 1-1 dimethylurea, and Ammate, ammonium sulphamate. There are chemicals which stimulate the rooting of cuttings, e.g. indole-3-butyric acid (IBA). There are chemicals which cause leaves or fruit to drop, e.g. Endothal, disodium, 3,6-endoxohexahydrophthalate. There are chemicals which promote fruit setting, e.g. NAA, a-naphthaleneacetic acid. There are chemicals which promote stem elongation, e.g. gibberellic acid (Gibrel) and chemicals which retard stem elongation, e.g. Alar; 1,1-dimethyl aminosuccinamic acid. There are chemicals which stimulate fruit ripening, e.g. ethylene, C_2H_4; and chemicals which depress fruit ripening, e.g. cargon dioxide, CO_2. Most of these substances can be synthesized, developed for a particular agricultural or horticultural need.

One can approach the problem of how growth in plants is regulated and controlled through attempting to understand the roles of these and other natural chemical substances which intervene to modulate the behaviour of cells and tissues of flowering plants. Inevitably, in so doing, one is impressed by the variety of plant responses that are involved in contrast to the often-held view that plants display little response to external and internal stimuli. This often-held view derives probably not from any lack of response in plants but from slow responses. These slow responses are many and include tropisms, responses to light (phototropism) gravity (geotropism) and chemicals (chemotropism); nastic responses or sleep movements of leaves, stems and flowers; rhythmic pheonomena in growth and development; organ growth by cell enlargement and division; initiation of lateral organs and related problems of phyllotaxy; induction of flowering; formation of perennating organs such as buds, tubers and bulbs; periodicities in growth, such as the cambium displays; regulatory effects of light and temperature on growth; and the induction of sexuality. These then are some of the more usual forms of development, but as well, unusual development such as the formation of root nodules and pathological growth of galls and tumours also occur.

Chemical causation is implicit in all these morphogenetic responses and faced with such a range of responses the trend has been to invent classes of substances which are thought to exist within plants and which correspond to the observed morphogenetic responses. The list of these classes of substances is long and includes *auxins*, which increase cell size; *gibberellins*, which cause elongation; *cytokinins*, which increase the number of cells; *florigen*, which mediates flowerings; *anthesin*, which mediates temperature responses; *abscisic acid (dormin)* which controls dormancy and abscission; and *morphactins* as a class of substances controlling other morphological responses.

These classes of supposed biological substances have been described by plant physiologists following a period of feverish activity, but the very description of such substances and the subsequent searches for them have produced great confusion. For some of these classes of compounds however, evidence has been accumulating which establishes them certainly as important plant growth regulators or plant hormones.

Almost 50 years ago, and in opposite parts of the world, proof was given of the existence of substances which promote growth of plants. In 1926 in Holland, Went provided convincing proof of a diffusable substance obtained from oat seedlings which promoted their growth. This was the beginning of research into auxin. In the same year, Kurosawa in Japan gave proof of a substance in cell-free fungus filtrate which promoted growth of rice seedlings. This was the beginning of gibberellin research. Auxins and gibberellins are now recognised to be two separate classes of chemicals that cause distinct growth patterns in plants.

Auxins. It is now certain that the naturally occurring auxin in plants is indole-3-acetic acid (IAA). It occurs in minute quantities in growing tissue, e.g. in pineapple shoots about 6 ug per kg of plant, or about the weight of a needle in a 22 ton truck load of hay. This low concentration occurs, in part, because IAA is constantly being destroyed by the enzyme, IAA-oxidase, which is present in all plant tissues. Many synthetic auxins have been found; some, e.g. 2,4-D, are more potent than the natural IAA.

Auxins are required for cell expansion and as well for cell division but they have a multitude of additional effects. Auxins promote root formation in cuttings; they can convert vegetative growth to reproductive growth; they can change the sex of flower buds. Auxins are synthesized in the apical meristems of flowering plants in the light and are transmitted throughout the plant by diffusion from cell to cell.

Gibberellins. Gibberellins (GA) are normal components of higher plants where they regulate cell elongation. Some gibberellins can cause flower formation. Gibberellins are synthesized in bud leaves, developing embryos, and root apices. Roots rarely respond to GA. Other organs show varying responses depending on whether they grow primarily by enlargement or division. GA also affects dormancy, e.g. in deciduous plants. Gibberellins are translocated by cell-to-cell diffusion.

Cytokinins. First suspected in 1941 as necessary for cell division, cytokinins now well established as potent cell division factors. Cytokinin activity is found in translocating xylem sap, in seeds and embryos and in green leaves. Concentrations of 50 to 100 ppb are found in sap. In 1964, 6-amino purines were identified as cytokinins by D. C. Letham at the Plant Diseases Division, Auckland. Cytokinins also function in delaying senescence of leaves on deciduous trees. Importantly they also seem to affect specific transport.

As well as these three important classes of plant growth regulators several more have been described. Some of these may simply be artifacts of the interaction of auxins, gibberellins and cytokinins. Significantly, moreover, ethylene is becoming implicated more and more in the control of the action of auxins, gibberellins, and cytokinins. Ethylene may well prove to be the key to a complete understanding of the way in which plants naturally regulate their growth and development or respond to applied chemicals. And while plant physiologists continue their efforts towards understanding this regulation, horticulturists and agriculturists will continue to use synthetic chemicals in an empirical way to obtain specific plant responses.

INAUGURAL MEETING IPPS AUSTRALIAN CHAPTER-AT-LARGE

JACK PIKE[1]

Pike's Nurseries,
Rydalmere, New South Wales

It gives me a great deal of pleasure on behalf of the Federation of Australian Nurserymen to officially open what is a very auspicious occasion in the history of the nursery industry in Australia.

I was reminiscing only last week about how maybe this Australian inaugural meeting of the International Plant Propagators' Society would have been if it had come along five or six years ago, when people in the industry were saying there was overproduction; we needed more merchandising; we needed more outlets and anyone who mentioned propagation or new techniques to produce more efficiently, well, they were sort of frowned upon. How things have changed.

There is one of the greatest shortages of plant material in Australia today than there has ever been in the history of the country and how timely it is that here at Leura, we should be holding an inaugural meeting to form the Australian chapter of the I.P.P.S. It is a very timely thing and I think it is going to, or it has, there's no question of doubt, gotten off to a very good start. This was very evident at the Conference in Sydney in March and many of you, most of you here today, got together and decided to give a mandate to the Queensland Wholesale Ornamental Growers Group (W.O.G.G.) to form or hold this meeting in New South Wales around about this time and the Queensland Wholesale Ornamental Growers Group have done a very good job in organizing and getting this meeting to the stage it is here today.

I am sure that give or take a few constitutional problems, we're in for a wonderful treat this weekend; the venue is wonderful — we're experiencing Blue Mountain greenery weather and it gives me a great deal of pleasure to declare the meeting open and I am sure that this will go down as a milestone in the short history of the nursery industry in Australia. We do not have the long history in horticulture of the United States or the mother land of England, but in a short time, I think we have come a long way and this is taking it another step forward.

It is a wonderful gesture by Mr. Wells to come out here. We appreciate all the spade work he has been doing throughout the world over the years in furthering the interest of our industry, and, I think he mentioned to me, an industry in which in the early fifties all that went on was behind padlocked glasshouse

[1]President — Federation of Australian Nurserymen

doors. I can remember this in our industry just after the War; you couldn't go in there because such and such is going on and people were reticent to tell you anything about their trade secrets, but I think nobody in the world has done more to break that barrier down than our distinguished guest here today, and I am sure we are going to have a very enjoyable and informative seminar with Mr. Wells as our very distinguished guest.

It gives me a great deal of pleasure on behalf of the Federation of Australian Nurserymen to wish the seminar well. It is another step in the right direction and all those associated with the industry should be very proud . . . Thank you very much.

THE PLANT PROPAGATOR HOLDS THE FUTURE IN HIS HANDS

JAMES S. WELLS

James S. Wells Nursery, Inc.
474 Nut Swamp Road
Red Bank, New Jersey 07701

It has been my good fortune to have been able to travel fairly extensively during the past few years and this travel has of course been associated with my interest in plant propagation and the nursery industry, wherever it may be. I have been able to meet and talk with nurserymen in America, England, Europe, last year in New Zealand and now in your country, discussing with them problems of plants, production, propagation, business, all the items that together make the nursery world tick. Now one thing stands right out from all this and that is that the speed of change — whether in our business or in the world around us — is accelerating to such a degree that even if we are aware of what is taking place, we feel quite unable to cope. In fact a book has been written on the subject and in many of the highly industrialized areas of the world, the problem of "future shock" is a very real one, for the future is arriving so fast and in such solid doses that many of us feel we don't understand and moreover we really don't know what to do with it.

The shock waves of change are running through the nursery industry also, and the most serious one is undoubtedly economic. People, by and large, are refusing to accept as they have in the past the rather rough and ready working conditions usually associated with horticulture, and the modest financial returns which may come from work of this type. I don't know what the situation is in Australia, but certainly in America, a very large doors. I can remember this in our industry just after the War; you couldn't go in there because such and such is going on and people were reticent to tell you anything about their trade secrets, but I think nobody in the world has done more to break that barrier down than our distinguished guest here today, and I am sure we are going to have a very enjoyable and informative seminar with Mr. Wells as our very distinguished guest.

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But today these people, all people engaged in land activities are beginning to look at other industries and then to realize that although they may prefer working on the land, nevertheless if they take a job in a factory they immediately have much better working conditions, fringe benefits, higher rates of pay, pensions, and so on.

The horticultural industry the world over is now coming face to face with this hard fact, and if it is to survive then it has to realize that it must not only try to equal the level in industry, but will probably have to do a little better, so that people can be properly compensated for the inevitable drawbacks of working with the elements.

But there is another squeeze coming, an even more serious one, and that is the need for land, good productive land. It may seem strange to you here in this vast continent, but there are substantial areas of the world where land is already extremely precious, and is most jealously guarded by those who have it. Good land is beginning to run out in many areas, which means that what land there is must produce at maximum efficiency.

I heard two rather disturbing statistics the other day, first that it takes about 60 good-sized trees to provide sufficient oxygen for one person and second, that about one million acres of land are being denuded of vegetation each year in America, to provide new roads, car parks, and so on. The inference is obvious.

Some scientists say that these changes, taking place at an ever accelerating pace all over the world, are already having a measurable effect upon the amount of carbon dioxide in the air, and this can, if it is allowed to continue, drastically change our whole environment.

So what has all this to do with plant propagators? Twenty-three years ago when our Society began it was my good fortune to give an address to the first meeting entitled, "The Plant Propagator — the Basis of Our Industry." This is really the fifth time that I have been in the happy position of essentially repeating this message, which I am most glad to do here in Australia.

In my original thinking it seemed to me that the plant propagator was one of the last strongholds of the real craftsman. Here may I quote directly from the first Proceedings:

"It is well for us to consider that the craftsmanship and skill of the plant propagator is the beginning of a long chain of events running through every phase of our industry. It is upon this skill, and upon nothing else quite so much, that all other parts of our great industry ultimately depend. Of what use would the landscape architect or the garden contractor be to the homeowner if no plants of any kind were available? Where would the florist obtain his flowers, his bulbs and seeds, and what would be the value of fertilizers, barrows, garden centers and garden magazines without plants. Everything growing which is covered by the term horticulture has to originate with the plant propagator. He is, in very fact, the basis of our industry."

This was the way I put it 22 years ago. It has been repeated through the years, yet it bears repeating once again because it is so absolutely true.

> THE PLANT PROPAGATOR, THE MAN WHO ORIGINATES PLANTS OF ALL KINDS, IS THE CORNERSTONE UPON WHICH ALL OTHER PARTS OF THIS VAST INDUSTRY DEPEND. WITHOUT HIM, WITHOUT HIS WORK AND HIS PRODUCTS *THERE WOULD BE NO HORTICULTURAL INDUSTRY.*

A further point which has become abundantly clear as I have traveled is that there is now a world-wide shortage of plants. I don't know what the situation is here, but in America anything of reasonable size is almost unobtainable. The same is true in England and on the European continent. Last year I was in New Zealand where I visited many nurseries and the situation seemed to be similar.

As one American grower put it to me recently, "We are in a seller's market and will be for at least the next ten years. People will be glad for anything they can get and we should take advantage of this situation to put our house in order and come right into the twentieth century as equal partners with other industries."

Throughout the world the demand for plants far exceeds the supply, and harking back to what I said earlier, with the vast urbanization of many areas, the need for and demand for plants is going to increase and will continue to exceed the supply for the forseeable future. This means, therefore, that the future does quite literally rest in the hands of plant propagators everywhere because the ravages which are being perpetrated on the natural vegetation of the world have to be replaced and replenished somehow. If the plant propagator does not do it, then who will?

Now, generally speaking, I do not think that the average propagator is actively conscious of this exceptional position which I believe he holds in the world of tomorrow — and perhaps that's a good thing, yet there is taking place a drastic change — note that word change again —in the attitude of the propagator towards both his work, and his fellow workers.

There was a time when the stringencies of economic competition made it necessary for the skilled grower to hold onto the small piece of individual knowledge which he had acquired, and to exploit it as much as he was able, to his own benefit. This philosophy produced the "locked greenhouse door," and similar restrictive measures which could perhaps have been justified under the conditions then prevailing. This did not matter too much, for the speed of change was extremely slow, the demands for stock were easily met with cheap and plentiful labor and profits might depend upon jealously guarding some small piece of information. However, the whole procedure could hardly be termed dynamic.

Today, of course, none of these conditions apply. We don't have the people and the demand exceeds the supply. The bottleneck is in production and in the rapid application of new knowledge, new ideas and techniques, so that we can all begin to meet the demand.

Now if all this is to take place, it needs the right climate of mental stimulation to succeed. The individual grower, working in his own little patch, usually just cannot generate enough ideas on his own, think up new methods, test and inovate, while still carrying on the everyday tasks which are inevitable in any land operation. He — or she — needs the stimulus of other minds, an opportunity to pause, and with kindred people to sit back and look at a problem together, argue, discuss and eventually arrive at an answer. This "meeting of the minds," this collection and re-distribution of ideas from one to another, is what the IPPS is all about.

I come now to the beginning of the Society. It commenced in 1951 and the first meeting was convened in Cleveland by Ed Scanlon. The Society had existed in the early twenties but had died a natural death as the depression developed, mainly because with the economic restrictions of the time, people with a little knowledge felt unwilling to share. When the meeting was called in 1951 it fell quite by chance to me to suggest the way in which we should organize. I thought a great deal about it and made suggestions which, at the time, received a "mixed" reception.

It was proposed that the Society should be organized on the basis of craftsmanship and that its purpose should be to bring together people with a knowledge of the craft of plant propagating and thus establish a reservoir of skilled knowledge and experience which should be recorded and disseminated so that people everywhere could benefit and growers of the future would have a record from which they could learn. Obviously for this to succeed there had to be a free exchange of ideas and information among members. I, therefore, proposed at the first meeting that the three essentials for a person to become a member in good standing should be:

1) Knowledge and experience in some aspect of plant propagation
2) A high standard of integrity
3) A ready willingness, even a compelling desire, to share knowledge and skills with people of similar character.

These three criteria have been accepted as the cornerstone of our Society and as it has widened and extended its influence each new group has accepted the pattern with alacrity, and in most instances have been prepared to apply even more stringent demands so that the central governing body had to temper their enthusiasm to insure uniformity.

Three years ago at our twentieth meeting held in St. Paul, Minnesota, we had the pleasure of welcoming for the first time members from Great Britain and I presented a short paper on the "Philosophy of the Society," and I would like to quote briefly from what I said at that time.

"I am sure that very few of us really bother to read the By-laws, but they are important, and especially is this true of Article 2, which is deceptively short and simple. It reads:

The purpose of this organization is to secure recognition of the plant propagator as a craftsman, to provide for the dissemination of knowledge through proper channels, and to provide helpful guidance and assistance to plant propagators.

It is impossible to say how many hours of thoughtful consideration and study went into the phrasing of this simple sentence, but if you read it carefully and think about it, surely here is the simple essence of our philosophy.

First — recognition of the plant propagator as a craftsman. To achieve such recognition it is obvious that the person must indeed be a craftsman — a person of experience, knowledge and skill. We wished to seek out such people, recognize them, help them where possible but especially ask them to make available to similar people their wisdom in dealing with plants.

Second — In order to gather this knowledge, we needed to provide a method of collection and dissemination — our meetings and publications — and thus ensure that this knowledge would be recorded; and finally, we realized that we have a prime responsibility to help the young student, to encourage the new generation to learn what we know and to carry on the good work, extending the frontiers of knowledge, refining and, more especially, adapting our work to the rapidly changing techniques and vastly increased knowledge of this modern age."

These, then, were our objectives, and I think I can state without fear of contradiction that they have been amply fulfilled.

Which brings me to the present to you good people in Australia. I hope you can see from what I've said that the principles on which our Society was founded were thought through with great care and have been applied and developed through the years with similar care and adjusted as seemed necessary until we now come to the time when the Society is about to achieve a unique position in the horticultural world.

In the 23 years it has been in existence, it has exercised a profound effect upon the development of the horticultural industry, first in North America, then Canada, and more recently in Great Britain and Europe. With the current development of the Society in New Zealand and now Australia, we shall indeed be a truly international body dedicated to our craft and, most important of all, to helping one another. I am sure you can see that the potential is enormous.

May I try a simple illustration. We assume that 100 people come to a meeting, each bringing with him 10c worth of knowledge. Throughout the meeting each person shares freely with all the others from the communal "pot" of knowledge into which each has deposited his small share. Each person can thus withdraw from the pot, knowledge to a total value of $10, thus everyone returns home richer for having come to the meeting. No one has lost, everyone has gained.

This simple illustration shows what has been happening in America and more recently in Great Britain. Its effect upon the whole horticultural industry has been stimulating and most valuable, for people now are really beginning to want to help each other. There is no feeling of holding back and anyone with a problem, feels — perhaps for the first time — that he can call a fellow member on the telephone and receive helpful encouragement and advice. For this climate to come about everyone has to understand and accept the principles upon which our Society works. Members freely and generously help each other and if we achieve this then the whole thing just has to succeed.

There is no question whatsoever that you, and your fellow growers in New Zealand, have a great deal to offer the growers in other parts of the world. You should not feel that because you are down here in the South Pacific you are out of things for I can see on every hand good people with good ideas which should be recorded. There was a time when distance counted and 10,000 miles was a long way. That just is not true anymore.

What is true is that keen minds from all parts of the world are facing exactly the same problems that you are. They can't get good labor. Costs are rising every day. Everybody wants 3, 4, and

5 foot plants when the biggest plant you have is 15". The government is becoming more involved in all that you are doing. The need for mechanization is universal. You name your problems and with absolute certainty there are 1000 people somewhere in New Zealand, England, and America who face precisely the same problems.

Some of these people have come up with the answers — not necessarily the best answers and not necessarily the final answers, but answers of some sort. It is heartening, encouraging, and helpful to learn what they are doing.

This, then, is the purpose of the International Plant Propagators' Society. It wants to put you in touch with people everywhere and it wants to bring people everywhere to you.

The most valuable thing of all is to bring people together as we have in this meeting for then there is immediately an animated, brisk, vigorous discussion, and whether you actually leave such a meeting as this with a gem of information which you can use really doesn't matter because you most certainly will leave feeling stimulated, encouraged, and recharged to meet your tasks with better heart.

So I have great hopes that you in Australia will help yourselves. Perhaps you can combine with your fellow growers in New Zealand to form a South Pacific Region. In any event you will run your own affairs and meetings, all of which will be of great value but add to this the stimulus of new ideas from all over the world from people of like mind and we have a formula for success which is unbeatable. A simple formula, yes, but it can enable us to meet the challenge of change which is going to be the hallmark of the next 50 years and, with this formula, I believe that the plant propagator will indeed hold the future in his hands.

PROPAGATION OF VIRUS-SYMPTOMLESS MATERIAL

MICHAEL G. MULLINS

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The subject I have today is one in which I have considerable interest, but must admit, is one in which I have no great personal experience. I would not like it to be thought that I was an authority in the field of plant virology at the University of Sydney. It belongs more properly to my collegue, Professor Brian Deveral, Professor of Plant Pathology, a micrologist.

I hope to show in this lecture that the fields of virology and physiology and biochemistry have many affinities and it will be certain that new research programmes will be forthcoming which will be of some interest, I hope, to the nursery industry and plant propagators in general. So if we can just turn to the subject at hand, and that is virus-free plant propagation material. Many people are not too keen on the use of the term "virus-free material." That is because it implies that the plant is free of all known viruses and that it has been tested and shown to be free. The "in" term is *virus symptom-free material*, but we needn't be too purist. Virus-free is well entrenched and we know what it means and I use it in the sense that, if something is virus-free it is free from debilitating virus diseases.

The first point to bear in mind about virus diseases is, there are no practical cures for these conditions; once plants are infected and are set out in the field or the nursery, that's it. They can't be cured; the control of virus diseases is possible primarily through the maintenance of clean stock programmes. As you know, a multitude of virus diseases are of importance in horticulture and these are of particular significance in long-lived woody perennial crops. It is in the woody perennial crops, the ones that take a long time to come into bearing, ones which involve considerable capital investment to get them started, that the effects of the virus diseases are particularly serious. There is a long waiting period before you can get an economic return and the investment is a long term one and the grower here is particularly dependent on the integrity and competence of nurserymen for his livelihood and also for his long-term profitability. With all crops, the strategy of disease control through clean stock or virus-free material is the same.

The strategy of the clean stock programme works in the following way:

(a) First of all we hope to dilute the infection in the population of plants by the continuous introduction of virus-free, or virus-symptomless, material.

(b) Then we wish to replace or destroy the infected material and establish vigorous clean stock.
(c) The third part is the isolation of the foundation of the mother stock to produce propagating material for further populations.

That's the strategy, and it depends on, firstly, the recognition of the disease and then reliable indexing methods, then therapy or treatment to establish virus-free, or virus-symptomless clones, followed by measures to maintain the health of the foundation stocks once we have cleaned them.

Recognition: In developing clean stock programmes or recognising virus diseases in the field in general is not always particularly easy. Many diseases are extremely obvious, like fan leaf, or leaf roll in the grapevine; anyone who has seen them once does not forget them. Other virus diseases are much less easy to identify from symptoms, e.g. the grapevine virus, yellow speckle. This is wide spread in commercial grape cultivation and it is rather difficult to recognise unless you know what you are looking for. In addition, there are variegations due to gymerism. These variegations look like virus diseases and they are easy to confuse with it, so with recognition, we need reliable indexing methods; that is, tests that can be applied to the material which will tell us whether or not it is infected.

Of the six methods that I will describe here, the first one is by far the most important in practical terms; that is *infectivity tests,* where parts of an infected plant or a plant, which is suspected to be infected, is grafted onto a host — and if the virus is in the scion, then it will produce symptoms in the host.

Similarly, *Sap-rubbing inoculation* is another commonly and widely used method of indexing, quite often using plants in differing species, differing genera, differing families. Plants of the family Canopodeacea can be used as indicator plants because these produce leaf symptoms which are recognisable.

The serological tests involves the antigen-antibody reaction where virus particles are injected into rabbits and then tests are done of the serum afterwards.

Electronmicroscopy is using the electron microscope to examine, not usually parts of tissues, but plant extracts, to see if the virus particles can be seen in the extract. This, of course, requires a high concentration of the virus to be visible.

Density gradient centrifugation. This is a technique where the plant is homogenised, an extract is made of it and this extract is placed in a centrifuge tube with a solution of sucrose or dextran, or some other compound, and it is then subjected to very very high speed centrifugation of the various subcellular particles which have been subtracted from the plant. They sediment out in differing positions in the centrifuge tube; it is just a way of concentrating the virus so that one can separate the virus from the other particles which is found in the plant tissues.

Histological and systological tests. This is cutting plant sections, treating them with various chemical compounds to determine if differences in reactions between infected and clean plants can be seen,. Chemical tests, either to extracts or to the plants themselves, were at one time thought to hold a lot of promise, but really they do not seem to have lived up to expectations.

So we can recognise the presence of a virus condition by visual symptoms or indexing techniques and, having discovered that the material is infected, we then want to see what we can do about it. We now proceed to consider some of the techniques which can be used for eliminating debilitating viruses from horticultural crops.

1. *Natural escape.* This works because some viruses are not fully systemic; that is, their occurrence within any one plant is rather random and if bits and pieces are taken from an intact plant, some of them will be infected and some will not. An example is in apple-mosaic. Buds from a mosaic infected tree when grafted onto healthy trees will give a proportion of infected plants and a proportion of clean plants. Another example is carnation-mosaic in gladioli. Some cormlets from the mother corm escape infection so this is random natural escape.
2. *Shoot tips.* This is a zone of the plant which can sometimes escape virus infection. In rapidly growing plants the shoot tips may be free from virus particles which are systemic throughout other parts of the plant; e.g. in dahlia, which can be freed from tomato spotted-wilt virus by just growing rapidly and taking a shoot tip cutting; similarly, pelargonium can be freed of leaf-curl virus in this way.
3. *Apomixis* is another very useful way of getting virus-symptomless material, related strictly to the sexual behaviour of plants. In plants the embryo sac is surrounded by a tissue called the nucellus and when the pollen tube grows into the embryo sac during the fertilization process, resulting in the embryo in the seed, this signals certain cell divisions to take place in the nucellus — and these cell divisions lead to the formation of other embryos. This is particularly important in citrus where we get nucellar embryos; these are usually virus free and this is thought to be due to the fact that there are no direct vascular connections between the nucellus and the other parts of the plant.

   Apomixis, or nucellar embryony is of great commercial importance in citrus and mango, but no great use has been made of this phenomenon in other species. Some of the research that we are doing is looking at plants which have a well developed nucellus (a good example of this is the grape) to see if we can, by using tissue culture techniques, artificially induce the formation of embryos in nucellar tissues. This work is still in its early stages.

4. *Chemotherapy* for cleaning plants. There are very few instances indeed where this has been successful. What happens is by applying chemicals to plants in order to cure them of a virus, the symptoms are suppressed for a while. Compounds like cytovirin 2 and thiouracil work by becoming incorporated into the nucleic acid of the virus. The problem is that these compounds are also incorporated into the nucleic acid, the DNA, of the plant. These techniques, which showed fairly early promise, are not particularly practical.
5. *Heat treatment* is the most practical way of all for cleaning plant stock of virus conditions; this is very successful and has been widely used for many years. Hot water treatment of sugar cane sets is an example of this. The techniques of heat treatment have been refined and expanded considerably in recent years. There are two main methods — use of hot water, and hot air.

   Hot water treatments are usually used on dormant material, sugar cane sets, budwood, dormant trees, potato tubers, and the like.

The effects of subjecting plant tissues to high temperatures when they are virus infected is supposed to work this way: At high temperature, there is a destruction of the virus which takes place at a greater rate than its replication. Storing of these tissues at 35° to 45°C is done for periods of a few minutes up to a few hours, or a few months.

I suppose, in the case of *hot air treatment,* it is sufficient to clean the viruses from at least a large proportion of them by bringing about destruction of the virus particles.

The Hot Box Methods using growing material. Plants are grown at a high temperature, around 35° to 45°C, depending on the cultivar, and in many cases viruses can be eliminated from the very top parts of these plants. When cuttings are made from these tips of heat-treated plants, the progeny are more often than not virus symptomless.

It is thought to work in this way — in the apical and subapical meristematic dome, the vascular elements are not well developed and, this being so, virus particles which are allegedly translocated mainly in the woody tissues, are unable to get into this area. When this tip is chopped off, the plant which will grow from it is virus-symptomless.

Heat treatment is more often than not these days combined with organ culture — the techniques of sterile culture of plant tissues. In fact, one can produce virus-symptomless plants by just chopping off the shoot tip and growing it in tissue culture without previously subjecting the plant to heat treatment but in many species, particularly in carnation, it has been shown that a combination of heat treatment and tissue culture is extremely advantageous in cleaning up infected tissue; it is thought that the mechanism of this treatment is that under the conditions of tissue culture or heat treatment the rate of replication of the virus is less than its rate of synthesis.

We should, perhaps, tell you something about the techniques of plant tissue culture. *Apical meristems* is a term often used for the micro cuttings. The very tip, the very growing point of a plant, is a structure called the apical dome. It is here that the cell divisions take place that lead to the formation of the tissues of the stem. Apices on either side are the leaf primordia in their very early stages; additional leaf primordia occur further down the stem. They occur in a sort of spiral way in the same way that leaves do since they will ultimately produce the leaves. Culture of apices involves dissection under a microscope in which a piece of tissue, usually 10 to 20 microns in size — extremely small — is chopped out of the apex of a plant. This is maintained by aseptic culture methods, including treatments with plant hormones such as auxins. Usually included in the mixture is coconut milk, which is a source of one of the families of plant hormones involved in regeneration. By the use of this mixture of coconut milk and auxin it is possible to generate a new plant from these tissues which will be virus symptomless.

Apical meristem culture is a term which can be used to describe growing the very apex plus a few leaf primordia. This involves chopping off only a few millimeters below the top. *Shoot tip* or micro cuttings involves a bigger section again.

We know that heat treatment works and Dr. Posnett, a well known virologist at East Malling Research Station, England, who was out here some time ago — and I know many of you met him — has calculated that about half of the virus diseases affecting horticultural plants could be eliminated by heat treatment. This means that if we could develop plant tissue culture techniques to a fair level of sophistication, we could do a lot more in eliminating virus diseases.

One of the problems, however, is that there are relatively few species which can be handled in this manner. Many of the highly desirable species, like apples, pears, plums, avocados and such nature cannot be regenerated from apices. We are taking particular interest in looking at biochemical differences between tissues which are easily regenerated in aseptic culture and those which are not. Some of the main problems which we encounter in growing shoot tips and apices in tissue culture is that we may remove virus from them, giving foundation material for a propagation programme, but at the same time many other problems arise; we may get cytological abnormalities, changes in chromosome number, giving polyploids; many of you are familiar with this.

We have found in our asparagus programme that we get a very high incidence of fasciation. There are many techniques available to clean up material for foundation mother stock but the techniques I have been describing are only half the story. Once we have cleaned the material or taken it through these various steps, then we have to go back and re-index the material to make sure the treatments have worked. This is a particularly long job in plants such as the grapevine.

I am not going to say too much about the organisational procedural or legislative measures that are obvious companions with any technical work on the cleaning of propagation material, i.e. the measures to prevent the dissemination of "dirty" materials, and such things as the development of repositories for virus-free mother stock. I am aware that much is being done in this country along these lines with pome and stone fruits, with grapevines and strawberries.

I did say that this sphere is not my own so I am not too certain about what is being done with the ornamental species. I am aware of work going on in Britain — the "Emlar" scheme; that is, a joint venture between the East Malling Research Station and the Long Ashton Research for the production of high quality material. This has been used for pome fruits and stone fruits for some time. Now the latest annual report from Long Ashton informs us that they are using these techniques to clean up ornamental *Prunus* species.

From the brief account I have given, you can see that the production of virus-free material is in some ways a big enterprise. It has a high capital cost, a high running cost, a high labour requirement and it requires well-qualified labour. I think you would agree that it would not be a job for the general nurseryman. It would be a specialist operation undertaken by the State Department of Agriculture, perhaps, or by co-operative ventures such as nucleus stock associations financed and controlled by participant members. Anyone who has suffered the economic consequences of infected material knows that the cleaning up of this material is well worth while.

[1]What we have done is to take ovules from one of the immature seeds of the grapevine and have cleared it so that it is transparent, then when we look at it through a microscope we can get some idea of the internal structure. We see the integments, the outer parts of the immature ovule, and the hole where the pollen tube enters for fertilization; the embryo sac is here but cannot be seen. The nucellus can also be seen.

We can induce the nucellar tissue to start growing. That happens normally in citrus and mango after fertilization, but does occur in the grape unless we remove the ovules under sterile conditions at a certain stage of growth, then grow them under tissue culture, giving treatments such as coconut milk or some other constituants.

What we have managed to do is to produce an embryo; this is the apical dome that I told you about and it will, in fact, develop cotyledons. It is an embryo of the grape cultivar *Cabernet Savignon*. That is quite an interesting point.

One of the aspects of our undergraduate programme is that every fourth-year student becomes involved with his own research project; one aspect of the work that interested us was to take shoot tips — not apices but shoot tips — of carnations and grow them in tissue culture and see if from one shoot tip we could produce large numbers of plants.

Normally when shoot tips are grown in tissue culture one plant grows from the apex but, as you know, in the axils of leaves there are buds; well, in the axils of leaf primordia there are small pockets of tissue designed to grow into buds and my student, Mr. Batten, by taking these tips was able to get several carnation plants with one shoot tip.

One of the major programmes we have is on the rapid multiplication of asparagus by tissue culture. Asparagus in commerce is grown from seed and since there are no sure cultivars it is highly variable; it would be a very good scheme if we could produce a clone of asparagus, especially from a male plant of good commercial characteristics. It is possible to grow plants from single cells and this is what we are doing in this project.

Cells have been planted out in Petri dishes, and the new asparagus plants will grow from them. Plant tissues have the capability to produce plants from cells but you can see that in a slice of tissue one millimetre thick with several hundred thousand cells there is a capacity to produce a vast number of plants and techniques such as this, if we can overcome the problems of polyploiding, this will make the propagation of virus-free or virus-symptomless material a much less expensive and a much more practical proposition mainly because there are several million cells in a plant.

We start with a male plant grown from a single cell and we are able to produce these by the hundreds of thousands. The main technical difficulties are not in the plant physiology, but the horticulture and nursery practice because the real skill comes in hardening them for transfer to the glasshouse.

In finalising, we go back to the point I made of the close relationship between work in plant physiology and work in virology. This gives the procedure we use for growing asparagus. We have a couple of possibilities here; we can produce a callus, we can then disperse it into free cells; the free cells will then produce embryos and then form plants. Take them in solid medium into the glasshouse or nursery field. Our first clone of asparagus is being grown at our new field station at Camden. On the other hand we can treat the callus rather like a cutting, i.e. induce roots to form and then induce buds to form and so forth but the yield of plants in this way is not so great.

PROPAGATION OF CONTAINER-GROWN ROSES

ROY RUMSEY

Rumsey's Rose Nursery,
Dural, New South Wales

Off and on, over the years, we had grown miniature roses from cuttings, but it was not until about 1968 that we stopped budding miniature roses, with the exception of "Standards", and grew them entirely from cuttings. It is quite satisfactory to take cuttings from either softwood or hardwood material and, according to the time of the year, a salable plant can be produced in quite a short time. We root the cuttings under constant daytime mist, harden them off outside, then pot them up as needed.

None of this is really news, as everyone knows by now, that miniature roses from rooted cuttings are, by far, better than budded plants; sales also have increased greatly since they were available for the public propagated in this manner.

However, this started us wondering if it would be possible to produce the larger type roses as budded plants, completely container-grown, with the rootstock placed in the soil mix and, at no time would the plants be field-grown. Of course, we had already seen the advantages of container-grown nursery stock amply demonstrated by growers of other plants, using steam-treated soil, etc. but, in spite of our queries all over the globe, we could not find anyone who had actually done this on a commermore practical proposition mainly because there are several million cells in a plant.

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We use *Rosa multiflora* rootstock, but have several different clones, each with definite characteristics, some serving special purposes. The cuttings from the briars are taken during winter, and made up exactly as for field-grown plants. The first time we did this we put 10,000 unrooted cuttings into 2" tubes and they were rooted and ready for budding in about six weeks. We had a special bench made in the shed and the budders inserted on the buds in a comfortable standing position. The budded plants in the tubes were then placed in boxes and set down outside. After about 14 days it appeared as though we were going to have a high bud strike, but just at this point the exercise failed — the reason, confirmed later, was a lack of food supply in the tubes.

The next trial of 10,000 cuttings were again placed in tubes in January (in Australia we can take summer cuttings as well as winter), and they were rooted and ready for budding in about three weeks. From this particular batch we had only 12 buds which failed to "take" in the 10,000. This, of course, was phenomenally high, and we were naturally very happy. However, after a few more exercises of this nature, and with the help we had from Department of Agriculture officers on our project, it appeared that around January, under outside conditions, was about the only time of the year that we could expect these good results. At this time stocks were at their peak growth activity while there was still sufficient food left in the tubes to last until the process of "healing" of the bud and stock was completed. Naturally, not all of our budding can be done in such a short time, so the tube method was abandoned. Our next trial was to put the unrooted cuttings into 6" containers in a soil mix which has been worked out to feed the cutting until the bud had completely "taken", and the stock ready for heading off. This method is the one we have finally adopted and which we have found to be so successful. In good weather conditions budding is done outside but if wet weather persists, and we cannot afford to wait for a fine break the plants are brought into the shed and we can get the buds on and not lose valuable production time. Naturally the plants are placed outside again as soon as possible. In the spring/summer season a saleable plant can be produced in six to eight months from the time the stock cutting is planted. This plant, of course, can only be sold in the soil in the container; it does have to be left longer if it is to be sold bare-root.

We usually commence budding in late October unless we have some stored budwood which can be used as soon as the cuttings are rooted; we do not do very much of this as we have a fairly long budding season which we can extend into April if necessary, although we do like to be finished by the end of March.

We use the same soil mixture for all our roses whether they are miniatures or large-flowered types. We have naturally tried many different mixes over the years, but now seem to be reasonably settled on one which is 50% medium loam, 25% river sand, and the balance made up of peat and perlite. The fertilizer added to the soil mixture is a small amount of superphosphate, sulfate of potash, blood meal, and bone meal; a little dolomite lime is also added, depending on the pH test. We start with a pH of 5.5 which will rise to about 5.75. This soil mix, with the fertilizer added, is sufficient for the first three months, after which additional nutrients are added by using RiteGro fertilizer tablets. We found that liquid feeding was costly and was soon leached out by watering. Otherwise, the plants are sprayed regularly and, in general, treated as should be done to keep up a high quality.

Some interesting observations on these container-grown plants are worthy of mention. The first thing that surprised us, and which we had not actually expected, was the terrific system of fine fibrous roots which are the results of the special soil mix and the steam treated soil. It is natural in the field to get a reasonably good root system, but it is quite impossible to get anything like this tremendous mass of fibrous root which every plant has. Now it has been recognised for many years that a plant with an abundance of feeding roots will transplant with greater success than one which has just a large tap and/or anchor roots, which has to make sufficient feeder roots to see the plant on its way in the new position where it has been planted. There is also the factor of large cut surfaces on these roots, leaving entry for soil or water-borne pathogens. We still send out quite a lot of plants bare-root in the winter, and here we just shake off the soil, wash it off if required by quarantine regulations, and pack in the usual manner with moist peat around the roots. There is absolutely no doubt that this type of plant will make a quicker recovery than one with less fibrous roots.

The container-grown rose has, of course, considerably extended our selling season so that now not a week goes by without some rose sales taking place. At first we did not know how well the public would accept this new idea, but this matter was soon made clear to us in a most favourable way. We also began to get the idea that maybe we could just sell through from spring to autumn, and that would do us but what has, in fact, happened is that our winter trade has also increased, so the final result is that we now work harder than ever as far as hours are concerned, but certainly not as laboriously.

Another point amply demonstrated in our nursery is that we can grow really beautiful specimens of some of the rose cultivars which cannot be successfully grown in the open field; these include some of the rich yellow and gold colours which the public so badly wants.

We have had our failures, of course, with container-grown roses; they were really all due to nutritional problems we encountered. At times we killed plants with fertilizers, so we are very wary of a change, even now. We do need a longer-lasting fertilizer and will probably start using one shortly; most of our larger-type roses are in the container from 8 to 18 months before sale.

We have also not succeeded in establishing plants for this length of time in any of the very light soil mixes; the roses do seem to need a compact soil to hold them for a long period of time. It has surprised us, too, what good plants can be grown in a not very large container. We do prefer a container with almost perpendicular sides as it seems, with this type of container, the roots just keep going to the edge, then just keep on making more; there is certainly no trouble with root binding in the pots.

Some of you must be wondering about the cost; it is hard for me to state categorically if the plants are appreciably more costly to produce in the containers than in the field. I would say they are, but the quality is there, and I know the price can be obtained for quality. Because the plants are sold with the leaves on throughout the spring to autumn months, we have to use fungicidal sprays every 10 days. Watering, too, is a constant task; this cannot be left as is possible with field-grown plants. However, all in all, the plants do repay for the extra care and attention and it is very satisfying to produce something really well and, of course, there is less waste.

We were assured by many people at the outset of one container-grown rose venture that you couldn't possibly produce a rose in a container and at times we did, of course, have very real doubts about it ourselves; however, we stuck it out and have now established this most satisfactory production method. We know for sure that we will never return to growing roses in the field again.

SOME ASPECTS OF RHODODENDRON PROPAGATION

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"Rhododendrons cannot be grown from cuttings with the exception of *R. fragrantissimum*." This statement was commonly quoted in books and gardening journals prior to 1940. It is difficult to understand why many of the smaller types were not generally propagated from cuttings prior to this time but it would seem that the discovery of "hormones" (more correctly, synthetic auxin stimulants for root production) really started commercial production by cuttings. Rimingtons, the well-known nursery firm in Victoria had some success with heat treatments and plant preparation techniques prior to the use of hormones, using bell jars. Olover Streeton (son of famed artist Sir Arthur Streeton) was one of the early experimenters with hormones.

The genus *Rhododendron* is divided into 43 series — Excluding the Malesian group — 22 of the series are "Lepidote" (with scales). *Azalea* is one of the "Elepidote" series. There are approximately 900 species. For the purposes of this paper we will discuss only the elepidote hybrids, e.g. Alice, Pink Pearl, etc. Komissirov in his compilation of the rooting history of 250,000 cuttings of 200 different genera summed up by saying, "There is no optimum condition or treatment which applies to more than one alone." This applies particularly to rhododendrons, as so many species are involved in their breeding and the genus is generally so variable.

To Mist or not to Mist. My first experience with commercial rhododendron propagation in quantity was in a "window lite" covered house with frames covered with the same material. A unique method of heating was used. A cement water bath about three inches deep with 3" x 1½" timber spaced approximately 1" apart was placed across the tank about one inch above the water.

Over the timber was a sheet of hessian and then some 4" of sawdust. In this sawdust 5" clay pots were sunk to their rims in which the cuttings were placed. The water was heated by a coke boiler by thermal syphon. Later the boiler was replaced by, firstly, an automatic briquette, and then by an oil burner. As there was variable temperature at each end of the frame by the thermal syphon method, a thermostatically controlled pump was installed and a ½" copper pipe laid in the water to heat by heat exchange. This is the method we mostly use to this day.

In the meantime an electrically heated bench and one bench with a mist system were installed. After a number of years with the different systems, operating results indicate that rising steam gives us, overall, better results than either mist or electric heating. Electric heating is too expensive in our aea. There is less leaf drop under mist but generally slower rooting; control of disease is a little more difficult under the highly humid conditions of the water bath. A certain amount of airing by opening the frames for an hour or more each day in cool weather helps considerably — even more than fungicidal sprays.

Hormones and Chemicals. After attempts with everything from acetic acid to 2,4,5-alpha propionic acid, etc. to finally indole-butyric acid, and with many complete kills, it was finally found that IBA in various strengths, from 0.25% to 2%, in talc gave us the best results. In the process of experimenting, it was found that the softness of the cutting had little to do with the strength of hormone required, but the cultivar does. Jelly-soft cuttings of deciduous azaleas, for instance, could take a higher hormone concentration than many quite hard-wooded rhododendrons.

In recent years a number of fungicides have been added to hormones on the recommendation of American scientists. I have tried Phygon and Benlate — also minute quantities of boric acid — as an aid to hormone effectiveness, and combinations of these, but must say that in the most cases, while keeping leaf drop and basal decay down a little, have found a tendency to promote larger callus and slower rooting. The ultimate percentage may be similar but, on the average, rooting took at least one month longer. One interesting point was that stronger hormones with fungicides gave the best results — perhaps suggesting that one could double the hormone strength where fungicides were used to offset the inhibitory effects of the fungicide. Overhead spraying with Brassicol Super did not seem to detrimentally affect rooting time. This subject obviously needs further experimentation.

Tip Cutting Method: Juvenility is an interesting subject. It has been proved that cuttings from the tips of one-year-old seedlings strike quite readily but rooting drops dramatically in older plants. No valid reason is forthcoming as yet. One of our amateur rhododendron growers tried this method with rhododendron seedlings of the vinera section and found that tip cuttings of tiny, one-year-old rhododendron plants flowered in half the time normally required for seedlings. These cuttings were rooted in a few weeks in peat moss or sphagnum under glass and then exposed to 16 hour light. By this method, only half the time is required to prove a generation of breeding stock.

Grafting. Although grafting is regarded as an outmoded means of rhododendron propagation, it would seem unwise for propagators to lose the technique. Firstly, there are a number of rhododendrons still defying the best techniques to strike them commercially from cuttings and, secondly, some do not thrive on their own roots in certain soils. There is another reason — the world-wide spread of *Phytophthora cinnamomi*. Some few rhododendrons seem to be immune to this disease and it may become necessary to use these species as stocks if we are to sell rhododendrons interstate or overseas in the future.

THE SELECTION OF AUSTRALIAN NATIVE PLANTS FOR CULTIVATION

R.J.E. DAVIDSON

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Queensland

With the gradual acceptance in the late 1950's and 1960's by the Australian community of the necessity of plant life for the community, it became obvious that for Queensland's sub-tropical and tropical conditions we could no longer rely on obtaining new plant material from the traditional temperate climate sources.

Some plants from colder climates — although we could produce them effectively as nurserymen — did not perform well in the State's gardens. We believed that either we introduce shrubs, trees, palms and ground covers to the public that would grow and thrive in the average person's garden, or continue to produce seasonally those species which flowered in containers but did not always grow well for the average gardener.

As we introduced indigenous species that gave satisfaction to the customer and could be planted from containers at any time of the year, the sales graph has changed. This has been achieved by the selection and introduction of selected forms of Australian flora which have been introduced from climatic conditions similar to ours.

From my experience over the years, I have put forward the following points as guidelines for selection of plant material:

1. **Make a study of ecology as well as the soils, weather conditions, and microclimates in your area.**
2. **A basic knowledge of botany is required to recognise species and families of plants.** Obtain as many botanical publications as possible, especially those dealing with local flora. In Queensland — "The Queensland Flora", by F. M. Bailey, published at the turn of the century, is a good one. "Australian Rain Forest Trees," by W. D. Frances, and "Key to the Eucalyptus", by Blakely, are helpful, as well as all publications from your local Botany Department. Study

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these books and learn to recognise flora. Get to know the plants and their requirements in your marketing area.

3. **Travel widely throughout your area.** Undisturbed roadsides in developed areas contain plants of many species. The lonelier the road in fenced areas, the wider the range of plants. Recognise the species wherever grown, paying particular attention to how plants perform in nature under a wide range of these conditions under which any species grows, the more likely it is to turn out to be a good garden subject. Never neglect the native species growing in your local area. They can give satisfaction to your customers.

   We have seen the demand grow for indigenous species in the area where we live. With *Eucalyptus*, the demand used to be for *E. ficifolia* and other species from Western Australia but today we are flat out producing the so-called common local gum tree and gradually introducing new species from other places which we have found thrive in our area.

4. **Selection of specific forms from nature for propagation.** We have adopted a policy of seeking out variations in nature of any given species, always looking at habit of growth as well as quality of foliage and flower for marketing purposes. That is selecting the best form of any species for propagation and multiplication.

   If the species is growing in nature under a wide range of climatic conditions, as well as in the local marketing area, we have found any form of the species to be adaptable to local conditions. In some cases of seed-produced cultivars, even though it is growing in the marketing area, in our experience it has been best to produce stock from seed collected in areas of completely different weather conditions to obtain the best results. We always try to bring back cutting material for propagation wherever possible. In collecting seed we make sure that form is growing in isolation, without reach of cross pollination, so that we can successfully reproduce the form.

5. **Selection of Forms on the Nursery.** When I started in the industry it was the practice to propagate from stock plants or pruning the same gardens regularly to obtain one's propagation material. Today we reproduce the majority of our cutting-grown plant material from the nursery row. Always take the cuttings from the most vigorous and healthy containers. This has enabled us to propagate most species the year around whereas in the past one was forced into rushed periods of propagation.

The overall standard of plants produced has risen dramatically and good looking plants in containers are the best sales builders for our industry, provided they grow for the customer. Today, if you have a good form of plant, the public quickly becomes aware of its value. Today we are getting sales volume in an ever increasing number of cultivars. This trend will continue and the number of new forms of Australian plants you can discover on your nursery will lead to greater productivity and sales if you are capable of recognising different forms in the propagation and growing period which can be marketed as new forms or cultivars. If the plant grows for your customer easily without too many problems, remember he also wants, in our economy, something different, be it a larger better home, relaxation at the golf course or bowling green, a colour T.V., a boat to relax away from work, and above all a better environment which can be created by our product. Trees will shade his home and keep his house warm in winter and cool in summer. Provided it has some purpose, he will spend money in pruning and shaping. Shrubs will give him privacy and a beautiful flower display so that in an urban community he can live within his own secluded environment.

There is no doubt in my mind that the continuing interest being shown will encourage us to produce many species of Australian flora from cuttings, after selection of the best flowering forms, rather than growing them from seed with variable flowering results. Provided we are active and obtain Plant Patents or Plant Breeder's rights in this country we can reciprocate with other countries in the planned marketing of our product.

6. **The Great Australian Heritage — Flora.** The multiplicity of species in most families of Australian flora never ceases to amaze me and, without doubt, it is a tremendous challenge to the plant hybridizer who could produce spectacular new plants for the world provided he is given the opportunity in the future.

SOME ASPECTS OF GREVILLEA PROPAGATION

V. LEVEY

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Our nursery is close to the coast, approximately 5-6 miles inland at Northgate, which is a northeastern suburb of Brisbane. We are approximately 12' above sea level. We enjoy a mild climate, frosts in winter are rare and usually not severe, and summers are usually tempered with afternoon sea breezes. For those who like figures, our winter temperatures are usually from 10° to 20°C and summer from 18° to 30°C so we have an ideal climate which enables us to use very simple propagating facilities. We use very little glass.

Most of our propagation is done on raised benches which are covered with polythene; these are in the form of roll-up shades which, in turn, are covered by 30% shade approximately 7' from ground level. At present we use perlite and peat moss as the medium; this is cleaned with air-cooled steam. For grevilleas, cutting material is inserted directly in plastic tubes, smaller cuttings going into 1½" and the larger into 2".

At this stage I would like to trace a little history so that you can appreciate why we have arrived at this method.

About 20-25 years ago when I first became interested in grevilleas, we had only to worry about *Grevillea rosmarinifolia*, *G. banksii var. forsteri* and, to a lesser extent, *G. robusta*. However, as *G. robusta* was, and still is, easily raised from seed, and being a large tree, its importance as a garden plant is strictly limited, I will not dwell on it. *G. banksii var. forsteri* is also easily raised from seed, which unfortunately is not always readily available. We used to propagate rosemary by taking short cuttings 1-2" in the spring and inserting them in sharp sand in community pots (clay). Generally, rooting was good but many losses occurred in the transplanting so here, of course, the advent of the plastic tube grew to be of great significance. A cutting is now inserted in its new tube, rooted, and hardened off still in its own container, and eventually potted on, losses at this stage now being non-existent.

In an effort to build up stocks we have tried putting down cuttings every month of the year. We found the spring cuttings to be the best. They strike in a matter of a few weeks whereas at other times the rooting process seems to take much longer. I mentioned the advent of the plastic tube as being of some importance. Of equal importance, of course, was intermittent misting. As far as *G. rosmarinifolia* and its family were concerned, for us it was disastrous. The cuttings regularly turned black in a matter of two to three weeks so we quickly learned to turn off the mist and kept them moist by manual methods, at the same time airing regularly to prevent the frames from getting too hot.

A number of grevilleas allied to the rosemary family gave us mixed results; for example we had no difficulty in striking *G. dallachiana* but found it did not prove to be a long living shrub in the coastal gardens of Queensland although better results seemed to be obtained in the Toowoomba and inland districts. *G. jenkensii* and 'Olympic Flame,' (we are still trying to sort out the difference here) have proved very reliable both as to growth and flowering. We have also managed to sort out and clarify the confusion with G. 'Pink Pearl', 'Canberra' and *Juniperina* 'Rubra.' We have finally established that these three names refer to the same plant, and the true name is apparently 'Canberra'.

Now, of course, we come to the latest introduction — 'Desert Flame'. This has proved a bit of a disaster in Queensland, at least in coastal gardens. Our original plant strangely is still going strong. *Its first year was magnificent and encouraged us to give* glowing reports. It is still growing strongly although all its progeny growing in plastic bags out in full sun looked as if they had had a flame thrower over them by mid-January last. Other nurseries in Brisbane suffered similarly, and with the help of Dr. Helen Ogle of the D.P.I. it was established that the damage was caused by *Phytophthera parasitica*, which of all things, apparently is present in the Brisbane water supply, and judging by reports from other towns along the coast, is apparently in all coastal streams. Don't ask me why it survives the local treatment works because nobody can tell the answer to that one so far. Strangely, 'Desert Flame' is still selling for us in inland towns so one must assume that the higher alkalinity of the inland streams helps to inhibit it. We have not explored this further yet. However, as we seem to have a plant here that would not be successful for the home garden; production of this line in Queensland has been curtailed.

Two other very good grevilleas which have always been in short supply are *G. lavendulacea* and *G. beueri*. Both of these have performed well in our trial garden and appear to be readily propagated. We do not anticipate much difficulty in building up stocks of these two.

Another little grevillea with fine leaves and rich mauve flowers, not well known at this stage, called 'Shirley Howie' excites a lot of attention; I think this could also become a very popular small shrub. *G. punicea* (rich red) and *G. sericea* (mauve pink) are taller growing species which have an appeal to the native plant lovers. Grevilleas of course are such a wide ranging group of shrubs and there are so many from one end of Australia to the other that it is going to be difficult at all times to get a very good one to do well in all conditions. Quite a number of the best cultivars, it would appear, will have to be confined to fairly well-drained areas. I would not like to see a number of these not grown because of the feeling that they do not do well in other parts of Australia. I would like to talk briefly on some of the ground covers that have come to my notice. *G. bitenata*, grown on a well-drained site has proved excellent. In conditions of poor drainage or times of excessive rains, disaster has struck. For those that don't know it, it is a fine-leafed, thickly-growing ground cover, rich green in colour with masses of tiny creamy white flowers in spring. Sometimes the flower stalks are on stems 2' high. *G. gaudichaudii* is a richly coloured (red) broad-leafed cultivar, spreading rapidly over rocks and ground, and has brilliant scarlet flowers. *G. repens* has grown rather well for us, but flowering has been poor; we are persevering with it. *G. thelemanniana*, green and grey forms, have both grown very well in well-drained situations but the flowering on the grey form — brilliant red and gold — is far superior.

Now I would like to talk about that other group, probably the most cursed as far as we are concerned, the *Banksii* group. This rather broader-leaved, toothed group includes such species as *G. hookeriana*, 'Ivanhoe' and *G. asplenifolia*. These we have tried all ways and have not come up with a really satisfactory method of propagation. They appear to do equally as well, (or as badly) under mist, constant and/or intermittent, as without. They sit there merrily for months, firm to the gentle tug, lulling you into believing you have a batch of well-rooted cuttings. A close inspection reveals a great big callus, like some conifers, but no roots. Returning the cuttings to the bench merely results in an increased callus, percentage of strike being around 10-20%. We are seriously thinking of trying piped music, and the only advice I can offer you on these is to put a couch in your propagating shed, so that if you ever feel like starting on these cultivars, you can go and lie down until the feeling passes away.

Seriously though, grevilleas are a wonderful group of Australian shrubs and do have a definite place in the landscape and home garden, and as such, are of great economic importance.

GRAFTING OF AUSTRALIAN NATIVE PLANTS

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This is a follow-up of work (2) reported previously in *The Plant Propagator* by the present author and at the 1973 ANZAAS Conference by Keith McIntyre, also of Canberra Botanic Gardens (1). I will be drawing heavily from material from both of these papers for this present approach.

The Australian flora includes a great number of species of good horticultural potential. Many species have been introduced to cultivation only in the last few years and even now, large numbers of valuable plants remain untried. It is, therefore, only recently that some of the problems associated with the cultivation of Australian native plants have become apparent.

Canberra Botanic Gardens has concentrated its resources on the study of the Australian flora and has the largest living collection of Australian native plants in the world. In 1969, large scale deaths occurred in the Botanic Gardens nursery. These were traced to the root rot fungus *Phytophthora cinnamomi*. On further investigation, it became apparent that many deaths of plants in the open garden, previously attributed to "wet feet" etc. were in fact due to *P. cinnamomi* infection. This disease has also caused serious damage to native forest areas in many parts of Australia.

It was also evident that certain species were more susceptible to *P. cinnamomi* than others and, in fact, a few species showed considerable resistance to the disease. As a simple fungicidal cure to this problem seemed remote, it was resolved to seek other methods of overcoming the disease. The nursery problem was relatively easy and extensive improvements in hygiene proved the solution. The problem in the garden was far more difficult.

General drainage improvements seemed to do some good by making the conditions less desirable for fungal growth. Built-up garden beds achieved a similar result. Application of fungicides and fungistats seemed to have little effect. It was obvious that an answer had to be found elsewhere.

Grafting techniques had not been used on Australian native plants to any extent until now. However, it appeared that if susceptible species were grafted onto resistant rootstocks it may be possible to overcome the problem.

The first experimental work along these lines was done with the genus *Prostanthera*. Most members of the genus have some horticultural potential and some are outstanding. None, however, can be said to be reliable or long-lived in a garden situation.

As *Prostanthera* ssp. were generally considered susceptible to *Phytophthora* we had to look to the related genus *Westringia* for a resistant rootstock. *W. fruticosa* seemed a logical starting point as it had proved hardy in almost any situation and seedlings had been seen to germinate and develop in areas of known *P. cinnamomi* infection.

Whip grafts, side wedge grafts, and top cleft grafts have been tried but the technique of top cleft grafting has been settled on as the most satisfactory.

Thirty-one species of *Prostanthera* have now been successfully grafted in this way, the operation being carried out in spring or early summer.

The following species have been grafted onto *Westringia fruticosa:*

Prostanthera cuneata
P. coerulea
P. denticulata
P. grylloana
P. incana
P. incisa
P. leichhardtii
P. magnifica
P. marifolia
P. nivea
P. ovalifolia
P. rotundifolia
P. euphrasioides
P. lasianthos
P. serpyllifolia
P. seiberi
P. striatiflora
P. aspalathoides
P. rugosa
P. walteri
P. spinosa
P. howelliae
P. teretifolia
P. linearis
P. discolor
P. behriana
P. lanceolata
P. scutellarioides
P. rhombea
P. phylicifolia

Some *Westringia* ssp. have also proved unreliable and the following species have been successfully grafted onto *W. fruticosa:*

Westringia lucida
W. longifolia
W. amabilis
W. rubiifolia
(small percentage only)
W. williamsonii
W. rigida
W. glabra

The genera *Hemiandra* and *Hemigenia* have also been tried but initial trials have only been fair.

In initial trials, *Prostanther aspalathoides,* an attractive red species from western N.S.W., proved difficult to graft onto *Westringia fruticosa* and it was thought that it may be incompatible. Later work has yielded about 25% success. To overcome this apparent problem, 30 nurse grafts were carried out using *P. nivea* as the intermediate species. This resulted in 100% success.

The oldest of these *Prostanthera* grafts are now two years old and have been planted in the Botanic Gardens where earlier plantings of *Prostanthera* failed due to *Phytophthora cinnamomi*. No plants have yet died, a number are flowering this year, and the largest plants are about 1.2 m. high.

In the search for plants which will be more resistant to *Phytophthora*, three other major plant families, *Proteaceae*, *Myrtaceae*, and *Rutaceae* have been investigated.

The problem plants in the family *Proteaceae* are *Banksia* ssp and *Dryandra* ssp. from Western Australia. Many of these have tremendous horticultural potential but are extremely unreliable.

Initial trials here used *Banksia serrata* as a rootstock. Some success was had with this group although the percentage success was generally low, but at least the compatibility of *Dryandra* with *Banksia* looks satisfactory. The most successful graft on this rootstock was using *B. speciosa* as scion material.

Later trials have used *B. robur* as a rootstock and it is felt that this species would be the most reliable if general compatibility can be established. The western species, *B. occidentalis*, has been successfully grafted onto *B. robur* but plants have not yet been planted into the garden.

The family *Myrtaceae* offers another challenge as it contains some extremely hardy plants but others which are very short-lived. Recent trials have been most encouraging and have revealed an apparently wide range of intergeneric compatibility. In these trials *Callistemon citrinus* and *Kunzea ambigua* have been used as rootstocks.

Callistemon citrinus has accepted scions of the following species with almost complete success: *Darwinia leiostyla, Eremaea beaufortioides, Kunzea baxteri and Melaleuca radula.*

Kunzea ambigua has accepted scions of the following species:

Darwinia leiostyla	100 %	success
Kunzea recurva var. *montana*	83 %	,,
Kunzea baxteri	97 %	,,
Verticordia nitens	53 %	,,
Kunzea ericifolia	13 %	,,
Eremaea beaufortoides	90 %	,,
Kunzea pauciflora	33 %	,,
Kunzea pomifera	90 %	,,

It should be emphasized that these grafts are still young and long-term compatibility must still be determined.

The family *Rutaceae* is different again, in that we have found difficulty in finding an Australian member of the family which could be considered highly resistant to *Phytophthora cinnamomi*.

The first trials which have achieved some success have used *Coleonema pulchrum*, better known as *Diosma*, from South Africa. Those trials have concentrated on several *Boronia* ssp. *Boronia megastigma* was a complete failure but should be tried again. *B. denticulata* and *B. heterophylla* yielded about 66% success.

Because of the wealth of desirable species in this family, we intend to look more extensively at other stocks. Grafting to resist disease is only one use for this technique.

Standard *Grevillea* spp. have been produced by grafting prostrate species, such as *G. x gaudichaudii* and *G. laurifolia* onto *G. robust* a stock. These must surely have their place next to the weeping cherries presently available. Successful grafts have been made with *Clianthus formosus* (Sturt's Desert Pea) onto the New Zealand *Clianthus puniceus*. The object here is to try to obtain a perennial *C. formosus*. These plants are now flowering but only time will tell if we have achieved our aim.

In summary, we consider that grafting of native plants is here to stay if we want to grow the so-called "difficult species." We have merely opened the door; much development work is still to be done before we can determine the most suitable rootstock species.

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STORAGE AND MANIPULATION OF PLANT PROPAGATION MATERIAL

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Most of the published information on the storage of propagation material concerns species with a well defined dormant period. Deciduous perennial species are relatively easy to store. Dormant, bare root material can be kept in cold storage for up to two years. Desiccation is a potential problem and jacketed rooms are used to control this (7). There is also much information available on storage and manipulation of dormant bulbs. However, there is little information on the storage of actively growing vegetative material. Development of techniques to store this material could be of great benefit and will be the major consideration in this paper. The propagation industry is becoming increasingly sophisticated and uses involved techniques such as tissue and meristem culture and propagation from "virus free" clones. As a result there is an increasing need to be able to store and to transport actively growing plant material. It is essential to get this material from the specialised propagation units to the production nurseries without deterioration.

Although there is relatively little direct information available on propagation materials, we can learn much from existing technology for storage of vegetables and fruit. Modern storage and transport techniques are revolutionising the marketing of these commodities by enabling a continuity of supply of high quality product. Similar benefits should be possible for plant propagators.

The main aim of storage is to avoid change or to slow deterioration. Deterioration may take the form of continued growth and development, water loss, senescence, pathogenic infection, or attack by pests. All these forms of deterioration are slowed by reduced temperatures. At first it may seem strange to think of continued growth as deterioration. In most cases the freshly harvested propagation material is in the best condition and any change is undesirable. Lowering the temperature slows the normal metabolic and growth processes. The temperature used and duration of refrigeration that can be tolerated without causing damage will vary with different plant materials.

Senescence is the term used to describe the general degradation and ultimate death of living tissue. It includes yellowing and abscission of leaves and inability of the plant material to grow. Harvesting vegetative propagating material involves injury to the plant, removes its source of water and nutrients, and greatly accelerates senescence. Storage or transport usually involves prolonged periods of darkness which again accelerates senescence. Lowering the temperature slows the senescence and therefore prolongs the useful life of the plant material.

Similarly, the activity of pests and diseases is generally reduced at lowered temperatures. However, there are exceptions to this and some pathogens may actively be stimulated at the low temperature. So there may be need for other pathogen control techniques as well.

Another factor in deterioration is loss of water. Vegetative cuttings are particularly susceptible to water loss. Their normal source of water, the root system, has been removed. Care must be taken to ensure a continual supply of water to the cuttings or to prevent the loss of water from them. Providing a continuous water supply during storage or transport can be cumbersome and messy. It is generally more practicable to prevent loss by enclosing the material inside a vapour barrier. However, there are complications with this also. The high humidity inside the container encourages pathogens and the composition of the atmosphere around the plant becomes modified. This aspect will be considered in more detail later. Once again, lowering the temperature can greatly reduce the rate of water loss but only if high humidity is maintained in the cool store. The conventional cool store is in fact a very effective dessicating system because the cooling coils are as much as 6^{0}C below the required temperature of the room. Under these conditions there is extensive condensation and freezing of water onto the cooling coils. This dries out the atmosphere in the store and so increases the loss of water from the plants to the atmosphere.

Another factor is air movement. Forced circulation of the cooled air removes the high humidity air from around the plants, replacing it with the dried out air off the cooling coils. Dufresne (6) describes the jacketed room technique that is used to avoid drying out of propagating material. This is essentially a room within a room. Air is circulated over the cooling coils and through the space between the inner and outer rooms. So the walls and ceilings of the inner room become a very large cooling surface for the inner storage space. With this large cooling surface the temperature difference between it and the desired room temperature can be very small. Then there is little condensation onto the cooling surface and high humidity is maintained in the chamber. There is also no air movement in the inner chamber to hasten water loss. Rigid construction of this type of store is expensive.

An alternative is to use a conventional store and to enclose individual units or packages in plastic bags. On a large scale this is impracticable and uneconomic, and jacketed rooms were developed to avoid this problem (7). However, the C.S I.R.O has developed a system for converting conventional apple cool stores into controlled atmosphere stores by suspending a plastic tent inside the room. This is essentially a jacketed room and should be effective at a much lower cost. It should be a useful system for converting part or the whole of the storage space in existing cool stores into effective units for prolonged storage of propagation material.

Fruit and vegetables are frequently waxed to reduce water loss and to give an attractive gloss to the product. Perhaps there is some scope for using spray-on wax preparations on propagation materials. It would be necessary to ensure that the solvents used are not toxic to plants. The use of growth regulating compounds, particularly abscisic acid (ABA) may also hold promise. This has been shown to close the stomates on plant leaves and therefore greatly reduce transpiration. Certain analogues of ABA have been shown to close the stomates without inhibiting growth appreciably. The effect of one surface application lasted for 16 hours in Xanthium and for more than 9 days in young barley plants (8). It has been considered as a potential treatment to eliminate the need for mist in propagation of cuttings. Liitle and Eidt (10) showed that ABA reduced transpiration in hardwood cuttings.

In certain species low temperature may bring about desirable changes in the plant material. In Irish potatoes stored at low temperatures there is a change of starch into sugars. By putting them back to higher temperature the sugars revert to starch again (14). Perhaps it is possible to get better rooting of some cuttings after storing them at low temperature and so providing more sugars for the rooting process. However, each species will need to be tested because in some plants, e.g. sweet potato, sugars accumulate at high rather than at low temperatures.

Although refrigeration is the most important means of reducing deterioration, the effects of it are not all good. The most important disadvantage is chilling injury. This is damage to plant material by temperatures above freezing point (11). Not all plants are susceptible, and prolonged exposure is usually required to cause injury. A generalisation is that plants of tropical and subtropical origin are susceptible, while those from cool temperate regions are not. There are no specific symptoms of chilling injury, but it is expressed in different ways in different plants. Common sorts of symptoms are necrotic lesions or spots over the tissue and discolouration around veins. Lesions are frequently sunken because there is localised water loss from damaged cuticle and collapse of the cells beneath these damaged areas. In other cases the damage is present but the lesions are not visible. However, these damaged cells are very much more susceptible to pathogenic infection and the only visible symptom therefore is excessive fungal and bacterial rots. An even more subtle form of chilling injury is only expressed as reduced capacity for growth. This type of injury can occur in early season field grown crops like beans or tomatoes, as well as in material exposed to low temperatures from mechanical refrigeration. The temperature and the duration of exposure influence the severity of the chilling injury. This type of injury where there are no specific symptoms but just reduced growth is extremely difficult to recognise. It is therefore imperative that propagating material is thoroughly tested for susceptibility to chilling injury before prolonged cool storage is attempted. There is evidence available to show that mild chilling injury in some species can be reversed by heat treatment (11).

Apparently chilling causes a change in the character of membranes in the plant cells so that normal volatile products cannot diffuse out. These then accumulate to toxic levels within the cells. A short heat treatment can revert the membranes to their normal state and allow the accumulated gases to escape. So it still may be possible and desirable to cool store susceptible material and briefly expose it to high temperatures at defined intervals to avoid chilling injury.

Another gaseous product of plant material is ethylene. This is, in fact, an important plant growth regulator (1). It is commonly used to induce ripening in fruits, particularly bananas. Ethylene is a normal product of plant metabolism and influences many aspects of plant growth. Although it is generally thought of as an inductant of ripening and senescence processes, there is now evidence for stimulation of root growth, fruit growth, germination and of elongation of cereals (9, 12, 16, 17, 18). However, the majority of known responses by harvested material are undesirable. It induces abscission of leaves, opening and discolouration of rose flowers, sleepiness in carnations and inhibits cell division (5). As with other growth regulating substances it is possible to find different plants which respond in opposite ways to the same compound. For propagation materials ethylene would be an undesirable compound, particularly in transport situations, as it speeds up the senescence processes. In cool storage it is not so serious as plants show less response at low temperatures. However, ethylene is a very common substance and handling plants, changing their orientation, and particularly cutting or injuring them induces very high rates of ethylene production. In preparing vegetative propagation materials there is extensive injury and therefore high rates of ethylene production. In the open air this gaseous ehtylene escapes quickly and so has little or no effect. If cuttings were prepared for transportation to distant locations, they would be enclosed in a sealed container and the ethylene could accumulate. This is most undesirable and means of removing the ethylene should be considered. One convenient way is with potassium permanganate.

Scott (15) has developed a system for shipping bananas by enclosing them in a plastic bag with an absorbent block (vermiculite and cement) soaked in potassium permanganate. The permanganate inactivates ethylene produced by the bananas. Enclosing the fruit in a bag also results in modification of other gaseous components of the atmosphere. As the plant material continues to respire, it uses up oxygen and releases carbon dioxide. Both these changes depress the rate of respiration and therefore slows down the overall metabolism of the plant material, as does refrigeration.

Refrigeration is normally used to slow metabolism and so to extend the life of plant material. The same extension of life can be obtained with bananas by using refrigeration or the potassium permanganate block. I am not aware of this system having been used for propagation materials, but it could have application where they are stored or transported over periods of several days. If, as in the case of bananas, it is as effective as refrigeration, it should be a more economic practice. However, this sort of success is only possible if ethylene is an important cause of deterioration, as is the case with shipping of bananas or carnation flowers (3, 15).

Whenever living plant material is enclosed, whether in a plastic bag or in a sealed cold room, the atmosphere is modified by the respiration. We can deliberately alter the oxygen and carbon dioxide concentrations by absorbing or adding these as desired. This is known as controlled atmosphere storage and is highly successful with commodities like apples. Different plant material can tolerate different concentration of these gases without inducing damage. There is scope for testing controlled atmosphere storage with propagating materials. It may help to control specific storage disorders and to enable much longer storage.

Finally, I would like to mention a very interesting development by Burg in Florida (4). It is known as hypobaric storage and involves storage under a partial vacuum. This has three important effects. Firstly, reducing the pressure creates a refrigeration system. At the reduced pressure water evaporates and the energy required for this comes from the heat energy of the product. So, as water vaporises the temperature falls. The temperature reached is dependent on the extent of the vacuum. Typically, the pressure is reduced to one-fifth of an atmosphere and this would result in a temperature of approximately 20°C. It should be noted that this temperature reduction is only achieved by the evaporation of water. Unless free water is available, it will vaporise from the plant material and eventually cause wilting. This is avoided by bleeding in humidified air or by injecting water vapour into the chamber.

The second effect is modification of the atmosphere. If the pressure is reduced to one-fifth of an atmosphere, the partial pressure of all component gases will be reduced to one-fifth of the normal concentration. Therefore the oxygen concentration will be reduced from approximately 20 % to 4 %, and will consequently reduce respiration rate.

The third and most important effect is the removal of ethylene. At the reduced pressure gases diffuse much more rapidly. Ethylene and other gaseous products of plant metabolism diffuse out of the tissue so rapidly that they do not have their normal effects. Ethylene is produced by all plant tissues and especially by injured tissue, and it stimulates respiration and senescence. A technique like hypobaric storage therefore has great potential for slowing deterioration of propagation materials.

Burg has shown that difficult-to-store cultivars of chrysanthemums can be stored for at least six weeks in hypobaric conditions. In normal storage they only last for 10 to 14 days. After the six weeks in hypobaric storage the cuttings were kept in normal storage for 10 days and still produced new plantlets as well as the fresh material. Other lines of chrysanthemum cuttings were kept in hypobaric storage for 12 weeks, then put in rooting beds for 2 weeks. After this treatment they grew perfectly and developed normal flowers in the usual time. This system seems to virtually suspend activity of these cuttings and offers great promise for the nursery industry.

JIM WELLS: Could you tell us precisely how those blocks are made with the potassium permanganate?

D. SIMONS: I think the proportions are one part cement to three parts vermiculite. Detailed information is available from C.S.I.R.O. Division of Food Science or from Departments of Agriculture. The block is merely a carrier — a material that will absorb a lot of liquid. It is important that the potassium permanganate not come into direct contact with the plant material as it is quite toxic. The blocks can be cut to any size to suit the container and the amount of ethylene expected.

VOICE: How would sponge plastic work?

D. SIMONS: It may be of some use, but the water holding capacity is much less than that of vermiculite. When sponge plastic is wet, it drains for a long time; vermiculite doesn't drain so much. Any carrier will work, or even free liquid potassium permanganate, so long as you avoid contact with the plant.

ARNOLD TEASE: In sending cuttings from one country to another could this have practical application?

D. SIMONS: Certainly. It should have application anywhere cuttings are kept in a closed space.

VOICE: Is literature available on the low pressure system?

D. SIMONS: Yes. The most recent information is in the article by S. P. Burg.

VOICE: You mentioned the use of abscisic acid sprayed on cuttings. Are there references to this?

D. SIMONS: There are numerous references to the effects of applied abscisic acid but I know of none in the specific context mentioned. I suggested it as one of the possibilities. References (8, 10) may be useful.

KEN TURNINGS: Is it true that cuttings taken from plants whose foliage normally hangs pendulous and then turned into an upright position would give off more ethylene than cuttings taken from a plant which normally stands erect?

D. SIMONS: I can't really answer that because I don't know of it having been tested. Work done about 40 years ago showed that if asparagus spears were placed horizontally, they produced more ethylene than if they were in the vertical position. Tomato fruits placed with their stem scar down ripen more quickly than those in the normal position of stem up. Rotating plants in a klinostat or movement in the wind also induces ethylene production. It appears that changing the orientation of plants induces ethylene production and I would expect the same to apply in the situation you proposed.

JOHN OAKLEY: You mentioned that storing cuttings at different temperatures could change the conversion of starch to sugars. How long would it take for this conversion to be effective?

D. SIMONS: This would vary with the temperatures used and the plant material. In very general terms it is a slow change, particularly at low temperatures. In potato, where this has been thoroughly investigated, the change from starch to sugar occurs slowly over several weeks. If this sort of change is of any significance in cuttings, I would expect it only to occur slowly over prolonged storage periods. To my knowledge it has not been tested in cuttings.

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TREATMENT OF SOIL WITH AERATED STEAM

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When I started my nursery career, I was a bright-eyed lad of 15 and it was at the nursery that we are going to visit this afternoon. Among my first jobs was sterilizing or "cooking" the soil, as we called it in those days, and I can vividly remember putting many a load of soil and cow manure through the cooker. This cooker consisted of a waterproof steel tank roughly 6' long, 3' wide and 3' deep. It had some house bricks in the bottom of it, and it was built up so you could place a fire underneath. On top of the bricks it had a perforated steel plate. You filled this tank up with water to the top of the plate, then you filled it up with soil. To get the soil in you used to have a plank which came back about 15 feet. Then you loaded the barrow — they were big barrows in those days and I was only a little bloke then — and you used to make a terrific run up the plank and tip it in; the tank held about 3 yards of soil. You filled it and lit the fire, generating steam that moved upward through the soil. The key to the whole thing was a small potato; we used to religiously put this potato in the top inch of soil. When the "Murphy" was cooked, the soil was cooked. You might laugh, but it only cost about $20. Anyway, it was a good efficient sterilizer. You couldn't get Aquasol or Thrive or Rite-Gro Liquid Manure or anything like that in those days. When you treated a load of cow manure you used to drain the excess water out through the bottom — that was the best liquid manure you could get anywhere. We used to be able to dilute it considerably.

When I left the nursery here in the mountains I went to the "big smoke," then into the Air Force. I was lucky to come back, and then started my own nursery. I bought the tank out at Mascot for 120 and it served me as a sterilizer for 4 or 5 years.

In the meantime, from Sorenson's Nurseries here in the mountains I was fortunate enough to take the horticulture course down at Ultimo, 4 nights a week. One thing I learned at Tech. was to get a thermometer and put it in the soil. You could quickly find you were at the right temperature (212°F) — it would always come up — you couldn't control it.

About 1958 Dr. Lilian Fraser, who just retired from our Department of Agriculture, introduced our association to the University of California Manual 23(1) on growing healthy container plants. This started a revolution within our industry which has spread throughout Australia and the world. By this time I had my own nursery about 8 years. At lunch today a chap said to me, "I never do any sterilizing or any fumigating or anything like that; I don't find it necessary." I said, "How long have you been in business in that place?" and he said, "7 years", and I said, "Watch out for the next year because it is usually about 8 years that things start to catch up with you in a nursery." Well, they caught up with us, and where we had put in about 100 *Aphelandra* cuttings, we might pot off and successfully sell 50 or 60. The rest would damp-off or otherwise fail. Now this is bad economics; even I could understand that you couldn't stay in business very long with this. The U.C. Manual was of great help to us in introducing hygiene into our nursery, and it started to pay off.

In 1960, Dr. Kenneth F. Baker, who was one of the authors of the U.C. Manual, came to Australia on a Fulbright Scholarship to study aerated steaming of soils at the Waite Agricultural Research Institute in Adelaide. I think this has been one of the greatest steps forward in successful nursery production on an economic basis that we have known in the last 30 to 100 years — ever since 1888 when soil was first steamed at 212°F in Germany. It was a major breakthrough when you treated soil mixtures at 140°F, whereas before you could only treat them at 212°F, creating a biological vacuum. Because you have created a biological vacuum with the 212°F steaming, any pathogen introduced into that soil can run riot, unchecked. Someone could put their hands into the soil in a bench and contaminate the whole lot; your losses, as they have been in the past, would be severe. It was the pleasure of 7 or 8 New South Wales Nurserymen to go down to Adelaide for a weekend with Dr. Baker; I think it was the most mementous weekend that any of us had ever spent. There are quite a few here in the room today who were there.

That weekend he introduced for the first time to a group of nurserymen this concept of aerated steam. He had been producing it there in the laboratory at the Waite Institute. To get aerated steam at 140°F, you mix 6-1/2 pounds of air to 1 pound of 212°F steam. In the laboratory he used a big air compressor but was concerned about the economics of it in commercial use. He gave us facts and figures and showed pictures of a venturi under test. When we returned home we started to work with the idea of how we could make steam at 140°F — "aerated steam."

Alan Newport and I worked together on this problem and, after many frustrations, finally came up with the answer, a series of venturis. At the time we were getting close to success, Gavin Wilton from Adelaide joined us. However, with the advent of the venturi, we successfully developed aerated steam on a commercial basis and Dr. Baker credits us with being the first nurserymen to use aerated steam at 140°F on a commercial basis. A venturi consists of a 1/2" or 3/4" steam line, comes into a 2 inch T pipe with a stainless steel orifice (around 1/4 or 3/16 inch). Steam at a pressure of 15 to 100 psi comes through the orifice and the actual location of it in relation to the inlet, if everything is right you get steam at 140°F very economically. The particular setting which draws in 6-1/2 lb of air to 1 lb of steam, regardless of any other factors gives steam at 140°F.

In our nurseries we used this type of venturi very successfully until about 2 years ago, when soil volume started to catch up with us. Many other nurseries also used these venturis for quite a few years. The most important thing, apart from the venturi was the treatment bin and the most important thing in the bin was the perforated plate at the bottom. For any type of bulk-soil treating bin for aerated steam the perforated plate is the most important part. This one had 3/16ths holes with 9/16ths staggered pitch, which we have used for quite a number of years, but we now find that one with 5/16ths, 1/2" staggered pitch is much more successful. You would say the soil would fall through; it doesn't really, however; there is a tendency for clogging with the small holes.

You should have a steel or a wooden bin. With a steel bin it is desirable to insulate it on the outside; if the bin is in a breeze and it is not insulated the soil at the side of the bin can be down to 120°F, whereas further inside the temperature would be 140°F. For many years we used wooden bins made out of waterproof plywood; they lasted very well.

The area below the perforated plate is the plenum, which must be 3 to 6 inches in depth. This is where the steam develops the low back pressure necessary for uniform flow through the soil. The depth of the plenum is not very critical. One other thing — in any type of bin it is a good idea to put a triangular wooden filler in the corners so that you do not have a right angle.

With venturis you could only run round 12 to 15 inches of soil; this is the maximum depth because of the back pressure developed. When steam came from the venturi into the plenum then up through the perforated plate and soil, back pressure develops, increasing with the density and dampness of the mixture. With soil over 15 inches in depth there is difficulty in making a venturi work.

About 1963 another great breakthrough came with aerated steam. This occurred in Melbourne when a Shell engineer working with Ron Gross used a centrifugal blower which could cope with much more back pressure than the venturis could, and put the system on a much bigger scale than the venturis could ever hope to do. Another thing, it made it a bit quieter because the venturis tend to scream as they are sucking in air.

Centrifugal blowers are usually the straight-bladed type. We use ones about 8" wide, 15" round, and to treat a batch of soil 24 inches deep, we need one having about a 6" water gauge capacity at 3,000 cu ft per minute (this is the capacity of fan required — a term used in measuring the output of the blower). A moveable damper over the blower intake provides excellent control of the air volume. There is no need for air under great pressure; you only need to get 6" water gauge from your centrifugal blower.

The centrifugal blower usually is portable — it can be on wheels since you have a flexible hose which hooks on the outlet of the blower. Steam is introduced into the slipstream of the blower so that it mixes there. The steam supply can be manually controlled. You can get excellent control with this equipment. Instead of the manually operated steam inlet, you can get a pressure-operated steam valve controlled by a thermostat. In other words, you can have a thermostat bulb in the mixing chamber or in the plenum of the soil bin, which controls the entry or the rate of steam which is mixing with this air. It is then possible to set this steam valve by trial and error at 140°F air-steam temperature and it will automatically keep the steam-air mixture going into your bin at 140°F without further adjustments.

If you are using a continuous flash steam generator, which produces steam a lot moister than that from an orthodox boiler, you should put it through a steam drier. This is a 44-gallon drum with a basal tangential steam inlet. The steam goes around the walls and exits through the outlet at the top, centrifugally expelling water drops, which drain out at the bottom of the drum through a tap. This provides dry steam to your bin. We have never found it necessary when steam is introduced through a bottom plenum, and I haven't seen many units used. Another big advantage with the blower is the ability to rapidly cool the mixture after treating; venturis do not have this feature.

The idea of aerated steam pasteurization of soil is to bring the mixture up to 140°F as quickly as possible, hold it at 140°F for 1/2 hour, and then cool it as quickly as possible. At 140°F, harmful pathogens such as nematodes, pythium, water molds, *Rhizoctinia*, and most weed seeds (of course, clover and very hard-coated seeds, even 212°F steam won't kill) are killed, but helpful saprophytes remain. In the lighter type mix, weed seeds usually are no problem.

As soon as the soil attains the desired temperature you can throttle back the steam because you are not using as much heat. If you have one of these automatic valves it may throttle itself back, or you can do it manually. As soon as treatment is finished the steam is cut off completely, the blower air intake opened; with the air intake you have an adjustment so that you can adjust your air through the fan to get that 140°F, regardless of the steam, as well. It is desirable to put a filter over the intake because you are going to drive air, and perhaps contaminating pathogens, from within the area up through your treated soil. It is desirable to use a fiberglass filter — we don't do it; I don't think we have had any problems through not doing it; but it is the right thing to do.

With this rapid cooling you can use Osmocote or urea-formaldehyde or other types of slow-release fertilizer; without the rapid cooling from the fan it is dangerous because you would then have no advantage from the slow-release feature in your mixture.

The use of the blower was a big step forward and it is catching on over the world. What are the advantages that you can expect from using aerated steam?

(1) Buffering against disease. At 140°F, instead of the biological vacuum created by 212°F treatment, the harmful pathogens are killed but the saprophytic micro-organisms increase because of reduced competition. Instead of a biological vacuum you could finish with more "goodies" in the soil, less the "baddies." If contamination develops later, as is likely, there is a buffering effect of good soil microorganisms which can decrease the growth of pathogens.

(2) Less or even no phytotoxicity. Seedling growers have known ever since 212°F steam was started that they had trouble with different plants. They would damp-off and wouldn't grow; this was caused by ammonium toxicity. With 140°F there is practically no ammonium toxicity in the soil, and you can steam soil with plenty of humus, even fertiliziers in it. I mentioned slow-release fertilizers which you could never use at 212°F because it would burn the roots.

(3) We are all interested in this one — lower cost. You use 6-1/2 lbs of air to every lb. of steam. You can virtually do with a boiler twice as much soil, economically, and better and more efficiently than you could with 212°F.

(4) Ready for immediate use. With steamed soil at 212°F it can be up to 10 hours before you could use that soil. Steam-air

treated soil, even uncooled, can be used immediately after treatment to pot up. With the blower, you can cool soil in 10-15 minutes, bringing it down to 90 or 80°F, depending on the outside temperature.

(5) Suitable for treating plastic pots without deforming their shape. This is important. The bin can be loaded up with plastic pots and you can steam them at 140°F, kill all those harmful pathogens that I mentioned, and at the same tend to re-plasticize your plastic. Plastic starts to get brittle from ultra-violet radiation. By heating the plastic to 140°F it tends to plasticize again and become more pliable; this will give them a bit of extra life and save a considerable amount of labour.

In conclusion, you cannot afford not to use aerated steam. I firmly believe that part of our success has been this great breakthrough in the commercial treatment of soil. Instead of sterilizing you are pasteurizing, and I think this development has been one of the great things in horticulture in this century. I have told you in layman's terms about aerated steam. But there is a document (2) written by Ken Baker which provides practical, down to earth, but up-to-date scientific information on aerated steam and even chemical treatment of soil. I don't think you would use chemical treatment of bulk soils if you knew the advantages of aerated steam.

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AERATED STEAM TREATMENT OF SEED[1]

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There has been a lot of controversy on seed-borne pathogens and there are a lot of seed merchants who get up in arms when one mentions them. They say that this doesn't happen very often, but the more one delves into the seed business the more one realizes it's a lucky thing to get a seed that has no pathogen either on it or in it.

If one is going to have plant production, the propagating material, whether it be a plant material or seeds, has to be treated against pathogens. We have found that steam-air treatment has been the most satisfactory. I am going to talk on flower and vegetable seedlings, but the same procedures would apply to tree and shrub seedlings.

The problem associated with flower and vegetable seeds is similar to those for trees and shrubs — what stands for one will hold for the other. Our first experiences as seedling (bedding plant) growers came when we were using 212°F soil sterilizing in 1956. When seeds are sown into a mix thus treated one experiences a great deal of trouble because it is nearly a biological vacuum. If you introduced a pepper or a tomato seed with *Rhizoctonia* on or in it you probably would get a complete wipe-out of your crop, whereas if you hadn't sterilized your soil you would have had some competition in the soil and you might not have a complete wipeout. You would have had *Rhizoctonia* anyway, so you couldn't have sold the box. This led us to experimenting with some form of seed treatment. In those days we used dusts and hot water. It wasn't until 1961 when steam-air treatment of seed really started that we had the results we are getting today.

Seed-borne pathogens are transmitted in several ways: in the embryo of the seed; on the seed coat itself; under the seed coat; in dust particles accompanying the seed; perhaps in fruiting bodies similar in size to the seed so that cleaning by seedsmen doesn't eliminate it. Consequently, quite often it is not the seed itself that has the pathogen; it may be some particle adhering to it or with the seed itself. I want to discuss some of the diseases

[1] I have borrowed freely from Dr Kenneth Baker's paper on Seed Pathology printed in Seed Biology Volume 2, 1972 published by Academic Press, Inc All the work we have done on seed treatments has been with the help of Dr Baker, whose invaluable help to the nursery industry is well known to most, if not all, of you here today

before we go into the actual treatment; I think you will then appreciate the types of diseases and the way in which they operate.

METHODS OF SEED INFECTION BY PATHOGENS

The pathogen accompanies the seed but is independent of it. Most, if not all pathogens may be transported with plant or other debris mixed with seed. One of these, for example is *Sclerotinia sclerotiorum*, which causes the cottony rot disease, prevalent in many crops. The sclerotia develop in or on plant parts and become mixed with the seed in threshing and are not always removed by cleaning; for example, cornflower is subject to this particular disease. The sclerotia (disease carrying body) is very similar in size to the seed and seed cleaning does not remove it. Hollyhock rust teliospores are on bits of the plant mixed with seed during threshing. Another example is bacterial canker of tomato [*Corynebacterium michiganense*]. The bacteria invade the fruit and the infected pulp mingles with the seed during the seed extraction process.

The pathogen is a passive contaminant on the exterior of the seed. In this case the pathogen may be present as sclerotia, spores, vegetative cells, nematodes, or virus particles. Snapdragon rust [*Puccinea antirrhini*] contaminates seeds in threshing. A very good example is fusarium wilt of china aster; macroconidia produced at the base of the infected stems get onto the seeds during threshing. *Rhizoctonia solani* I have mentioned on capsicum and egg plant and tomatoes; mycelium in the soil infects fruit that may be lying on the ground, comes in contact with it, decays the pulp and may form sclerotia or mycelium on the surface of the seed itself. Another one is *Corynebacterium fascians*, the bacterial fasciation disease of sweet peas and nasturtiums. Generally sweet pea seed comes from California, a very dry area when they are threshing this seed; the bacteria are in the dry dust. If you have seen harvesting there you can appreciate how dusty it is; this pathogen again gets on the seed in threshing. The tobacco mosaic virus on tomato plants is carried into the fruit pulp and remains on the seed surface after extraction.

Pathogen spreads into the seed from the fruit. Some of the most important seed-borne diseases are of this type. They are usually internally borne and difficult to control. Transmission is by vegetative cells, spores, nematodes, or virus particles. *Rhizoctonia solani* — already mentioned, is one of the chief ones of this type. The fruits are invaded by mycelium when in contact with the soil; the seeds may be wholly or partly decayed. The mycelium might spread through the mass of the pulped fruit and seeds during the fermentation process. The mycelium actually invades the seed itself prior to the separation of the seeds. A very bad one is known to most seedling growers as alternaria of zinnias [*Alternaria zinniae*]. The dew on the flowers in the seed field keeps the flower head moist and the spores in the flower head infect the seed. Zinnia seed from the United States is usually superior in this regard to that from Europe, where they have wetter conditions and Alternaria in zinnia seeds is much more prevalent. Another one in this field is *Phoma lingam*, which causes black leg of cabbage; spores from plant lesions infect the seed pod and penetrate the seed on which the fungus may produce its pycnidia. *Botrytis cinerea* you all know very well. I don't know any nursery in the world that has not had *Botrytis* in one form or another. The spores of this pathogen are common in the flower seed growing areas and, under moist conditions, petals are infected and the mycelium spreads down into the seed itself.

The pathogen penetrates the seed through the vascular system of the plant itself. There are relatively few pathogens known to infect seeds through the vascular elements and most of them are in the vascular elements of the seed coat. The most common is *Xanthomonas campestris* that causes black rot of cabbage, and *Santhomonas incanae* that causes the bacterial blight of stock. The bacteria are systemic; they move up through the water-conducting tissues of the plant and into the actual seed pod itself.

The pathogen actively and directly penetrates the seed is the last one I will use as an example. Most common is *Septoria* and the worst one is *Septoria apiicola* — cause of late blight of celery. The pycnidia form on infected seedlings, and spores are spread by water as the plant grows. Seeds are infected directly and may develop pycnidia in the seed coat.

There are other instances of both diseases and hosts too numerous to mention here, but I think you can appreciate that these are only a few of the many very serious pathogens that are seed-borne with which we have to contend. Seedling growers throughout the world are familiar with the serious problem we have with these diseases, and they ask what they can do to combat them. Others of importance are *Septoria* on phlox, *Alternaria* on pansy, *Pseudomonas* on polyanthus. Seedling growers know this last one — it is a nasty seed-borne pathogen on polyanthus and primula generally. It is probably more common in the warmer than the colder states of Australia. I have seen it in all states, but it is probably held down by the colder conditions in Tasmania and Melbourne. Where we have warm summers and wet winters you can get a very serious outbreak of this disease. Another bad one is *Phoma betae* in silver beet. This is a nasty disease which turns seedlings black. Just when the seedlings are ready to go out, the weather changes and the healthy seedlings look like they have been hit with a blow torch.

Many of these disease pathogens are currently carried on seed of trees and shrubs, including our native ones as well. The same type of treatment that I am suggesting for flower and vegetable seedlings would also be applicable for trees and shrubs.

METHODS OF SEED TREATMENT

In 1888 in Denmark the first hot water treatment of seed took place for the control of loose smuts of oats and barley. From then on, hot water treatment has been used on a wide front. There are a lot of things seed producers can do that would reduce seed-borne pathogens such as growing their crops differently, by water control, by treating seed before planting, and by better harvesting. I think it is only in the last 10 to 20 years that large seed houses in the United States have really appreciated some of the problems in their methods and I am very pleased to say that quite a lot of them have tightened up their methods of seed collection and treatment in the field itself. I think the important controls of seed-borne pathogens should be carried out there. Some of the European countries and Japan, however, have not appreciated some of the problems associated with seed-borne pathogens. It is important that they do, however, for the loss in the nurseries can be of major importance.

Chemical treatments. These are, of course, advocated by the chemical firms as the best methods. I personally have not found chemical treatments satisfactory for a commercial seedling operation because they don't really do the job 100% and I think if you can't get that type of control then it is of little use. You must remember that we, as nurserymen, are upsetting the balance of nature and if we do, have to have a very good control of diseases. If you have 100 seedlings in a 12 x 12 flat you are really asking for trouble; you have to use every preventive method you can. Chemical treatments also give problems with your technical staff. If you are using any mechanical means of sowing seeds, as a lot of nurseries are now doing throughout the world, they find that chemical treatments have an irritating and a very dangerous effect on personnel; we found very early in the piece that we were not able to coat any of our seeds with fungicides. After a few minutes the staff just refused to sow because of respiratory irritation.

The hot water method. This presents a lot of problems but it also has important assets as well. It is a very good means of controlling seedling seed-borne pathogens and is still carried out today. It has a physical effect on the seed itself. If you put peas into hot water and heat them at 125°F for 30 minutes you might get pea soup. However, seeds of plants like cabbage, pepper, tomato and others can quite successfully be treated with hot water. However, the physical effect is very bad and it also has a leaching effect on the seed itself. However, there are many plants whose seeds cannot be so treated. If you put seeds of stocks, alyssum or flax through hot water, you will get a mucilaginous mess at the end. It is very difficult to dry it again or to separate it and sow individual seeds. There is another method that has recently been recommended; that is, the thiram soak method, where one uses about 10 ppm thiram for a 24 hour soak. This has proven very successful in the Brassica family, but it has limitations. Hard seeds, such as in bean, which do not soak well, are not satisfactory; it has been found that this method with ornamental flower seeds, as nemesia, phlox, marigolds, celosia, salvia, dianthus, lobelia, is very injurious; it will damage the seed. Methyl bromide has been used in certain instances for control of nematodes in onion, clover, etc.; that method has its advantages and is still used.

Steam-air treatment. As already mentioned the hot-water methods have several disadvantages. With the advent of steam-air it was possible to overcome these and still maintain the moist heat necessary to kill the pathogens at temperatures which do not kill the seed. The low moisture content of steam-air does not physically damage the seed and makes drying and cooling simple. This factor made the treatment of difficult seeds like Mathiola and Cineraria no different than that of cabbages, etc., the mucilaginous effect being completely eradicated.

Steam-air then has all the advantages of hot water without any of the problems that method has — all seeds can be steam-air treated.

Our original steam-air seed treatment equipment was in fact an adaptation of the vault method of steaming seedling flats. It consisted of an efficient venturi, the steam being passed through a simple dryer before entering same. An accurate thermometer was placed in the mixing chamber. The steam-air entered at the base of the box, a perforated plate forming the top of the plenum. From the top of the plenum to the top of the hinged lid of the box was approximately 18". The sloping lid permitted the condensation to run off. The box also had a drain hole in the base as well as baffles to ensure that the steam-air covered the entire floor area and so rose in an even volume through the perforated plate. The seed for treatment was placed in standard sieves with varying hole sizes, the hole size chosen being as large as possible without allowing the seed to come through. The steam-air temperature adjustment was simply achieved by increasing or decreasing the amount of air sucked in by the venturi. For cooling, a centrifugal blower was mounted beneath the box and on completion of the steam-air treatment the steam was cut off and the blower started and blown into the plenum, care being taken to ensure that the cooling and drying air was not too high a velocity to blow the seeds from the trays. Heating treatment was for 30 minutes, with cooling and drying approximately 15 minutes. Temperature of the seeds was read through thermisters. The treatment box was made from 9-ply marine plywood, giving reasonable insulating quality. The important thing to remember in this method is to carefully cover areas that were not covered by the seed sieves. This then forced the steam-air to go through the seed in the sieves. The depth of seeds in the sieves was also important, a thin layer being essential.

Several nurseries used this method and still do with quite good results; the temperature is usually maintained at 130°F and 135°F for pepper, tomato, brassicas, etc., the whole operation being a prophylactic treatment. Several plants such as delphiniums, marigolds, and verbena, however, reduced germination to such an extent that treatment was suspended on marigold and verbena, but we persisted with delphiniums because of high disease factors.

In 1969 we, with the help of Dr. Kenneth Baker, built a unit that would give a greater degree of control and accuracy. It is essential to be able to control the temperatures to within 1/2°F and to use a blower rather than the compressor required by Dr. Baker's laboratory model, as it was considered that compressors would not be available in nurseries.

The treater (Bakeriser) is built around a centrifugal blower which has a twofold purpose — to supply air for the steam-air and for cooling and drying. An electric modulating valve was used to bring the steam into the air stream through a solenoid valve. The steam pressure was reduced through a pressure regulating valve to a constant 10 lbs. per square inch; the steam is also dried in a steam dryer. The treating chamber is made from polypropylene and is cylindrical with several walls to give the steam-air a swirling effect which also drops excess moisture to the base of the treating chamber. The three large treating sieves are mounted on each other on a base plate that is hydraulically lifted into position, forming the base of the cylinder, with the sieves then sitting in the centre. For small quantities of seed each of the sieves holds 6 smaller units giving an overall capacity of 18 different varieties. Temperatures are read from 6 thermister probes on a meter.

The unit works very well and has been in use since 1969. However, the disadvantages are several; namely, the unit still requires constant vigilance and takes a little time to stabilize, the modulating valve is a little slow in operating, as well as several other minor problems. A new model is being built at Falg Nurseries, South Australia, by Mr. Gavin Welton. This unit is completely automatic with extremely accurate temperature control and with safeguards against malfunctions. The prototype is now completed and the first batch to be manufactured will commence shortly; the price of this unit will be in the range of 3,000 to 3,500 Australian dollars.

With this unit, with its accurate control characteristics, temperatures for specific pathogens, such as the *Pseudomonas* on primula and polyanthus can be experimented with, as this disease and *Alternaria* on pansy and zinnia needs higher temperatures, perhaps for shorter periods, 140°F for ten minutes, etc. Work on these types of diseases is urgently required.

Our own treatments of 130°F and 135°F have been most successful for the control of rusts — *Septoria*, *Rhizoctonia*, and similar pathogens. In the near future it is hoped that, with the aid of University and Department of Agriculture Pathologists, together with the latest equipment, research on the more difficult seedborne diseases and germination effects will be undertaken.