SIDALCEA 'DOUBLE DELIGHT' - Alison Bland. An unusual variant of this herbaceous plant with double flowers. Propagated by division or Irishman's cuttings.

AJUGA REPTANS 'RAINBOW' - Muriel Blore. A startling variegated form of this native plant used for carpet ground cover. Easily propagated by division.

VERATRUM - Christopher Lloyd - showed several species of this liliaceous subject. Propagation by seed which exhibits epicotyl dormancy.

PHORMIUM - Brian Halliwell showed several of these "architects" plants from New Zealand including *P. COLENSOI (P. COOKIANUM) 'TRISTE'* a 3 foot high, hardy form and *P. COLENSOI*, also a very hardy type.

DIERVILLA SESSILIFOLIA - J.A. Hayes. An unusual plant with sulphur yellow flowers and good, small habit. Easily propagated from cuttings.

EUCALYPTUS PAUCIFLORA - J. Simmerley. A 40 foot high tree with a white trunk and deciduous bark. A good skyline tree. Hardy - surviving to 0°F. Propagation from seed which is readily available; plant out as soon as feasible; do not hold in containers.

RAISING HARDWOODS FROM SEED

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In the pattern of nursery stock production in the United Kingdom the propagation of plants from seed is a subject which has received scant attention from a practical standpoint during recent decades. Although much has been achieved in furthering our knowledge of most aspects of vegetative propagation and our forefathers would marvel at the sophistication of our techniques in this field, our normal practical methods of seed propagation show little change from their day.

Many of us grow hardwoods from seed and probably give the matter little thought except perhaps in terms of mechanisation. We accept too thick a stand this year - too thin a stand next year, we use rule-of-thumb measures for achieving sowing rates, which are based on figures culled from forestry publications or out-of-date and unreliable horticultural textbooks. What I hope to do is to present a few new facts, correlate existing information, and apply some scientific background to produce a logical sequence of events to aid this facet of propagation.

It is important to accept that growing hardwoods from seed is a task in its own right and that we should give the matter as much thought in terms of planning as we would give to other techniques of propagation. When raising hardwoods from seed on a commercial scale, the object must necessarily be to produce the crop of seedlings as economically as possible. In general terms this entails the production of the maximum number of acceptable seedlings from a minimum area of seedbed in the shortest reasonable time. However, the most important aspect of determining techniques revolves around the definition of "acceptable", and this is represented by the particular quality expected — in this context by the size and grade of the seedlings.

Nevertheless before embarking on a project to grow seedling trees it is important to define, in reasonably exact terms, what is required as an end product in any particular instance. To achieve this aim the following factors are relevant and require assessment when raising a crop of seedlings. It is necessary to know from where seed can be obtained, how it should be stored, how it should be dealt with to ensure satisfactory germination and how the seedling population should managed.

SOURCES OF SEED

Seeds can be obtained either by collection from particular local sources and personal contacts or from the usual commercial seed houses throughout the world. The former source is, practically, more desirable as it is then possible that the parent specimen can be correctly identified, will be known to be hardy in that particular geographic area, is of acceptable characteristics and what is more important, can be collected at that moment of maturity which is designated as desirable. However not all species will be available in a mature seed-bearing condition within the localised catchment area which any one nursery can service efficiently. Thus, unless the propagator is able to obtain seed from reliable personal contacts, it is necessary to obtain seed from the conventional commercial seed houses. These have the advantage that as wholesale agents they are able to offer an extensive range of species from widely scattered areas. But, because of the quantities involved and the time scale in collection, organisation and despatch, as well as the methods employed in the collection and storage of seed, the viability of the sample may well materially be influenced. Similarly it is not always possible to rely on the supply of seed or on its accurate identification until it is too late to be able to compensate for it in any particular year. Nevertheless these firms are a useful adjunct to the nursery trade and a very necessary aid to the propagator who produces a wide range of ornamental subjects from seed. A selection of the seedhouses which are currently operative in this field is appended. (Appendix I).

Much has been written about the provenance and the selection of sources of seed in relation to forest tree subjects, but in the context of ornamental plants, it has little significance as choice of source is not widely available, and little or no assessment or proving of mother trees has taken place on a commercial scale. Wherever possible, seed should be selected from well-shaped, typical specimens which are vigorous and healthy.

STORAGE OF SEED

For reasons which are, for the most part, obscure adult seed-bearing trees and shrubs of many species do not produce full crops of seeds annually and it is therefore necessary to be able to store seed of these subjects so that quantities in excess of normal requirements can be collected in productive years to make up for the deficiencies of the "off" years and so ensure a continuous availability of seed annually (e.g. *Fagus*, *Quercus*, etc.)

The chief interest in collecting, processing and storing seeds under commercial conditions is the level of viability of the finished sample and it is obvious that any unnecessary loss of viability during these processes makes the surviving viable propro-*tion more expensive. (The viability of a seed sample is an expres-*sion of that proportion of seed which is alive at the time at which it is assessed and hence it is a measure of the potential number of new plants which could be produced if the seed were able to be germinated at that moment)

The term *longevity* is also employed in the context of viability. This refers to the period over which an acceptable level of viability will be sustained and this, in part, will be influenced by storage conditions although primarily it is an inherent factor. However, what is of importance to the propagator is how the proportion of viable seeds can be recognised, as it is only this part of the sample which is of value to him.

The viability of seeds can be assesed by different methods — one is the so-called "Cutting Test" in which a sample of seeds is opened and a visual assessment is made of those which are alive (this test only works satisfactorily on reasonable sized seeds and those which have a mature embryo); another method is the "Tetrazolium Test", which is a more accurate and sophisticated system depending on simple laboratory tests. In this case the seed is treated with a chemical which changes colour only upon contact with the living tissue of the embryo. When no dormancy problems are exhibited an ordinary "germination test" will suffice.

Storage Conditions The maintenance of viability at its highest economic level is an important factor in the production of trees from seed and thus it is relevant to indicate those conditions which are suitable for the storage of particular seed types in order that the maximum degree of viability is maintained but,. at the same time, being aware that there is a natural ageing process which represents the longevity of the sample.

Although much has been written about the storage of various seeds there is little available and useful factual information which can be applied with confidence. The object in the successful storage of a seed sample is to enhance longevity, that is to maintain adequate levels of viability for longer periods than would normally exist without artificial aid. This is achieved by slowing the metabolic processes of the seed (chiefly the process of respiration) or by reducing the rate of deterioration of stored food within the seed. In practice this is attained by:

(i) reducing temperatures at which the seeds are stored so that biochemical reactions are curtailed; this effectively occurs below 38°F.

(ii) attention to the moisture content of the seed. Some seeds will respond to virtual dessication, i.e. the reduction of moisture content to below 8-14% so that reactions are prevented by the reduction in mobilisation of water soluble materials. Other seeds deteriorate rapidly if dried to this level and hence must be maintained at or about the water content at which they are dispersed or collected.

(iii) modification of the storage atmosphere so that respiration is curtailed by a limited supply of oxygen or the inhibiting influence of high concentration of other gases (such as CO_2).

A few generalisations can be made which may have proved successful in the storage of the following types of seed:

(a) Those species producing 'nut' type seeds such as *Quercus*, *Castanea*, *Fagus*, *Aesculus*, *Corylus*, *Juglans* and *Acer* mostly store fats and oils. This sort of seed degenerates rapidly, especially with drying, and loses viability quickly. Hence storage of freshly-harvested seed is achieved under conditions which arrest the process of deterioration as far as possible. This can be done by cold storage (34°-38°fi) at relatively high humidity. With subjects such as *Aesculus* and *Juglans* this extends viability at an acceptable level to about 12 months, whereas more stable types such as *Quercus*, *Fagus*, etc. can be kept longer.

(b) Many other seeds which have traditionally been stored dry have been found to benefit from similar storage conditions, as dehydration to below a critical level has been shown to cause serious losses, e.g. *Fraxinus*, *Liriodendron*, *Pterocarya*, etc. although they will withstand a limited degree of dessication.

Those types with hard seed coast are generally not affected by moisture loss problems and can hence be stored dry at normal air temperature for considerable periods, *viz Robinia, Koelreuteria*, etc. Although this treatment may enhance the durability of a hard seedcoat, and highlights one of the problems concerned with incorrect or unsuitable storage conditions (especially high temperatures), there is the possibility that dormancy effects could be induced or enhanced.

One of the drawbacks to seed storage, however successful it may be, is that there is an inevitable deterioration in the quality of the seed. The vigour of seedlings produced also declines with the age of the seed. Fresh seed virtually always produces the most vigorous seedlings.

GERMINATING THE SEEDS

Thus having considered the development of a useful sample of seed, it is necessary to have some knowledge of the factors which influence how this seed may be successfully converted into a crop of seedlings. The basic process by which a seed becomes a new plant is termed, "germination". This is a nebulous concept but can be defined as the process by which the embryo "awakes" from the resting stage, enlarges and emerges from within the seed until its immediate development as an established individual.

However before a seed will germinate two sets of conditions must be satisfied: (a) that all necessary environmental conditions are favourable and, (b) that the seed is capable of germination. Some seeds will germinate as soon as they are dispersed if conditions are favourable but a large number, especially tree seeds will not respond despite the provision of favourable environmental conditions. These seeds are described as being dormant.

Germination Environmental factors influencing germination are well known and documented thus it is sufficient to note that the process of germination depends on the availability of sufficient water, adequate diffusion of atmospheric gases, and that the rate of the process will be a function of temperature.

Dormancy When the seed is subjected to satisfactory environmental conditions it will normally germinate; however despite favourable conditions many seeds do not germinate and will not do so until subjected to certain particular treatments. Under these circumstances the seed is described as being dormant.

Although presenting a problem to the nurseryman this phenomenon of dormancy is a natural, inbuilt system which the plant has developed to ensure its survival; most types of dormancy have developed to prevent the seed from germinating at unfavourable times for its survival and establishment as a seedling.

Types of Dormancy In general terms the causes of dormancy in seed can be attributed to a number of different factors which can be categorised from a practical viewpoint into three groups as follows:

(i) Those effects which cause a physical limitation on the process of germination by:
a) preventing water uptake; b) restricting gaseous exchange; c) limiting embryo expansion and are usually a function of the seedcoat.

(ii) Immature embryo conditions.

(iii) Those effects which are basically chemical in action and prevent germination by some form of inhibiting agency, this can be affected by either: a) preventing the mobilisation of stored food; or b) limiting embryo development and are of two types either:
1.)water soluble chemicals which can be removed by leaching, or
2.)chemicals which require a cold temperature treatment to inactivate them.

Seedcoat dormancy is caused by the various separate effects already listed — or a combination of them. Seeds may develop a very *hard coat* which can either restrict the expansion of the embryo or prevent the access of oxygen and/or water to the embryo, in either case causing germination to fail. If such seeds are left to germinate under natural conditions in the soil the seedcoat will slowly be broken down by normal decay-producing agencies. Germination will occur as soon as the seedcoat is sufficiently reduced to be ineffective and satisfactory environmental conditions are prevalent. However germination will necessarily be erratic throughout the season and, under natural conditions, may occur over a number of seasons. This breakdown process will naturally be more effective when the seed is moist and conditions are warm. Pre-treatments to ensure even and uniform germination are aimed at reducing the seedcoat to below the critical level at which it is effective in preventing germination. This can be achieved by any of the following agencies, but which technique is used will depend on the size of the individual seeds, the relative hardness of the seedcoat, and the general efficiency of the treatment:

a) scarification; b) chipping; c) acid treatment

Impermeable seedcoats are difficult to distinguish from the foregoing as they are often combined witha hardened seedcoat, although this is not invariably true. The impermeability of seedcoats is caused by the seedcoat and/or pericarp being permeated or coated with a water repellent material, usually an organic material of the wax, fat or oil type and this prevents the embryo taking up water. Under natural conditions this type of dormancy is relatively transient as the normal agencies of decomposition in the soil are easily able to reduce these substances fairly quickly. Treatment of the seed to ensure rapid and even germination in many cases is merely a question of extracting the casual agent; this can be done either by hot water soaking or by treating the seed with a suitable solvent such as alcohol, although dilute inorganic acids will also usually be effective.

Dormancy due to an immature embryo is fairly straightforward, in that germination will not occur until the embryo has reached a sufficiently mature state. Immaturity of embryo may be due to the existence of a rudimentary embryo which requires anatomical and morphological differentiation to reach the mature phase at which germination will occur; this condition will usually be associated with plants of particular habit, such as parasites. However immaturity may be simply a question of size — as is found in the seeds of *Fraxinus excelsior* which, although having a fully differentiated embryo, requires a period of enlargement to bring it into the mature phase. Thus for most types of seed in this condition the treatment involves a sufficient period of exposure to warm temperature, but it is important that the seed has a sufficient water content and satisfactory aeration, as the process must involve cell division and some differentiation.

Many plants of cold temperate climate produce seeds which exhibit a dormancy condition which can only be overcome by exposing the seed, in an imbibed state, to a period of *cold temperature*. The mechanics of this type of dormancy are somewhat obscure although they appear to be connected in some cases with the immobilisation of certain stored foods and in others with an arresting embryo development. However, the alteration of these chemical situations is achieved by a certain specific degree of cold. The level and duration of cold temperature required to produce the effect varies from species to species in broad terms but in any particular seed sample there is also a variation to a marginal degree.

In most types of plants showing this type of dormancy the cold requirement is fairly small and if seeds, in the imbibed condition, are exposed to a normal winter's cold, dormancy effects will be overcome. In this context "cold" represents temperatures below 38°-40°F and hence, artificially, this action can be achieved by storing the imbibed seed in the cabinet of a conventional refrigerator. Some seeds, however, require a much heavier dosage of cold and it is necessary to store at temperatures at 30°-32°F; temperatures below this level may be deterimental due to cold temperature damage within the seed.

In order to avoid the use and maintenance of seedbeds for more than one season because of a large cold requirement and when artificial cold treatment is not available, the seeds can be stratified in order to break dormancy.

Multiple dormancy If the foregoing details on dormancy applied singly to particular plants, dormancy might not be such a problem. Unfortunately the picture is complicated by the fact that many species exhibit combinations of dormancy types, and practical treatments to overcome this situation become more complex; for example, many viburnums and common ash (*Fraxinus excelsior*) seeds exhibit immature embryo conditions. Such embryos, when mature, require a cold temperature treatment; similarly seeds of some *Tilia* spp. exhibit a hard seed coat state which, when overcome, still leaves a cold temperature dormancy.

Avoiding dormancy As dormancy conditions can cause a number of vexing problems to the raiser of trees from seed, it may be prudent to determine whether it is possible to avoid the onset and development of dormancy phases within the seed rather than have to overcome them subsequently. Unfortunately it is obvious that any system of dormancy involving an immature embryo condition cannot be avoided and that ripening to full maturity must be expected and provided.

However, it does appear possible that other forms of dormancy could be reduced or avoided and in some cases this has proved possible. The development of those factors causing the prevention or inhibition of germination usually appear very late in the maturation of the seed and are enhanced by the final phase — usually drying out of the seed prior to its dispersal. If the embryo, however, has matured to a stage of ripening so that it is capable of germinating and will reach this stage before the development of any considerable dormancy factor, then it should be possible to collect seeds at this particular phase, prevent further drying, and so arrest the developmentof the dormancy condition and allow germination at any predetermined occasion. This system has been evaluated and used very successfully and consistently for a number of plants which require extended periods of dormancy-breaking under natural conditions — viz, *Acer campestre*, *A. japonicum*, *A. pennsylvanicum*, *Carpinus betulus*, and *Viburnum lantana*. This latter species also illustrates the problem of dealing with berried subjects. Extraction may be necessary, as the flesh of berried fruits often produce an inhibitor as it ripens, thus further enhancing the dormancy of the seed. In some instances this technique has proved a feasible proposition for those subjects, especially found among the *Leguminosae*, which develop hard seed coats.

In deciding to produce a crop of tree seedlings, a number of factors related to the area and the practicalities of production must be considered in general terms if a satisfactory and economic crop is to be produced.

Site Although the positioning of seedbed area on a nursery is limited by the cropping and policy of the nursery, there are a number of features which should influence the choice of site. Perhaps the most significant is the incidence of radiation frost, liability to which should be reduced as much as possible. This can be achieved by selecting a sloping site with good air drainage so that frost occurs only when very cold conditions are being experienced.

The selection of a warm site, so that the basic ambient temperature of the site is high, will provide earlier and more satisfactory germination and faster seedling growth during a longer growing season, but should be balanced against the likelihood of frost.

The establishment of the site in a position of good light characteristics is also important so that the seedlings will not be limited in photosynthetic activity and consequent carbohydrate supply

The provision of shelter to reduce wind speed is very relevant in the production of a seedling crop as this environmental factor is probably the most under-estimated single deleterious agency in the microclimate of the seedbed. It certainly influences the rate of seedling growth by its effects in terms of physical damage, water loss, temperature reduction etc.; exposure even to limited prevailing breezes may, by these agencies, reduce the growth rate of susceptible subjects (e.g. *Acer* spp) by as much as half when compared with seedlings receiving above 50% wind breaking.

Preparation of the seedbed Probably the most important feature in the production of a seedbed is the provision of adequate drainage, as successful germination will depend on good aeration of the seed. Germination represents a rapid and massive cell division and differentiation which, in consequence, will depend on an ability to respire at a high level and hence will require a non-limiting oxygen supply. The seedbed must, therefore, be made up to develop this aspect but, at the same time, must not detract from the equally important water requirement of the seed for germination and growth cannot occur without sufficient water being constantly available. Hence the construction of the seedbed must compromise these two factors.

Satisfactory drainage of the seedbed can be achieved by raising the level of the bed above the normal surrounding surface level and the incorporation of coarse, sharp grit to modity the texture of the compost. The composition of the seedbed should necessarily be based, at least from the economic standpoint, on the naturally occuring mineral soil of the nursery, as the production of an artificial seedbed (such as the Dunemann type) is too expensive to develop under normal conditions. However, the incorporation of as much leaf mould as is available in order to achieve some of the benefits of the Dunemann principle (i.e. to simulate conditions of the forest floor, improve water retention, and provide mycorrhizal associations) appears, with many hardwoods at least, to produce a more fibrous seedling root system than is normally exhibited on a conventional soil seedbed. The nutrient status of the seedbed is often disregarded. The addition of a base dressing of fairly slow acting fertiliser prior to autumn sowing should provide adequate available nutrients at germination. It is probable that phosphorus is the most important nutrient at this stage because of the role it plays in energy transfer. Some nitrogen is, of course, required while potassium is not so heavily used until green leaves are produced. Thus the use of an NPK compound fertiliser to provide a dressing of the fertiliser units 6:120:60/acre provides a reasonable margin. The type of fertiliser and its rate of availability will be determined by its season of application and soil analysis.

The elimination of perennial weeds is exceedingly important in the preparation of the bed. Such weeds are notoriously difficult to eradicate later, after the crop has been sown. The annual weed problem is best overcome by adopting a "stalke seed bed" technique in the previous late summer prior to sowing and killing the weeds off with a contact herbicide. Weed control after germination is best done by hand until the crop provides sufficient leaf cover to smother newly-germinated weeds.

Some form of seedbed sterilization which can nowadays be achieved by chemical means, may be of value if there is a massive weed problem or it is suspected that there is a particular pest or disease problem; however before it is used it is worthwhile assessing its value in relation to the possible elimination of fungi which may help with the breakdown of hard or impermeable seedcoats and the provision of mycorrhizal associations.

When the seedbed has been made up and worked to a uniform constituency it is levelled off and lightly firmed but not packed down; subsequently weed control sprays may be used against germinating annual seedlings using the "stale seedbed" technique. Prior to sowing the bed should be irrigated as necessary to bring it to field capacity and then, before sowing, finally levelled.

Sowing the seed The seed is sown at the predetermined rate on the surface of the prepared seedbed, or in the case of large "nut type" seeds individually dibbled in. Before sowing it may be considered worthwhile to dress such seed with a fungicide if "damping off" is a problem or, with some material such as red lead, if the seeds are likely to be taken by rodents, etc. The bed is then lightly rolled to bring the seeds into contact with the compost. Finally the bed is covered with a layer of coarse, sharp grit at least ½ in. thick.

This latter technique provides for, (i) the even percolation of precipitation; (ii) the maintenance of well-aerated conditions around the seed; (iii) the easy removal of wind-blown weed seedlings; and (iv) the elimination of capping and splashing. Although a current school of thought favours sowing in drills in order to facilitate weed control in the seedbed, broadcast sowing provides a more satisfactory product and is realistic if weed control has been achieved prior to sowing.

Determination of the seedrate If the seedbed is to be used to its maximum effect it must be exploited economically. This entails the production of the maximum number of seedlings from a given area but at the same time these, for the greater part, must be of a particular size or grade. This latter characteristic is a function of the density of the seedlings but it is also very much dependent or the quality of the seedbed itself and the level of husbandry which is practiced.

Thus, in determining the quality and size of the seedling to be produced, it is also necessary to assess the population maximum at which this will be achieved, with the proviso that a particular standard of husbandry is maintained. This knowledge, unfortunately, is not readily available and can, in any particular instance, only be determined by experience and knowledge of the conditions locally.

Therefore, in determining the rate at which any particular sample of seed is to be sown, the sowing rate must, first of all, depend on the ultimate plant population which is required and then working backwards from this figure, the various limiting factors are calculated to produce the number of seeds to be sown in order to achieve this aim. Hence the rate of sowing will be a function of the following factors:

(i) the required population of seedlings

(ii) The viability of the seed sample

(iii) the field factor (the survival rate)

(iv) the number of the seeds/unit weight

In assessing seed viability in the sample it is relevant to emphasise that this should be determined at the time of sowing as it will undoubtedly be affected by storage conditions and dormancy-breaking treatments such as stratification, acid treatments, etc. The field factor represents an assessment of the rate of survival of those viable seeds in the sample and it is thus more realistically an assessment of the probable losses prior to the appearance of the established seedlings. The level of loss is chiefly a function of the seedbed conditions and represents the toll due to decay, water-logging, "damping off", frost damage etc. It is extremely difficult to estimate with any accuracy; however, it should be reduced to an acceptable minimum and this is achieved by producing seedbed conditions with a high degree of perfection. The actual determination of the figure can only be made with personal experience of the conditions. In practice the field factor should always be assessed from a severe standpoint as it is economically more realistic to thin the crop if too many seedlings do appear rather than have a thin crop on such a relatively expensive feature.

The number of seeds in any particular weight of a sample will vary and although approximate indications can be obtained from available tables, seeds from different sources, stages of maturity, and moisture context will exhibit widely varying counts. Therefore, when accurate population data is needed each seed sample must be individually assessed.

In assessing seeding rates the following equation is employed:

$$\text{Rate} = \frac{\text{Required population of seedlings}}{\text{Sample viability x field factor x seed count}}$$

Although no firm recommendations can be made for suitable populations for each particular species, the following examples of spacing provide an idea of population densities which have proved suitable for the English Midlands. Large-seeded vigorous subjects such as *Juglans, Aesculus, Castanea,* etc. sown at 3" x 3" gives a population of 150/sq. yd. and nuts of less vigorous types such as *Corylus, Quercus, Gingko,* etc. at 2" x 3" provide densities of 200/sq. yd. with a virtual 100 per cent germination as it is relatively easy to eliminate nonviable seeds by flotation or by visual observation. Subjects such as *Acer, Carpinus, Fraxinus,* etc., grown at 2" x 2" provides a seedling density of 325/sq. yd. while 1.8" square or 2" x 1.6" gives a density of 400/sq. yd. — the optimum being in this region.

It should be remembered that these are seedling densities and not seed rates, and are the base of the calculation.

When to Sow When to sow seeds is a factor governed by a number of imponderables and is largely a question of experience and knowledge in assessing the probable requirements of the seed. Those seeds with transient vitality such as willows and poplars and, to a lesser extent, subjects such as *Acer rubrum* and *A. saccharinum* must be sown as soon as they are ripe — which will be during the late spring/summer period when germination will commence immediately.

Certain seeds exhibit short term longevity which is usually associated with drying of the seed (especially these which store food as fats and oils). Hence it is prudent to sow such subjects (*Aesculus*, *Acer*, *Juglans*, *Gingko*, etc.) in the fresh condition as and when they are dispersed.

Those seeds which exhibit a simple, short-term, cold temperature dormancy should be autumn-sown so that this factor is catered for in the seedbed and germination occurs in the spring.

If the seeds have been collected before they are fully ripe in order to overcome more attenuated dormancy problems, then these should be sown immediately and the seedbed prevented from drying out.

All other seeds; i.e. those which require special treatment to break dormancy, and those which do not develop dormancy may be spring-sown after any necessary treatment.

Thus, from a management aspect, it will be seen that it is necessary to have a certain proportion of seedbed vacant every year so that early autumn sowing can be carried out effectively before the normal season for lifting the crop and preparing the seedbeds.

SEEDLING PRODUCTION

The satisfactory production of an economic crop of tree seedlings not only depends on the assessment of the various factors involved in persuading the seed to germinate and then establish as a seedling, but that it subsequently grows and develops to the size and grade envisaged.

Whether a satisfactory crop is produced is then a function of the maintenance of a particular level of husbandry performance. Such a standard must be set and adhered to, as the calculation determining seed rates is dependent on a specific level of husbandry at a particular plant population so that seedlings of the grade and size required will be reached by the end of the growing season. If it is assured that the seedbed has been satisfactorily prepared and is even and uniform in its characteristics, then the production of the required crop is a function of the husbandry techniques applied to it.

In relation to seedling production, husbandry can be assessed as being affected by three series of factors:

(i) Nutrition

(ii) Control of the environment

(iii) Crop protection

(i) Satisfactory *nutrition* depends on the availability of adequate *water* so that the seedling is not subject to water stress and the sufficient nutrients of all the important elements are provided, as any deficiency will naturally check growth. If the water stress is reduced to a minimum and levels are maintained at a figure approaching "field capacity", strong vigorous seedlings will be produced. With the availability of much and varied irrigation equipment this factor is no longer a problem. Although little is known, in terms of detail, on the subject of tree seedling nutrition, seedlings will certainly benefit from a top dressing or feeding with the more soluble elements such as nitrogen, potassium and magnesium.

(ii) Although seedling production in outdoor seedbeds does not permit a great deal of *environmental control*, certain factors in the environment can be influenced to the benefit of plant growth. Perhpas the most significant factor which has a direct influence on plant growth throughout the season is the incidence of *wind*; hence the provision of sufficient effective shelter to reduce wind speed will enable continued plant growth by reducing mechanical damage, reducing water loss (and thus excessive water stress within the seedling) and increasing the ambient temperature within the microclimate surrounding the seedlings.

Because of the limited seasons of occurrence, the incidence of *radiation frosts* have less of a continued influence on plant growth, but nevertheless their occurrence has a marked effect, firstly by reducing temperatures and thus shortening the growing season and secondly, but more important, by the severe checks to growth, or even death, due to cold temperature damage. Tree seedlings normally are protected by the forest canopy but, in the artificial conditions of the seedbed, they are fully exposed so that it is necessary to provide some form of frost protection.

In some cases the provision of adequate *shade* is necessary as the seedlings, because of their normal habitat in the forest floor, are not adapted to full light conditions.

(iii) The protection of the crop against competition and outside agencies is an important factor and these limitations can reduce crop growth more than any other series of factors. Obviously the elimination of competition from weeds is of prime importance as this type of competition will upset all the calculations of growth. Perennial weeds and annual weed seedlings should, of course, have been eliminated in the seedbed preparation and the only problem should be the incidence of wind-blown seed; these will, of necessity, have to be hand-weeded until the crop provides its own cover to smother the weeds, as there are virtually no satisfactory herbicides for selective seedbed use.

The control of pests and diseases is *sine qua non* in the satisfactory production of seedlings and, although many tree seedlings will tolerate light infestations of certain more uncommon agents, there are several major pests and diseases which must be controlled regularly; even a moderate infestation or infection may well check or stop growth. Aphids especially among pests must be controlled by regular sprays while slugs may do much unrecognised damage. Among the diseases powdery mildew type fungi are usually the chief problem and can cause severe checks in some crops such as hawthorns, and these should be controlled with routine sprays of suitable chemicals. Similarly much unrecognised loss is caused by the "damping off" fungi, especially in high density seedlings populations.

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15. Spring Frosts, W.R. Day and T.S. Peace; For. Comm. Bull. *18*, H.M.S.O. 1946.
16. Plant Physiology in Relation to Horticulture, J.K.A. Bleasdale, Macmillan: 1973.

Appendix I

SEED HOUSES[1]

1. Barilli and Giagi,
   Casella Postale, 1645 - Ab.,
   1-40, 100 Bologna, Italy.

2. Soc. Florsilva, Ansaloni,
   via Emilia Levanti 15,
   Casella Postale, 2100 - EL,
   1-40, 100 Bologna, Italy.

3. Soren Levinsen,
   Baunedalsvej 28,
   Kollerod,
   DK - 3450 Allerod,
   Denmark.

4. Martin Renz Nachf GmbH,
   D - 7271 Emmingen,
   West Germany

5. Van Iersal,
   B.V. Boomkewkerij Udenhout,
   Udenhout,
   Schoorstraat 21,
   Postbus 21,
   Holland.

6. The Old Farm Nurseries,
   H.den Ouden and Son Ltd.,
   Boskoop, Holland.

7. Julius Stainer,
   Klengenstallen,
   Stauntrichgasse 13,
   2700, Wiener-Neustadt,
   Austria.

8. Franz Kluger,
   Obere Augartenstrasse 18,
   Vienna 2,
   Austria.

9. F.W. Schumacher,
   Sandwich,
   Mass. 02563,
   U.S.A.

10. Herbst Brothers (Seedsmen) Inc.
    1,000 N. Main St.,
    Brewster,
    N.Y. 10509
    U.S.A.

11. Thompson and Morgan,
    London Road,
    Ipswich,
    Suffolk, England.

12. Ben Reid and Co. Ltd.,
    Pinewood Park Nurseries,
    Countesswells Road,
    Aberdeen, Scotland.

[1] This list is by no means exhaustive but it represents a reasonable range of seedhouses offering a general selection of tree seeds. There are, of course, numerous specialist distributors who offer only a limited range of seed from a particular geographic area, especially in Australia and South Africa.