PLANT BREEDING

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INTRODUCTION

Plant breeding is one of the oldest arts and is basic to our civilization. Hunter/gatherers in different parts of the world became so familiar with the wild plants which they gathered each year that they began planting them and selecting seed to be saved each year for the following season. This occurred around 10,000 years ago in the Middle East (based on wheat, barley, peas, lucerne and other crops), and somewhat more recently in Central America (maize, beans, tomatoes, sunflower) and Asia (rice, soybeans). The main domestication process in these crops was completed at an early stage, whereas many other food and fibre crops and ornamental plants have been taken into cultivation since, with the process still underway for crops such as fennel and boronia.

As a science, plant breeding dates to the 19th century, in either established crops like cereals, where the Australian, William Farrer, was a pioneer, or in new crops such as sugar beet and rubber. An understanding of genetics, following Gregor Mendel, and evolution, after Charles Darwin, gave the subject a sound theoretical basis, built on by advances in cytology, biochemistry, statistics, and plant physiology.

I will review the main features of plant breeding from a practical point of view, to suggest how decisions could be made as to whether a programme is needed or not and how objectives and methods can be defined. I work with agricultural crops, having been involved in breeding programmes on perennial tree crops in the tropics and annual seed crops in temperate areas. I hope you will, therefore, pardon the lack of emphasis on ornamental plants, but instead be able to arrive at some basic principles of use in any crop, taking the word in its widest sense.

BREEDING OBJECTIVES

These will sometimes be obvious and relate to either demands of processors and consumers, or weaknesses which develop in the crops such as disease susceptibility. Many plant breeders spend most of their time on such "fire brigade" duties, broadly classified as "elimination of defects." They will range from adaptation of the crops, to make them flower and fruit in a particular environment, through greater resistance to drought, lodging, disease or pest

attack, to suitability for mechanical harvesting. This involves uniformity of ripening, presentation of the parts to be removed and separation of desired parts such as seeds from leaves, stems, chaff, etc. Product quality is also increasingly important in nutritional value, flavour, and keeping quality.

Other objectives may be to breed for higher yields, allowing the crop to integrate all the various internal and environmental factors to produce the desired result, or to breed a "model" plant or ideotype. Most of our annual seed crops are being constrained towards a similar type with short strong stems, a minimum of leaf to intercept sunlight, and efficient distribution of photosynthate to seeds.

UNDERSTANDING THE CROP AND ITS BIOLOGY

Good plant breeders are very careful "students" of their crop, developing an almost instinctive understanding of how it reacts to different conditions and a flair for picking out useful variants, often from segregating populations. Incidentally, they often become allergic to the crop or its pollen! An understanding is needed of where the crop came from originally (soil and climate as well as location) and what range of variation is currently available. This would be either from the wild or in breeders' or international collections which are becoming increasingly the main source of new material for the major crops. Often "new" types can be induced by mutation, interspecific hybridization, or other means, but the same may already be in existence—nature, or the evolutionary process, has tried most possibilities before.

The reproductive biology of the crop needs to be known before it can be "interfered with" by the breeder. Where propagation in nature is by vegetative means, such as runners, tubers, corms, or bulbs, the plants may have largely lost their ability to reproduce sexually, as with crops like yams and sweet potato where tricks, such as grafting, may be needed to get them to flower. Even where seeds are produced, they may be of parthenocarpic origin, i.e. produced without fertilization, as in some citrus, blackberries, and mangoes, so crossing with a male parent may not give a successful hybrid—a real trap for young players! Some plants are complex interspecific hybrids, such as sugar cane or blackberries, and the proportion of viable seed produced may be very low. Many cultivated crops are polyploids, with multiples of the basic chromosome number for the species. Some of these are triploids which again do not produce fertile seed. Examples are bananas, where only the wild "monkey bananas" produce seeds, and azaleas, where the absence of seed set is an asset as it prolongs flowering.

The crops which do successfully produce seed can be divided into two main groups for plant breeding purposes—those which pollinate themselves, such as wheat, subterranean clover, or peas (flowers never open up in the latter two), or cross-pollinators such as maize, pumpkins, and most of the perennials. Within some groups there are differences, such as in the brassicas. Cabbage, broccoli, and turnips are all diploid, cross-pollinated and hence closer to the wild type, whereas swede and rape are polyploid and mainly self-pollinated. Cross-pollinated species such as lucerne (alfalfa) or cabbage often have self-incompatibility mechanisms so that self-pollination is largely prevented, but the cunning breeder who wants to produce inbred lines can pollinate in the bud stage or even shave off the top of the stigma, where the incompatibility mechanism often operates.

To determine whether a crop is self-or cross-pollinated, a variety of means can be employed. Examination of the flowers will show whether they open up or not and which parts (male or female) are receptive and when. If a plant is isolated either in a glasshouse or by bagging and does not produce seeds, it is probably cross-pollinated. If it does produce seeds, however, it may either be self-pollinated or usually cross-pollinated but self compatible. A breeding test, with alternate rows of two different cultivars is needed, preferably with a marker gene on one cultivar, such as coloured seeds. Seed from the other cultivar, which normally produces colourless seeds, can then be harvested and the proportion of crossing determined.

BREEDING METHODS

Most breeding involves crossing of two different lines and then selection of new combinations of genes from the resulting generations. Crossing usually requires that the intended female parent be emasculated, the anthers being removed before pollen is shed. This is not necessary in self-incompatible species. The foreign pollen is then transferred from the male parent and the flower then bagged to prevent any accidental further pollination.

The self-pollinated crops mainly exist as "pure lines," which were originally selected out of the old "land races," or mixtures of lines with occasional outcrossing that were grown from ancient times. New lines now are generated by crossing two parents which complement each other (one makes up for the deficiencies in the other) or which appear to have potential for a new and better combination of genes between them. The resulting hybrid seed is then grown out, self-pollinated and selected for between five and seven generations to reach pure line status again. Various devices

such as two or more generations per year, or double haploids from pollen culture are available to speed this process.

The cross-pollinated crops exist as heterogenous, interbreeding populations and hence are more difficult to handle than the inbreeders. The population as a whole can be improved by mass selection, which means just collecting seed from desirable individuals from each generation to be mixed and used as seed for the next generation. This depends on being able to distinguish ''desirable'' types. Often this is not possible as environmental effects are too large and a progeny test is needed to determine breeding value.

Many crops are now marketed as hybrid cultivars, which is a way of combining hybrid vigour and uniformity into normally cross-pollinated crops. Usually inbred lines that breed true are first produced by self-pollination for 5 to 7 generations. These lines are tested by crossing with other inbred lines, preferably from more distantly related original sources, and the best hybrids can then be produced for commercial release. On a large scale,some form of male sterility (genetic and/or cytoplasmic) is used in the female so that the crossing is reliable. On a small scale, however, hand crossing is satisfactory if the resulting seed is of sufficient value to justify it, for example, in tomatoes where several hundred seeds may be produced from a single cross. It is not essential to use inbred lines to produce hybrids but it is the only way to ensure uniformity in the produce. Crosses between non-inbred parents are used in, for example, cocoa, rubber, and oil palm, taking advantage of hybrid vigour among different source populations without the hazards of inbreeding.

Crops normally propagated vegetatively, including many of the ornamentals and fruit crops are, as indicated previously, highly complex genetically. In principle, breeding is simple as all that is needed is to make a cross between two different lines or cultivars and grow out the resulting seeds. Every plant should be different, with plenty of scope for selection. Desirable lines can then be multiplied up by cuttings or increasingly, these days, by tissue culture, then tested and released. A real problem is in getting both parents to flower at the same time and then produce viable seed.

Many new techniques are now being used to aid plant breeders, although the basic methods are not being replaced. Tissue culture is widely used to multiply desirable clones, either where existing methods are too slow, as in pyrethrum and boronia, or where vegetative propagation was not previously possible, as in oil palms. Tissue culture itself is also generating useful variation under some conditions, where ''somaclones'' have been produced which resist, for example, high salt levels or toxins produced by diseases.

Mutation breeding, using X-rays or chemicals to produce a range of mutations, occasionally produces something useful in with all the "genetic junk"—it is like hitting a watch with a hammer and hoping to get a useful change in function. More refined techniques are now being used in "genetic engineering," to cut and paste the DNA which determines heredity, but little has yet been produced in the way of new crop cultivars. The potential is no doubt there, however.

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VIRUS TESTING OF PERENNIAL PROPAGATING STOCK

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INTRODUCTION

The presence of plant viruses can often be difficult to detect and, even if detected, the casual virus can be difficult to identify. This is in contrast to the obvious presence of most fungal disease and the ready identification of fungi. This difficulty creates a problem in perennials as the systemic nature of viruses in plant tissue and their persistence in plants means that all progeny obtained by vegetative propagation from infected perennial stock will also be infected.

The detection and identification of plant viruses is carried out by several means. Many virus diseases are self-indicating by their symptoms on leaves, flowers, or fruit. In cultivars that do not show clear symptoms infection can often be demonstrated by budding or grafting tissue into known sensitive "indicator" cultivars. Similarly herbaceous plants can be used as indicators if they show diagnostic symptoms when viruses are transmitted to them by insects or sap inoculation.

Other approaches to virus detection are electron microscopy and serology. Electron microscopy of sap preparations is effective when viruses are in high concentration and have particles of distinctive morphology—such as rod shapes. Serology relies on the use of an antiserum (which has been raised in an animal against a specific plant virus) producing a visible reaction when it reacts with this virus in plant sap

It is in serological tests, particularly the development of "enzyme linked immunosorbent assay" (ELISA), that there have been recent advances that benefit propagators. ELISA, described for plant viruses in 1977 (1), is a very sensitive test as it enhances otherwise undetectable virus—antiserum reactions by linking one component to an enzyme. The presence of the enzyme (and thus the virus) is revealed by adding a substrate that undergoes a visible colour change in the presence of the enzyme

DEVELOPMENT OF ELISA TESTING IN TASMANIA

1. **Antiserum availability.** ELISA is dependent upon the availability of an anti-serum against each virus to be tested. Thus when ELISA testing of hops *(Humulus lupulus)* was first commenced in our laboratory in 1980 it was dependent upon the

supply by the East Malling Research Station, East Malling, England, of antisera against six viruses known to infect hops. These antisera enabled the location or production of virus-free stock of major hop cultivars for propagation purposes (2). Subsequently, further supplies of antisera were produced against three of these viruses in our laboratory.

Antisera are now becoming commercially available. Although most antisera are produced in research establishments these establishments are now aware of the widespread demand for the antisera (for ELISA tests) so supplies are sold either directly or through commercial outlets. The cost of A $100 to 400 per milliliter reflects the 2 to 6 months work, expertise, and sophisticated laboratory equipment needed to produce an antiserum.

Testing is based, where possible, on the use of available commercial antisera: thus pollen-borne viruses of stone fruits are tested using two commercial antisera. For current tests on viruses of tulips and *Lilium* three commercial antisera are being used, plus two for which it had to be produced in our laboratory because of the lack of a commercial source.

2. **Rapid sap extraction.** The advantages of ELISA are its sensitivity plus its suitability for screening large numbers of specimens. For large scale testing of plant samples it is necessary to devise an automated method of sap extraction as use of a mortar and pestle is too slow. A motorised roller extractor is available commercially and similar equipment has been manufactured in our workshop for the following purposes:

i) To extract sap from leaves. A geared motor driving stainless steel rollers was constructed for approximately A$1,000.

ii) To extract sap from bulbs. A similar extractor (Figure 1) utilising matching helical rollers was constructed for approximately A$1,300. Similar equipment is used extensively for bulbs by the Dutch Bulb Inspection Service.

iii) To extract sap from woody tissue, such as dormant hop crowns, and also for bulk testing of numbers of samples. Tissue is placed in steel tubes and macerated with a rotary file driven by an electric drill. This is the technique developed by Washington State University's commercial ELISA laboratory at Prosser, Washington, USA, and used for all types of samples.

Figure 1. Extractor utilizing matching helical rollers.

3. **Developing reliability.** Under optimal conditions ELISA accurately detects virus infection. However, it is necessary to determine the optimal conditions and their limits for each virus-plant-antiserum system. Some of the variable conditions are: time of sampling of plants, the occurrence of virus strains, optimum buffer strength, and use of additives and degree to which samples are bulked.

Time of sampling is important as detectability may decrease with plant maturity. Thus tests for pollen-transmitted viruses in stone fruit are only carried out in spring (3); similarly we have noted a decreased accuracy of hop virus detection towards harvest.

The strains of tulip breaking virus are detected to differing degrees by two antisera (4) and in our tests there was a 5% difference in their ability to detect infection.

Bulb tissue may require cellulase to assist virus extraction and use of high molarity buffers to stabilise pH (5).

Bulking of several plants in one test decreases the cost per plant and is feasible if a low percentage of positives is expected and if these can still be detected when mixed with healthy samples (Figure 2).

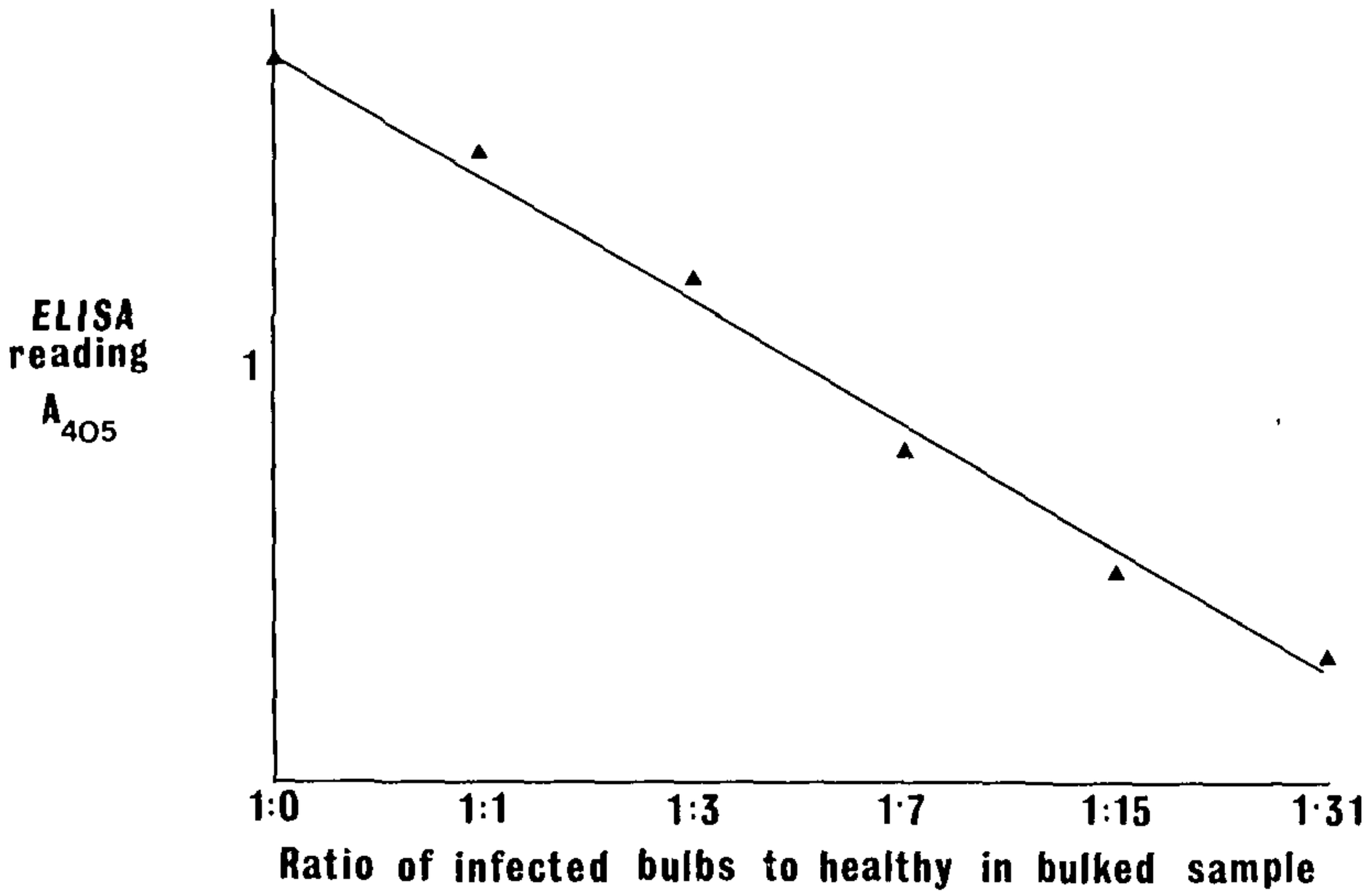

Figure 2. Effect of bulking of samples on virus detection.

The above steps of preparing or obtaining antisera, manufacturing sap extracting equipment and then determining optimal conditions for reliable tests have been the major stages in the development of a plant virus ELISA laboratory in the Tasmanian Department of Agriculture. The laboratory is able to test material for private propagators and thus greatly expand Tasmania's ability to supply virus-tested stock. Tests can be undertaken on hops, stone fruit, potatoes, tulips, *Lilium,* gladiolus, iris, freesia, orchids and roses. The information can then be used by propagators to locate clean stock, to reassure themselves that they are not selling diseased stock or, by labeling stock as virus-tested, to inform the customer of its high quality.

CURRENT DEVELOPMENTS

1. Plant virus antisera are becoming increasingly commercially available.
2. Monoclonal antisera, effective in detecting wider ranges of viruses, are now being produced. They will decrease the outlay on antisera required by ELISA laboratories.
3. Complete ELISA "kits" designed for simplicity of use will permit tests to be carried out by a wide range of users, including propagators.
4. ELISA tests for a range of bacterial and fungal diseases are being developed.

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DWARFING ROOTSTOCKS FOR APPLE *(MALUS)*

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Throughout the major apple producing areas in the world propagation of cultivars was carried out on seedling stocks for many years. An example of this is the use of French crabapple seedlings *(Malus sylvestris)* that were used widely in Europe and North America until the early 1930's. Since then, numerous clonal asexually propagated apple rootstocks have been developed. Popularity of the more dwarfing rootstocks has increased dramatically in the last 25 years. Financial constraints on the modern apple producer has necessitated earlier, higher yields per acre. One of the ways to achieve this has been to plant trees at higher densities on dwarfing rootstocks. Clonal rootstock selection now enables a grower to select a rootstock suitable for his soil, climate and cultivar.

HISTORY

Many clonal rootstock selections have been made throughout the world, the most notable being the ''Malling'' and ''Malling Merton'' series.

In 1912 work began at East Malling Research Station in England to select and classify a series of vegetatively propagated apple rootstocks, which ranged from very dwarfing to very vigorous in their effect on the scion cultivar. The fruit harvested was not affected by the dwarfing influence and in many cases was found to be larger, particularly on younger trees. The Malling stocks have been planted in many parts of the world, proving to be very hardy except in regions with extremely severe winters. They perform well on both light and heavy soils but are not resistant to woolly aphids *(Eriosoma lanigera).*

In 1928 a joint breeding programme between The John Innes Horticultural Institution and East Malling Research Station began to produce a series of rootstocks resistant to woolly aphids, and a new range in tree vigor. This series of rootstocks are known as ''Malling Merton.'' The most widely used stocks of this group are M.M. 104, M.M. 106, and M.M. 111. Other improved characteristics include higher yields, freedom from suckering and good propagation qualities.

Both the ''Malling'' and ''Malling-Merton'' stocks are readily propagated by stooling or mound layering. However some rootstock clones have responded well or even better to being propagated by hardwood cuttings.

Today in modern apple production there are two categories of rootstocks which are of importance: (1) dwarfing stocks, and (2) semi-dwarfing stocks.

DWARFING STOCKS

'Malling 27' This is the most dwarfing of all the Malling stocks. At maturity it reaches about 4 ft. tall. It is a cross between 'Malling 13' and 'Malling 9.' It has obvious use in very high density plantings. Suckering is not a problem. Virus-tested propagating material was released from East Malling Research Station in 1970.

'Malling 9' ('Jaune de Metz') This was a chance seedling which originated in France in 1878. Today virus-free selections are widely used as a dwarfing rootstock for high density orchard plantings and home garden situations. At maturity it reaches about 10 ft. tall and will start bearing fruit in the first and second year after planting; however, as with 'Malling 27,' it requires staking as the roots are very brittle. A fertile soil is required in addition to some form of irrigation if grown in a dry climate. It is resistant to crown rot (*Phytophthora*). but tends to sucker under some circumstances.

In recent years further selections have been made, i.e., EMLA 9 (East Malling-Long Ashton). Such stocks have undergone heat treatment and virus indexing and naturally tend to be slightly more vigorous than 'Malling 9.'

'Malling 26' This stock originated from a cross between 'Malling 16' and 'Malling 9' and was introduced by East Malling Research Station in 1959. It produces a tree which is slightly larger than 'Malling 9' and smaller than 'M.M. 106,' but still requires some form of support. It has been found to be a poor producer in the stool bed but is easily propagated by softwood cuttings under mist, or by hardwood cuttings. Some growers have also claimed that it produces a lot of blind buds along potential fruiting laterials.

SEMI-DWARFING STOCKS.

'Malling Merton 106.' This rootstock is the most widely used today. It produces a tree larger still than 'Malling 26' but half the size of a standard seedling. It has a vigorous root system and does not require staking. It tends to crop earlier and heavier and is popular in Europe and the United States. It does not sucker but the only slight drawback is that some growers claim it is more susceptible to crown rot (*Phytophthora*).

PROPAGATION METHODS

Today clonal apple rootstocks are propagated by three methods: stool or mound layering, hardwood cuttings, and micro propagation.

1. **Stool or Mound Layering** is commonly used today for most dwarfing rootstocks except, perhaps, 'Malling 26.' In the first year the mother stock is planted out and allowed to grow on for one year. Before growth commences the following year the stock is cut back to 1 in. above ground. Stock plants are spaced 12 in. apart with the rows a minimum of 4 ft. apart, depending on what mechanical aids are used, if any. When the new shoots are 5 to 6 in. high, the soil should be mounded up to half their height. Timing is fairly critical. If done too late then poor rooting can result. The addition of sawdust to the soil can help to make it more friable. The hilling-up process should be done three times during the summer in order that the base of the shoots are covered with 6 to 8 in. of soil. It is important to ensure the soil surrounds each shoot properly. At the end of the growing season the layered shoots should have rooted sufficiently and can then be separated from the mother plant and lined out in nursery rows. Well-cared-for stool beds can be used for 15 to 20 years. It is essential, therefore, that insects, diseases, and weeds are kept under control.

2. **Hardwood Cuttings.** This method is used for the more difficult to root subjects, such as 'Malling 26.' Today heated bins are used for the establishment of roots. This method was pioneered by R.J. Garner and further developed by B. H. Howard of East Malling Research Station, Kent, England.

There are three procedures that one must adopt for successful rooting of cuttings in heated bins:

a) The pre-conditioning of one-year-old shoots from heavily-pruned stock plants.
b) The provision of an environment to reduce stem decay so as to maximise root initials and to reduce vegetative buds from growing out.
c) To encourage the successful transplanting of the cuttings into the open ground.

For apple rootstocks the months of August and September are preferable for taking hardwood cuttings. The optimum cutting length is 24 in. They are then dipped into a liquid rooting hormone solution containing 2,500 ppm of indolebutyric acid (IBA) for five sec. The solvent is allowed to evaporate for 20 to 30 min. before the cuttings are placed into the rooting medium in the bin. The optimum basal temperature is 21 °C (70 °F) for 2 to 3 weeks. The hardening-off process is carried out by lowering the temperatures

5 °C (9 °F) every two days and turning the heat off completely after two weeks. The air temperature should be kept at a constant 5 to 10 °C (41 to 50 °F) in order to delay bud break. For apple rootstocks it is preferable if they are grown on for a further year to establish a strong root system before being lined out ready for budding the following autumn.

3. **Micropropagation.** This is the newest of all techniques used for raising apple rootstocks today. For an industry requiring virus-free stock it has many advantages. Some of these are:

a) A means to remove viruses from a plant. i.e. The removal of the meristem from a heat-treated plant and its subsequent culture under sterile conditions. This led to the virus-free programme for apple rootstocks such as the E.M.L.A. Scheme in England.
b) The bulking-up of plants rapidly.
c) The selection of a seedling or mutation in a plant breeding programme to permit an earlier release date.
d) A means by which to propagate the year around.
e) A means by which to export plants to other parts of the world.
f) A reduction in the area required to raise stock plants and plant beds.

A disadvantage can be the initial capital required to establish a laboratory and its equipment and to find suitably qualified staff.

CONCLUSIONS

Dwarfing apple rootstocks are going to play an ever increasing role in modern apple production. The necessity to get earlier, higher production will involve planting trees at high densities per acre on dwarfing stock. With the cost of labour increasing all the time, the introduction of mechanical aids will become a necessity. Fortunately in the commercial production of apples, growers have a wide range of cultivars and rootstocks to choose from.

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LAVENDER CLONE SELECTION FOR ESSENTIAL OILS IN TASMANIA

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In my particular field there are two kinds of experts dealing with the volatile oils. First we have the specialist, who has narrowed and deepened his field of study to the point where he knows nearly everything about almost nothing. Conversely, there is the general consultant, who covers such a wide field that, in effect, he knows nothing about everything. Now, here am I, a better specialist than a consultant and a better consultant than a specialist, uncertain whether I know anything at all; least of all something that might be relevant to the objectives of your Society.

On the other hand, the propagation of plants, and the selection of those plants that are worth propagating, is fundamental to all those industries and individuals that depend ultimately on things that grow in the soil. One way or another that includes us all. But to speak in general terms on this subject, would be like Mark Anthony, to "tell you only that which you do know." However, it may interest you to hear how plant and clone selection affects the production of those volatile oils which are used in the flavour and perfume industries. Since we all must eat and wash, this narrower field would also concern all of us. For example, an old-time advertisement which begged, "If you won't use our soap, for heavens sake, use our scent," has said it all.

When steam is passed through a charge of plant material which bears a volatile oil and the emerging vapours are condensed, most of the oil will separate spontaneously from the water in the liquid phase. Many valuable materials are recovered from a wide variety of herbaceous sources by this process of "hydro-distillation." The products won from nature in this way are called "essential oils" because, being derived by distillation, they are, by definition, essences.

The annual value of the world output of these essential oils is very great indeed, many billions of dollars. Compared to other countries, Australia, despite incomparable opportunities, is missing out and our production is insignificant by world standards. But even Tasmania's small share of this unimportant output nears some 1½ million dollars each year. Due to the multiplier effect, the commercial importance of these oils is magnified many times by the value of the manufacturing industries which use them. In fact, the detergent, soap, perfumery and cosmetics industries are assessed

as having the fifth largest group turnover in world trade. This does not include the even larger consumption of essential oils in edible essences, prepared foods, soft drinks, liqueurs and, last but not least, pharmaceutical applications. Clearly, the importance of plant breeding and selection to improve all the species from which these oils are derived, can hardly be overstated.

With the advent of greatly improved synthetic chemicals to supply the less expensive sections of the market, natural essential oils will, in future, have to justify their higher production cost and the prices in the upper echelons of the market where only the very best will be good enough. Certainly, the products of unselected or unimproved planting stock will not be able to do this.

Essential oils are natural mixtures of one or more main compounds with numerous trace components; the latter are often the most important constituents of the oil. For example over 60% of the odour value of rose oil is provided by ketones which amount to less than ¼ of one percent of the whole oil. The trade requires these oils, either as a source of one of its main constituents, or for use in its natural state to take advantage of the synergic properties of the natural mixture which human science does not know how to duplicate. Many oils, in fact, are used in both these ways and it follows that any intending producer must first be sure that there is a ready market for his product in one or other of these established applications and that the composition of the oil will suit the use for which it is intended.

While having planting stock of the right species is, of course, necessary for this purpose, it by no means guarantees that a saleable oil can be produced from it. Even with oils that can be marketed, clonal type variations cause big differences in the price. Two examples will suffice:

Oil from the citronella grass grown in Ceylon contains only 10 to 15% of the desired adlehyde, contronellal. The same species grown in Java has some 50% of this component and is much more sought after. Similarly, the geranium oils from Reunion have a much greater rhodinol content and are far more highly prized than those from Egypt or Morocco.

The oils produced by many plants are influenced by length of day (or night). It follows that the variants of any species selected for oil production must be adapted not only to the climate but also to the latitude of the growing area. My own company imported mint plants to Tasmania in 1951 and produced oil from them in the north of the island for some 20 years. The project was then transferred to the south, scarcely 2° further from the equator, where due to the longer summer days and cooler nights, the same stock produced better oil and more of it.

Of course, the greatest cause of variation among the individuals of any species that can be propagated by fertile seed is undoubtedly genetic. The lavender genus provides an excellent example of the complex confusion that must be sorted out in selecting the best genotypes for essential oil production. There are only two *Lavandula* species of interest to the perfumery trade. Firstly, there is the vigorous, hardy *L. latifolia,* occurring naturally in the coastal regions of the northern Mediterranean. It yields a strong rich oil in which the odour of camphor is predominant. This restricts its use to those applications where the camphor odour can be tolerated. Native plants of the best form of the so-called "true lavender," *L. angustifolia,* are found only in a small area above 1000 metres altitude on the southern slopes of the French Alps. Its odour is very fine and completely free of any discernible camphor. It is, however, a smaller and more delicate plant than *L. latifolia* and yields far less oil.

At medium altitudes these species intermingle and are cross pollinated by bees, giving rise to sterile hybrids which are stronger and yield more oil than either parent. Unfortunately, despite its current very large production, the future of this oil is in some doubt. Having neither the richness of *L. latifolia* nor the refinement of the *L. angustifolia,* it may well be overtaken by synthetic substitutes which can exclude the still dominant camphor note.

Expert advice was that any two parents of either species can give rise to at least 2500 different viable genotypes in their progeny. Since all variants of both species appear to be interfertile, a mathematician might expect some 6.25×10^6 different genotypes among the hybrids. Since it is these hybrids that nurserymen have propagated asexually and given them names like "English Lavender," "French Lavender," etc. we find them in most home gardens. However, the hybrids can copy the visible characters of either parent as well as showing every possible combination of them. But the less desirable camphor component will still dominate the odour of most of the hybrid oils without any assurance that the rest of the oil will make it suitable for an established application. As will be seen, whatever its appearance may suggest, the chances of a garden lavender being suitable for oil production appear to be less than one in several million.

Since my company's lavender plantations were started from a large quantity of seed taken from high up in the Alps where no *L. latifolia* plants existed, there was little danger of any hybrids being included in the planting stock, and this did prove to be the case. At the same time we were advised that, due to the large number of seeds originally grown, it was probable that most viable genotypes of *L. angustifolia* would be found in our fields. All we

had to do was to isolate the most desirable variants and propagate them asexually by cuttings to preserve their genetic characters. In 1949 a long term research programme was initiated to do just that.

Of course, given time, those plants with inadequate longevity would eliminate themselves. Similarly, those with insufficient resistance to the normal hazards of existence in Tasmania would become weak and unproductive. Many more could be eliminated by experienced olfactory examination detecting undesirable odors in the flowers. In the event, after these eliminations, we still had 487 promising genotypes which we had to test in the field for periods from 7 to 11 years to confirm their ability to produce good oil in adequate quantities over a reasonable number of years.

Appearances were deceptive. One plot of exceptionally vigorous plants yielded 8500 kilos of flowers per hectare but only 8 kilos of oil. The adjacent plot had a slightly less vigorous type which yielded only 5000 kilos of flowers but some 60 kilos of oil per hectare. There were many plants which produced small quantities of good oil and even more that produced large quantities of indifferent oil. But from the presumed original 2500 genotypes only 13 produced large yields of quite good oil. Only three produced superior yields of very good oil. These are now the basis of our plantations, and of these three only one produces exceptional yields of superlative oil.

The selection programme took 23 years to complete It was tedious but not particularly difficult or costly. Since it costs no more to maintain a plantation yielding exceptional quantities of superior oil than one of mere average performance, the commercial advantages resulting from the research programme become significant. The present plantations yield at least double the normal amount of oil per hectare and the oil has 2½ times the average content of the most desirable trace component. At the same time, all the off-colour perfume notes normally contributed by inferior genotypes in unselected plantations, have now been eliminated. The clonal selection has given an advantage in lower production cost and a higher market value which is reflected in the selling price and the bottom line of the accounts.

As a final note, I would like to observe that selling price is important but it does not only depend on the quality of the product. It requires knowledge of the market and shrewd judgement of what is required right now and how this may change in the years ahead. The classic example of misjudging a market comes in a fable told me by a Scotsman many years ago. It is said that, during the great depression of the early thirties, the city council of Aberdeen lowered the bus fares from threepence to twopence a mile. The citizens were furious, because they could save only twopence instead of threepence by walking.

SEEDLING VARIATION IN ROOT FORMATION OF *EUCALYPTUS GLOBULUS* CUTTINGS

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Abstract. Cuttings of *Eucalyptus globulus* seedlings from a number of Tasmanian provenances were examined to assess inter and intra provenance differences in root production When grown under glasshouse conditions with bottom heat there were no significant differences in the rooting ability of cuttings between provenances However, within provenances there was a large amount of variation among individual seedlings Also, there were large differences in the number of roots produced on rooted cuttings. For clonal plantations of *E. globulus* intensive selection for easy propagation of cuttings is mandatory

REVIEW OF LITERATURE

With eucalypts, successful propagation of cuttings is affected by·

1) Individuals within a species (3, 6).
2) Juvenility, which encompasses position of the cutting on the mother plant (1, 7, 8), and the age of material used for the cutting (3, 4, 8).
3) Seasonal effects (2, 5).
4) Physiological condition of the mother plant (5).

The aim of this work was to investigate both inter and intra provenance differences in the rooting of *E. globulus* cuttings in order to identify seedlings with good rooting ability. The long term aim is to develop a commercial system for the production of cuttings to be used for clonal eucalypt plantations in Tasmania.

MATERIALS AND METHOD

Experiment 1. Inter-Provenance Effects. Nine provenances of *E. globulus* (King Island, North Flinders Island, St. Helens, Scamander, Seymour, Swansea, Jericho, Bruny Island, and Channel), (Figure 1), with 10 replicates and 5 cuttings per replicate were tested. Two or three leaf pair cuttings were taken at node 2 from 5 to 6 month old seedlings.

Leaves were trimmed and cuttings were placed in a fungicide solution (0.025% benomyl) before the base of the cuttings were dipped in IBA-talc (0.8%). Cuttings were then planted in a peat:perlite:sand (2:2:1) mix in individual pots (6cm x 7cm) and placed under intermittent mist. The cuttings were arranged in randomised blocks in a polythene tunnel without bottom heat. Cuttings received a weekly fungicide spray and were assessed after 6 weeks. Exp. 1 was carried out during late summer, February and

March, 1988; maximum temperatures ranged from 17 to 29 °C (mean 24.6 °C) and minimum temperatures ranged from 5 to 15 °C (mean 11.8 °C). Rooting success was calculated as the number of cuttings rooted/the number surviving at assessment and expressed as a percentage for each replication. An arc sine transformation was performed on the data.

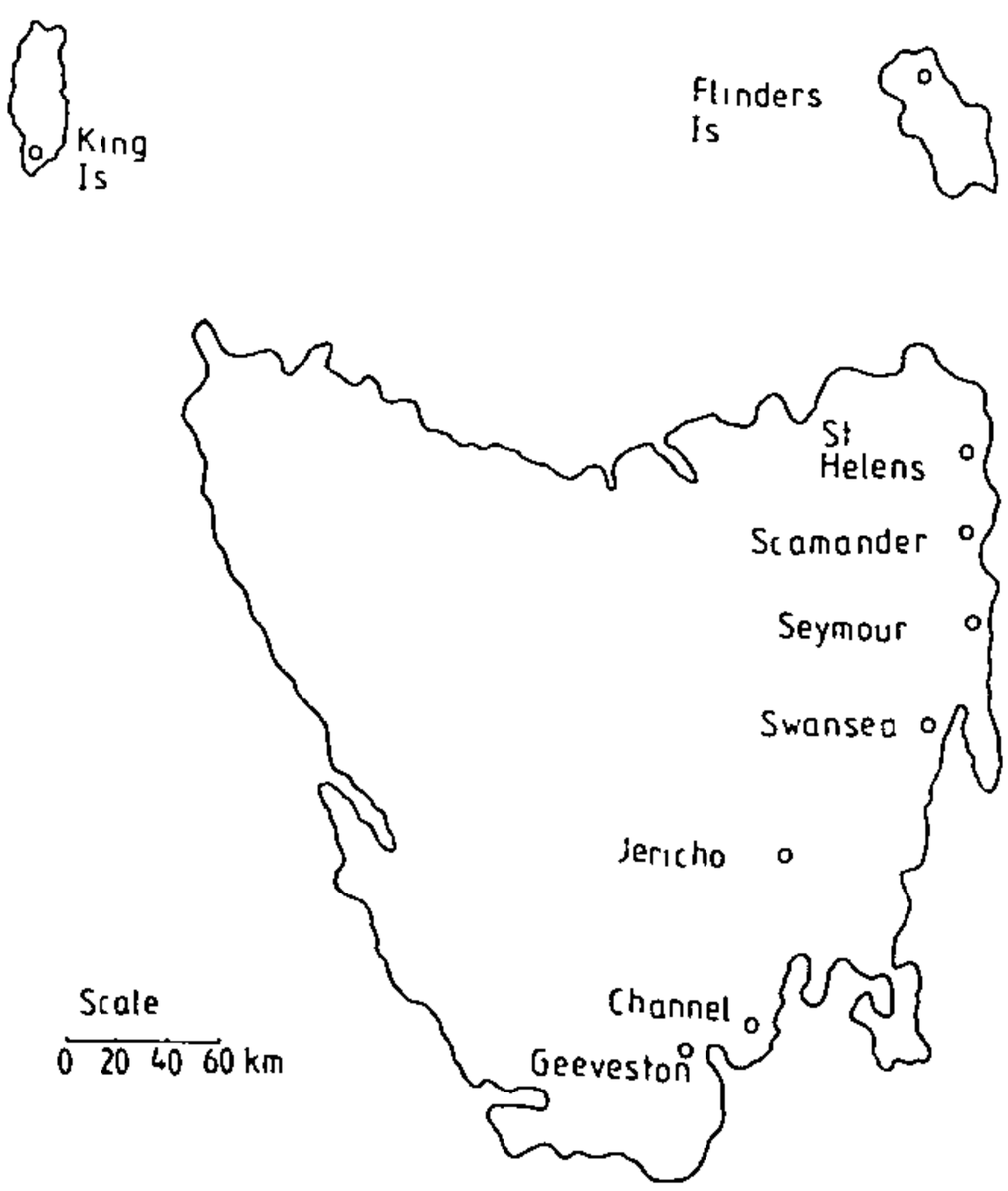

Figure 1. Location of *E globulus* Provenances in Tasmania

Experiment 2. Intra-Provenance Effects. Four to five month old seedlings from 5 provenances (St. Helens, Seymour, Scamander, Channel and Geeveston) were treated as for Experiment 1 except for a few details. Six seedling trees from each provenance were included with each group consisting of 6 replicates (each containing 5 cuttings per replicate). A vermiculite·perlite mix (1:1) was used as the rooting mix as this has been found to be more successful than the mix used in Experiment 1. Cuttings were placed in a glasshouse supplied with bottom heat (25 °C) and were assessed after 24 days. Experiment 2 was conducted in the autumn, April and May, 1989, with maximum temperatures ranging from 17 to 26 °C (Mean 22.8 °C) and minimum temperatures ranging from 7 to 16 °C (mean 12.3 °C). In order to detect differences in the amount of roots formed, the mean number of roots produced per rooted cutting was calculated.

RESULTS

There were large differences in the rooting success of cuttings taken from seedlings from different provenances in Experiment 1 (Table 1.) In Experiment 2 there were no significant differences in the rooting ability of cuttings from the 5 different provenances (Table 2), however, intra provenance differences were evident (Table 3).

A positive relationship between percent rooting success (y) and the number of roots produced for the successful cuttings (x) was established (1ny = A + Blnx; r = 0.725).

Table 1. Rooting success (transformed data) of a number of *E globulus* provenances, 6 weeks after setting (Exp 1)

Provenance	Rooting success (degrees)
Channel	5 0a *
N Flinders Island	5 5a
St Helens	24 2b
King Island	35 8bc
Swansea	36 5bc
Bruny Island	39 7c
Scamander	57 9d
Jericho	60 1d
Seymour	64 1d

Each value given is the mean of 10 replicates

* Means for each provenance having the same letter are not significantly different at the 5% level

Table 2. Rooting success of seedling cuttings from 5 *E globulus* provenances, 24 days after setting (Exp 2)

Provenance	Rooting success (degrees)	Mean number of roots/rooted cutting
Geeveston (G)	54 0	8 2
St Helens (SH)	59 9	8 4
Scamander (Sc)	60 6	8 4
Seymour (S)	63 5	9 9
Channel (C)	63 8	10 0
LSD 5%	11 9	3 0

Each value given is the mean of 36 replicates

Table 3. Rooting success of seedling cuttings of 6 different sources from 5 provenances (Exp. 2)

Source		Rooting success (degrees)	Number of roots/rooted cutting
S	3	60 9	7 9
	5	72 5	9 4
	11	64 0	18 1
	12	85 0	10 7
	16	30 9	1 8
	17	68 0	11 6
Sc	2	71 7	14 4
	7	55 0	6 1
	6	33 4	5 8
	10	34 0	4 3
	11	85 6	8 6
	13	83 5	11 1
SH	1	54 1	2 3
	5	65 8	5 7
	6	60.0	10 4
	7	61 5	10 6
	8	61 7	10 4
	10	56 3	11 3
C	2	59 0	4 8
	3	80 6	17 5
	5	60 0	6 4
	7	54 9	9 0
	8	72 7	9 6
	9	55 6	13 0
G	4	38 4	4 9
	7	34 1	4 3
	8	64 4	7 0
	10	62 8	11 7
	13	66 5	14 1
	14	57 8	7 5
LSD 5%		26 2	6 2

Each value is the mean of 6 replicates

DISCUSSION

These experiments demonstrate two important points about the clonal propagation of *E. globulus*. Firstly, Experiment 1 shows that there are significant differences among provenances in the ability of cuttings to produce roots under minimal controlled environmental conditions. In Experiment 2, where environmental conditions were less variable, differences among provenances were not apparent. However, between trees within these provenances significant differences were noted From this it appears that bottom heat is very important for the successful propagation of *E globulus* cuttings and some specific clones may have differing environmental requirements for successful propagation. Temperatures above

28 °C are also thought to be detrimental to rooting *E. globulus* cuttings.

The identification of seedlings whose cuttings show poor rooting indicates the need for greater research to improve rooting ability in these clones; otherwise favourable characteristics that they may possess could be lost from the genetic improvement program. The importance of maintaining genetic diversity in tree breeding has been stressed by van Wyk (9). Once good rooting trees and individual clones are identified they can be utilised in the breeding program to increase the rooting ability of inter and intra specific crosses.

Commercial clonal forestry with this species will require both good environmental control for the propagation of cuttings and sufficient numbers of clones that are easily propagated.

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THE PRODUCTION OF SALT TOLERANT TREES

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The southwestern part of Western Australia is under severe threat from salt encroachment across vast areas of agricultural and marginal lands. Already some 300,000 ha are so badly affected by salt that the land is useless for cropping.

My interest in arresting salt encroachment goes back many years. However I have only become involved in a positive way over the past ten years. My hope is that by encouraging the planting of salt tolerant species of native vegetation the land can be reclaimed, stabilised, and in time returned to productive use. It is well known that some species of plants are naturally salt tolerant but these plants may not suit particular areas or even the end use of the land. By selecting salt tolerant species that have a definite end use, and have been indigenous to the area, we are well on the way to successful rehabilitation.

Some nurseries have grown salt-tolerant species for many years. The methods used to select salt tolerant plants are many and varied. Simply collecting seed or vegetative material from plants growing on or close to salt scalds or saline waterways is the most common and has generally provided successful results. Seed collected from these plants is raised in the normal manner.

The other end of the scale begins as above but is taken many steps further. Researchers from the University of Western Australia and others have conducted many trials over the past few years involving salt tolerant plants (1).

METHODS

Initially a series of collecting trips were made into remote and salt affected areas to collect seed. The seed was mainly collected from single *Eucalyptus, Casuarina, Melaleuca,* and *Acacia* trees growing in "ideal" conditions. The better trees in an area that was worst affected by salt were selected. Each tree was photographed, numbered, and the seed lot labelled. The location was carefully recorded to allow future collectors to relocate the tree. Shrub species were also collected from these areas.

After returning from the trip each seed lot was cleaned, recorded, and stored in a cool room in sealed polyvinyl chloride screw top jars. Silica gel and a fungicide were added to each jar before storage.

In a trial in 1987 carried out in a rehabilitation nursery, 19 species of Western Australian eucalypts, representing a total of 48 provenances were selected, and seed from each was sown into Jiffy pots. The Jiffy pots were placed in standard punnet trays with open mesh bases. The trays rested on weldmesh benches allowing almost total air root pruning to occur, thereby avoiding tangled

rootbound plants. Watering and fertilising was carried out as a normal nursery practice.

After 18 weeks the seedlings in Jiffy pots were planted into 305 mm plastic buckets. A layer of crushed rock was placed in the base of each bucket, and it was then filled with fine white sand. Four plants were planted in each bucket, which were placed into large metal trays. Each tray had a valve in the base to facilitate drainage as required. The trays with the pots in them were then placed in a glasshouse for two weeks to become established before the treatments were applied

The following treatments were used:

C —Control. Drained and no saline solution.
S —Saline solution, but drained.
W —Waterlogged, but no saline solution
SW —Saline solution and waterlogged

The control and saline solution treatments were watered automatically three times daily for 15 min. each watering. At each watering one litre of solution was used. To achieve waterlogging the trays were filled to about 1 cm above the soil surface. The solution used for the C and W treatments was Hoagland's No 2 Nutrient Solution, diluted to $^1/_5$ strength with tap water. The nutrients used for treatments S and W were NaCl, $MgS0_4$, and $CaCl_2$, in the ratio by weight of Na.Mg:Ca of 10:2:1. The concentrations were increased weekly by 7ms/cm until a concentration of 35ms/cm was reached, 35ms/cm is approximately equivalent to the concentration of sea water. The solutions in the trays were changed weekly and fresh nutrients and salt added.

The experiment ran for five weeks in January and February, 1987 in a glasshouse where the maximum temperature was 31 °C and the minimum was 18 °C

RESULTS AND DISCUSSION

From Table 1 it can be seen how each species performed under saline and waterlogged conditions.

Plants from provenances exhibiting superior tolerances to salt and waterlogging can then be selected and multiplied by tissue culture. Trials have shown that plants raised from tissue culture can be successfully grown, potted on, and normal growth rates achieved. When these plants are hardened off, they are planted out in the field and trialed. Following field trialing the successful clones are then put into normal production.

Although some of the plants used may not be well known, they are some of the most salt tolerant eucalypts known, and will contribute to the reclamation and rehabilitation of salt affected areas. Following the lowering of the water table by these species other less salt tolerant plants can be re-introduced and pockets of vegetation can be re-established.

The salt tolerant tree story does not stop here, indeed this is only

a small part of the process. The pre-planting processes play an important role also. Deep ripping, furrow ploughing, mounding of rip lines, and contour grading are some of the jobs needed to be carried out to allow the young seedlings to get a successful start. The seeded or superior cloned trees cannot be expected to survive in a saline waterlogged paddock without this mechanical assistance. That, however, is another story.

Table 1. Percentage survival of seedlings from *Symphyomyrtus* eucalypt species after 5 weeks in non-saline drained (C), non-saline waterlogged (W), saline drained (S), and saline waterlogged (SW) conditions The value for each species is the mean of the provenance values. The range of provenance values is shown in brackets.

Eucalyptus Species	Number of Provenances	Survival, percent C	W	S	SW
E angustissima F Muell	1	100%	100%	100%	25%
E aspratilis Johnson et al. MS	2	100	100 (both 100)	100	31 (12-50)
E calycogona Turcz.	1	100	100	100	38
E eremophila (Diels) Maiden	1	100	88	100	25
E. halophila S & D. Carr	2	100	81 (62-100)	100	38 (both 38)
E. kondininensis Maiden & Blakely	3	100	96 (88-100)	100	12 (6-19)
E kumarlensis Brooker MS	1	100	88	100	12
E. loxophleba Benth.	3	100	96 (88-100)	100	17 (12-20)
E. micranthera F Muell, ex Benth.	1	100	62	100	12
E myriadena Brooker	1	100	100	100	31
E occidentalis Endl	12	100	100 (all 100)	100	59 (12-75)
E. platypus Hook.	1	100	100	100	0
E. plenissima (C. Gardner) Brooker	1	100	62	100	12
E quadrans Brooker & Hopper MS	1	100	62	100	6
E salicola Brooker MS	3	100	71 (50-88)	100	16 (6-31)
E. salicola (mallee form) Brooker MS	1	100	88	100	12
E sargentii Maiden	9	100	99 (88-100)	100	63 (38-94)
E spathulata Hook.	3	100	96 (88-100)	100	35 (25-44)
E yilgarnensis (Maiden) Brooker	1	100	100	100	25

This is only a simplified version of a long process and the many hours of research that has been undertaken to help stop the salt. I commend to everyone interested or involved in salt land work to make themselves aware of the work being carried out at the University of Western Australia.

Acknowledgements I wish to thank Mr Paul Van der Moezel of the University of Western Australia and Mr. David Kabay of Alcoa (Aust) for providing research information

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PRODUCTION OF ROOTSTOCKS FROM SEED COLLECTED FROM *FAGUS SYLVATICA* CULTIVARS[1]

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The production of *Fagus sylvatica* (beech) trees is generally carried out by grafting, and it is unusual for grafted cultivars to set seed. In autumn, 1988, however, several of our grafted cultivars did set seed. I was interested to discover whether these seeds were viable and whether any would be true to type.

With the small quantities of beech seed produced in Australia, it is extremely difficult to obtain seed and, hence, to produce seedlings for rootstocks.

Beech seed has only a very short life and must be sown very soon after collection or it loses its viability. For this reason it is not possible to obtain large amounts of seed from overseas.

As I was looking to attempt the grafting of many different beech cultivars I wanted to explore the best method of seedling production for my rootstocks.

METHODS

Seed is not normally collected from the selected cultivars of *F. sylvatica* but in 1988 there was seed available to me from five different cultivars. These were:

F. sylvatica cv. Riversii
F. sylvatica cv. Roseomarginata
F. sylvatica cv. Pendula
F. sylvatica cv. Zlatia
F. sylvatica cv. Atropurpurea

The seed was mainly collected in early autumn (March) and a small amount in April, 1988. Knowing when beech seed is ready for sowing is essential. The seed is considered mature when the fruit cup, which is covered in erect soft bristles, has opened and the beechnut has fallen.

Two simple methods were used to test whether the seed had developed.

a. Seed was placed in water, and any that floated were discarded. Those that sank to the bottom were probably viable.
b. The seed were squeezed between the fingers. If it flattened, it was discarded. Viable seed must be solid.

It was decided to test the effect of stratification on the germination of the seed, compared to direct sowing in autumn and leaving them outside over the winter in our area (the Dandenong Mountains near Melbourne).

Seeds were collected when wet, so they were allowed to dry for about two weeks before being sown or stratified.

Untreated seeds. These were sown on 24 April, 1988, into flats using a potting medium of ⅓ pine bark and ⅔ sandy loam. The flats were placed outside in the hope that the normal Dandenong

weather conditions would be enough to cause stratification.

Stratification. Peat moss was soaked for about 10 min. then all the excess water was squeezed out of it. Seed was mixed with the moist peat moss in a ratio of ¾ peat moss to ¼ seed, and placed in a plastic bag. The bag was closed with a tie, and placed in a refrigerator at approximately 4 °C. The seeds were left in the refrigerator for about 4½ months.

The seeds were taken out of the plastic bag in late winter (mid-August) and sown into squat pots. The medium used was the same as for the untreated seed. Some of the seed had begun to germinate; these were carefully placed in the medium with the radicle downwards. All seeds were covered with about 2mm of medium.

The pots were placed into an unheated glasshouse. The vents of the glasshouse were opened during the day, but closed at night. The glasshouse temperature was approximately 2 to 4 °C warmer than the outside temperature.

The pots were left in the glasshouse until early summer (mid-December), and then moved into a shadehouse.

RESULTS

Only 15% of the untreated seeds germinated after 7 months. Approximately 85% of the stratified seeds germinated in 2 to 3 weeks after being sown in the pots. By 12 weeks all seedlings had developed their first true leaves.

DISCUSSION

The period of stratification may have been too long as some of the seeds were beginning to germinate in the refrigerator. This time can be reduced in future trials.

The unstratified seeds showed a low germination rate, and this suggests that winter conditions of the Dandenong area were not cold enough to satisfy the stratification requirements of *F. sylvatica* seed.

Stratification did, however, produce a satisfactory and simple method of obtaining a high germination rate, provided the seed are sown fresh.

All seedlings produced were grown on until the end of February, 1989, when they were fertilised with 3 to 4 month Osmocote to increase their food reserves to help them survive the winter.

The seedlings will be over-wintered in the squat pots. They will then be planted out into the open ground in spring at bud burst. The seedlings were left in the squat pots because they were going to be planted out in the open ground. If it is necessary to transfer them to individual tubes, this is best done at the cotyledon stage.

Most of these seedlings will be used as rootstocks for budding and grafting, especially as at this moment there is not much variation in foliage colour or shape being shown. When a unique characteristic is found in an individual seedling this plant can be used as budding or grafting material to produce a new cultivar.

PRODUCTION OF SPRAY CHRYSANTHEMUMS IN A HYDROPONIC SYSTEM

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INTRODUCTION

Hydroponics as a propagation tool has come of age due to the lack of good clean soil and the cost of soil sterilization. In Australia, the nursery industry has been using different forms of hydroponics for some time. Propagators generally use a natural or artificial solid medium or a mixture of the two, but some produce bare-rooted plants in either a deep flow system, aeroponics, or nutrient film technique (N.F.T.), as in our case.

There are really only two types of systems—open and closed. In an open system the nutrient solution is not recovered while in a closed system the nutrient solution is recycled. In an ideal closed system, pure water is used and it is only necessary to flush out the system every four months or so. In our nursery, where high salts are present in the main's water, it is necessary to flush out the system every 10 to 14 days in summer and every 3 to 4 weeks in winter. In spring, our water showed a reading of 360 mg/l of chloride (Cl) and 170 mg/l of sodium (Na). Despite these high salt levels, we have found that plant quality is not affected provided that the system is regularly flushed out.

METHOD OF PROPAGATING IN OUR N.F.T. SYSTEM.

Our nursery is divided into two areas—a long-day and a short-day area. The long-day area is used for growing stock plants and propagating cuttings. Stock plants are grown on four elevated tables, 0.75m X 24m, made of Lysaght 305 steel roof decking with the depressions forming the growing channels. These are lined with black PVC damp-proof course which helps to distribute the solution evenly due to its rough surface.

The tables are then covered with black polythene and the plants are planted through holes cut in this polythene at 15cm X 10cm spacings. The tables are fixed at a 2% gradient and the nutrient solution is fed via an in-line filter into the top of each channel through a header pipe. The solution flows down each channel bathing the roots and is collected at the base of each table into a 100 litre reservoir. The solution is constantly recirculated by a submersible fountain pump.

Chrysanthemum cuttings are taken every 7 to 10 days according to the time of year. These are placed onto six similarly designed propagation tables, 1.2m X 6m, at approximately 20mm X 40mm spacings; however no black polythene cover is used. High pressure mist units are used in the early stages and the whole of each table is enclosed in a clear polythene sweat tent.

No heating is used for economy reasons but cuttings will still root within approximately 3 weeks in the depth of winter. In summer, when temperatures can reach 40 °C in the sweat tent, propagation can be as fast as 5 days. Provided good quality cuttings are used and the stock plants are well maintained, we have regularly achieved 100% rooting.

Initially, the reservoir for each propagation table contains only water, which is maintained via a float valve and the surplus water from the misters. Once root initiation takes place, the misters are turned off and the sweat tent is lifted. Cuttings are then supplied with nutrient solution and maintained on the propagation table until they reach the "20-leaf stage" (about 15cm). This takes from 3 to 6 weeks depending on the time of year (Figure 1). Mature cuttings are then transferred to the short-day area.

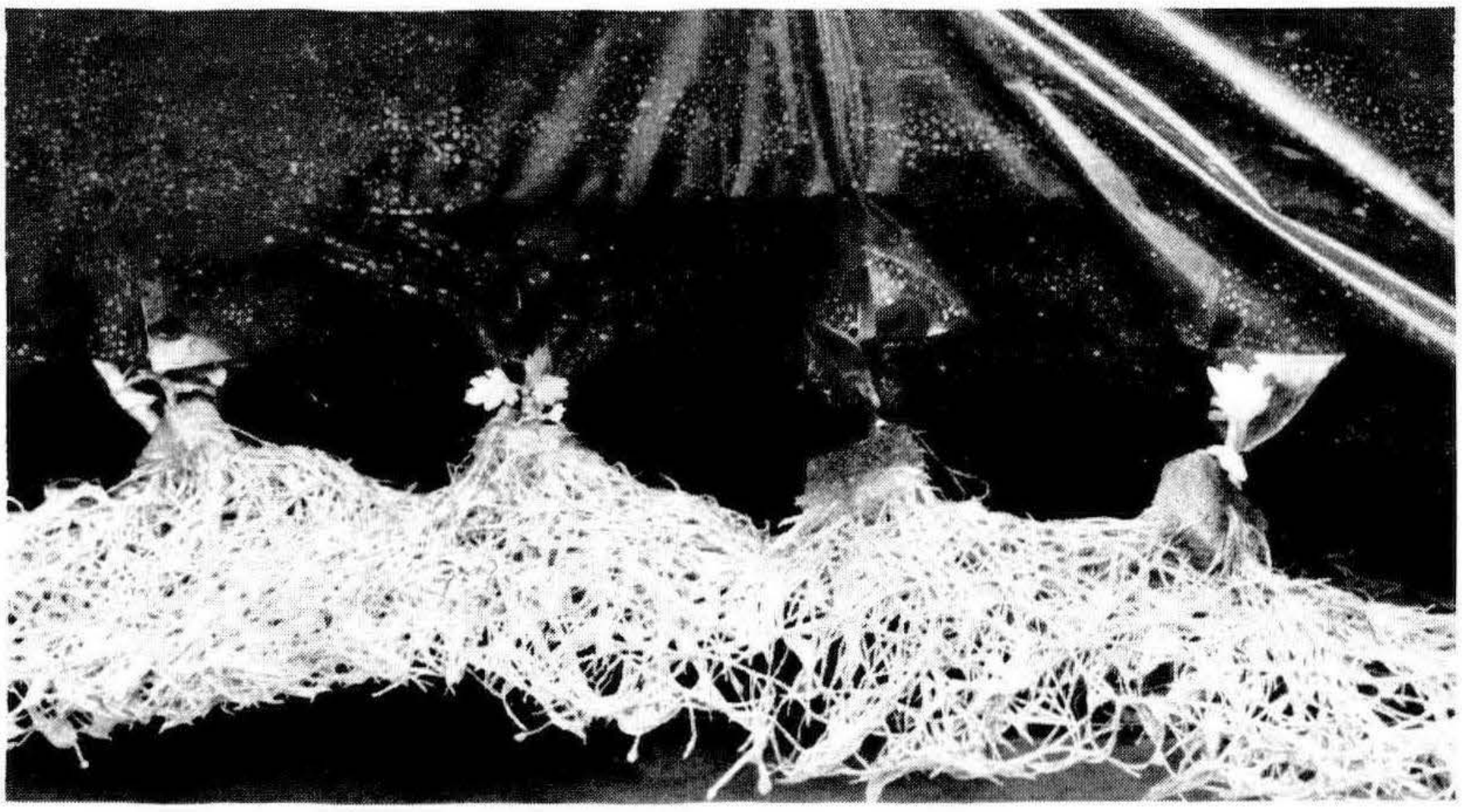

Figure 1. Root development on 9-week-old cuttings in short-day area.

The whole of the long-day area is automatically supplied with nutrient solution from the main supply tank in the pump house. This is fed into each reservoir via a float valve. The whole area is also lit at night to a level of 100 lux at crop height by means of 100 watt incandescent bulbs with reflectors. This is used as night-break

lighting for a period of 2 to 4 hours midway through the hours of darkness to maintain vegetative growth. The length of lighting depends on the time of year.

Both stock plants and cuttings are supported in Oasis Plant-in cubes. These were chosen because they were the only suitable media available when we started the nursery 8 years ago. In addition, the price was right and they were readily available as there is an Oasis factory in South Australia. The cubes are easy to use, clean, light, and above all, they do the job required of them. Of particular benefit to us in our split growing area system, the cubes remain intact when mature cuttings are moved from the propagation tables to the short-day area.

The short day area is the main production area. Mature cuttings are moved here on a weekly basis and planted onto the growing tables at spacings of 15cm X 10cm. These tables are laid out in similar fashion to the stock plant tables but they are only 1.2m X 6m in size and mobile. There are a total of 60 of these tables, each holding 400 plants. Approximately 4 to 8 tables are planted out each week depending on the time of year. In this way, a total of 5 crops per year can be achieved using 9 to 10 week response group spray chrysanthemum cultivars.

The nutrient solution is added to the main supply tank at each initial fill-up stage after flushing. The entire system holds 5000 litres at any one time. The pH is first corrected down to 6.5 by adding sulfuric acid. The required quantities of nutrients are then pre-mixed and added to the circulating water. Our solution is made up by using 80% Top Australia Hydroponic mix (See Table 1) together with 500g/1000 liters of KNO_3 (potassium nitrate) and 20g/1000 liters of iron sequestrene. Further nutrients are added each time

Table 1. Hydroponic mix used in the N.F.T. System

Nutrient element	Range in concentration mg/l (ppm)	Top hydroponic nutrient solution	Langtry nursery solution
Nitrogen (nitrate)	70-200	185	235
Nitrogen (ammonium)	0-31	27	22
Phosphorus	30-90	40	32
Potassium	200-400	208	357
Calcium	150-400	152	122
Magnesium	25-75	55	44
Sulfur	60-333	76	61
Chlorine	to 350	—	360 (in water)
Iron	0 5-5	4.1	6
Boron	0.1-1	0 2	0.15
Zinc	0 02-0 2	0 06	0.05
Copper	0.02-0.2	0.07	0.06
Manganese	0.1-1	0.7	0.56
Moybdenum	0.01-0 1	0.01	0.008

the system is topped up to a maximum of 100% of the initial start-up solution. Initially we tried to monitor and control nutrient levels using sophisticated conductivity and pH probes; however as these were unable to distinguish between "good" and "bad" salts we found it easier to do the job manually. The solution is pumped from the main supply tank into the short-day area to maintain a flow rate of 1.5 to 2 litres per min. Solution is collected into a large common gutter at the end of each group of tables (20 tables per group) and returned to the supply tank by gravity through sealed PVC pipes.

BENEFITS OF THIS N.F.T. SYSTEM

1. As the propagation of plants really begins with stock plant management, this system is ideal as stock plants are never under stress.
2. The nutrient solution can be manipulated to ensure that all plant material at its various stages of growth is at optimum nutrient level to encourage new roots, vegetation, or blooms as the case may be.
3. Stock plants can be easily replaced on a regular basis with little work.
4. Mature cuttings can be moved from the long-day area to the short-day area with minimum root shock.
5. Once blooms have been cut, the stubble can be removed, the growing tables cleaned, and new cuttings planted all within the space of a few hours.
6. Nutrient deficiencies show up quickly and can be quickly remedied.
7. Chrysanthemum blooms tend to be larger and brighter than their soil-grown counterparts and the response time is often shorter than for soil-grown chrysanthemums. This experience has been confirmed by work carried out by the Department of Horticulture, University College, Dublin (1).

DISADVANTAGES OF THE N.F.T. SYSTEM

1. Initially our cuttings were placed in slabs of cubes on the propagation tables but the roots intertwined and damage was caused when the cubes were separated prior to planting-out in the short-day area. This then set them back several weeks. Cubes are now placed in single strips with a space of 30mm between each strip to overcome this.
2. Iron deficiency was a major problem initially. We now add iron sequestrene to the solution to increase the iron content. In addition, immediately after transplanting, cuttings are foliar sprayed with a solution of iron sulfate.

3. Although the system works well, it is only as good as the operator and any failure to maintain correct horticultural practices soon shows up as poor plant growth.

FUTURE PLANS

Although our system has worked well, experience has shown us that some minor modifications will be necessary. These will include improving the water flow from the header pipes by means of directors, replacing the misting units with fogging units, and the use of dilute nutrient solution in the fogging system to prevent leaching. In addition, we will shortly be changing over from rectangular Oasis cubes to the new Oasis Wedge which we will use inverted to form a pyramid. We believe that this will reduce the build up of algae and provide improved root aeration.

LITERATURE CITED

1 Moustafa, A T. and Morgan, J.V. 1981. Root zone warming of spray chrysanthemums in hydroponics *Acta Hortic* 115 217-226

MEDIA FOR CUTTING PROPAGATION

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The range of media used in cutting propagation is almost as great as the number of propagators in existence. This might suggest to the casual observer that media type is not important to the striking of cuttings. However, nothing could be further from the truth, except in the case of some cultivars that will strike root regardless of their ill treatment.

In general, cutting media should satisfy certain physical, chemical, and biological criteria as well as those of availability, consistency of quality, and ease of use by the propagator. In addition, other factors such as climate, cultivar, and housing for cuttings will also have some influence on selection of suitable media ingredients. Cost of ingredients should be of secondary importance in structuring successful propagation media.

PHYSICAL PROPERTIES

Media should provide adequate physical support for cuttings as well as good aeration, water holding capacity, and free drainage. Media should also be reasonably light, easy to handle and easy to stick cuttings into. Ingredients should not degrade on mixing or during use.

The size and shape of media particles as well as the compaction of the medium determines the amount and size of air spaces, or pores, between particles. Large round or irregularly shaped particles give bigger air spaces than flat, plate-like and very small particles, thus allowing for greater movement of air and water through the medium. A mixture of particles ranging in size from about 1mm to 5mm is suitable, with inclusion of finer particles of peat or composted pine bark. Ingredients such as perlite, expanded plastic foam beads, pumice, vermiculite, and scoria also have air spaces inside individual particles.

The importance of air spaces is three-fold. They allow for:

1) Good aeration of developing root systems which will absorb oxygen and release carbon dioxide
2) Penetration and drainage of water that is also vital for root growth, and
3) Space for roots to grow.

Suitable media should have at least 27% available air space spread throughout its volume. Optimum amounts will vary for different cultivars with, for example, some aerial rooting plants requiring much more. Heavy misting can also increase the need for a higher percentage of air porosity. The formation of callus tissue requires air but over-development of callus can occur with excessive aeration. In general, an upper limit of about 35 to 40% is advisable.

Available air space can be measured as follows:

1. Line the propagation pot or tray with thin plastic.
2. Fill to normal depth with a measured volume of moist, but not too wet, medium.
3. Pour water into medium until water level reaches surface of medium.
4. Cut a hole in the plastic and collect and measure water draining from the medium.

This volume of water is roughly the volume available as air space in the medium in that container. The percentage air space is thus equal to:

$$\frac{\text{volume of water}}{\text{volume of medium}} \quad X100$$

Sticking of cuttings into media can be made easier by light watering and then poking holes with a dibble stick, or cutting a trench with a knife. The medium should not be firmed down too heavily as this will reduce available air space.

Water holding capacity can be increased by the addition of peat or fine composted pine bark. Peat is a strong water absorber and can be used in varying proportions with free draining ingredients to achieve a desired moisture content in the medium. Fine composted pine bark, while not considered a water absorber, has the ability to store water between its fine particles and can be used in a similar way.

Many plants in the Australian Myrtaceae family grow best with a wet medium while Proteaceae, Epacridaceae, and softer, more succulent plants on the whole grow better with a drier medium.

More peat or fine pine bark can be added in hot, dry climates and during summer, with less added in cool, moist climates, and in winter. Media under heavy misting may need to be drier, i.e. contain less peat or pine bark, than media under fogging. Similarly, media on heated beds may need to be wetter than media on unheated beds. Where drying out is a problem, wetting agents can be incorporated during mixing to enable easier re-wetting.

CHEMICAL PROPERTIES

The chemical requirements of satisfactory media are that they be low in salts, chemically stable during use, and have a pH in the range of 4 to 6 and have some cation exchange capacity. While many plants root well at higher pH levels others, such as those in the Proteaceae, Epacridaceae, and Ericaceae families perform better if the medium pH is in the range of 4 to 5. Media can be made more alkaline (pH raised) by the addition of lime, and more acid (pH lowered) by increasing the proportion of low pH ingredients, such as peat or composted pine bark.

Water quality is important. Alkaline water or water containing impurities can alter the chemical or biological status of the medium with regular watering, misting, or fogging. If necessary rain water or deionized water should be used.

BIOLOGICAL PROPERTIES

Media should be as free as possible of biologically active substances and organisms such as weed seed, spores, insects, larvae, and any pathogenic materials. Some ingredients such as sand, soils, and peat should be pasteurized or chemically treated before use. Others such as perlite, plastic foams, and rockwool are sterile and need no treatment if correctly manufactured and stored. Properly composted pine bark is self-sterilizing.

FERTILIZERS

In general, fertilizers are not readily absorbed or used by cuttings until roots starts to develop. Fertilizers incorporated in media or applied as liquid feed often help to promote growth of undesirable organisms in cutting trays and sometimes promote growth of cutting foliage in preference to roots. However, some very slow to root cultivars may be kept in better condition by the occasional application of a dilute foliar feed.

As soon as cuttings are sufficiently rooted they should be potted into a medium containing fertilizer, or maintained by liquid feed in cutting trays, until potted. Where cuttings are struck in individual pots, liquid feeding should commence as soon as roots develop, or if cultivars strike very quickly, slow-release fertilizers can be incorporated in the medium.

MEDIA INGREDIENTS

Propagators can select from an enormous range of ingredients in developing their "ideal" medium. Some of the most readily available and commonly used are discussed below:

Bark: As a renewable resource, bark is of increasing importance to propagators. The most commonly used is that of *Pinus radiata,* which is available in huge quantities in Southern Australia. It can be milled to desired particle size from dust up to several centimetres in cross section. Bark milled from younger trees, up to 16 years, is often more plate-like in particle shape, which is not ideal for water penetration and drainage, as surface particles tend to lie flat reducing water and air entry to the medium.

Composting with added nitrogen deactivates harmful toxins, increases cation exchange capacity, wettability and water holding capacity, and eliminates the nitrogen drawdown problem experienced with raw sawdusts and barks. During composting, temperatures reach levels at which harmful pathogens are destroyed.

Composted bark has a pH of 4 to 5.5, is of reproducible quality and chemically stable. It has some fungus suppressing ability particularly towards *Fusarium, Phytophthora,* and *Pythium,* and is light and easy to handle.

If used as a major constituent in propagation media, at least 80% of the particles should be in the range of 2 to 5mm. However media of this nature can hold too much water for many Australian species, and is prone to algal growth on the media surface. If the medium dries out it can be difficult to re-wet.

Finer bark of particle size 3mm and less has proved an excellent constituent when combined in the ratio of one part of bark to 3 or 4 of expanded polystyrene foam beads. This medium has been used very successfully with Australian Proteaceae and many other plants growing best with drier media. Cuttings rooted in bark develop good root systems, and rooted cuttings can be removed from the medium with minimal root damage.

Fine composted bark has the potential to partially or fully replace peat in other propagation media and propagators should experiment with its use.

Rockwool: Rockwool is available in both block and granular form. Little work has been done with granulated rockwool; however rockwool blocks have been extensively used in both conventional and hydroponic propagation. Rockwool provides a fairly wet medium with low air porosity. It is useful for moisture requiring cuttings but others tend to aerially root above the rockwool and often decay below the surface. Rockwool could be of use in fog propagation where media wetness is less than that under misting.

Expanded Polystyrene Foam Beads: This material is chemically inert and provides excellent aeration because of its spherical particle shape. Particles contain a lot of air sealed inside them

and are consequently very light. Foam has no cation exchange capacity so this must be provided by other ingredients in the mix. The ideal particle size is about 3mm. This material has formed an excellent medium when mixed with fine composted pine bark in the ratio of 3 or 4 parts of foam to one part of bark, the higher proportion of foam giving a drier medium for winter or cool climate use. Water holding capacity, drainage, and aeration are excellent in these proportions. Media consisting of foam and peat in similar proportions have not performed as well.

As polystyrene is a chloro-fluoro-carbon, its use may be limited for environmental reasons, but a similar safe substance would be of enormous use in propagation.

Sand: Sand for propagation is usually of the quartz type and often dug from river beds. Quartz sand is stable, does not release minerals, and has no cation exchange capacity. It is abrasive on mixing equipment and very heavy to handle. Propagation sand should be sharp and of particle size from about 1 to 4mm to allow good drainage and aeration. It should be free of clay, lime, salts, and organic matter. Beach sand is not suitable unless salt is thoroughly washed out. Crushed rock is frequently mixed with sharp sand and may release some nutrient minerals in small quantities. Sand should be washed and sterilized before use.

Peat is usually mixed with sand in varying proportions to improve cation exchange and give better root systems. Sand used alone often promotes brittle roots, which are easily broken when rooted cuttings are removed from the medium.

Peat: Peat used in propagation is usually the form taken from sphagnum bogs. Partially decomposed sphagnum moss has the ability to store up to about 20 times its own weight in water, depending on the age and hence state of decomposition of the moss. Younger, less decomposed peat, has less water holding capacity but has the advantage of giving better aeration.

Peat usually has a pH in the range of 3 to 4 and has a good cation exchange capacity. While peat is an excellent propagation material, it is quite variable, depending on its source and sometimes the season of digging and subsequent treatment. Some peats have high levels of salts, some are mixed with soil and some may contain weed seeds, spores, and other undesirable organisms. Recently, some have been found to be radioactive. Peat should be sterilized before use. In the proportions of one part peat to 3 or 4 parts of perlite, or 2 to 4 parts of sand, it combines to give a range of well-tested media for Australian conditions. Peat is a dwindling and very expensive resource for propagators, who should be experimenting with substitutes.

Perlite: Perlite is produced from a crushed, glass-like volcanic rock. When heated to about 1000 °C it expands rapidly, developing

a very porous structure containing both sealed and unsealed air spaces. It is very light, is chemically inert, with a pH of about 7, has no cation exchange capacity and has some aeration and water-holding capacity. Breathing masks should be used when handling dry perlite as bags often contain perlite dust. Dust should not be used in media as it tends to set as an almost impervious base.

The grade known as P500, with particle sizes from about 3 to 5mm, or a coarser grade for more aeration, should be used either alone or in conjunction with peat, where lower pH or increased water holding is required. Root systems are usually less brittle and coarse when peat is included in the medium. For most Australian plants, one part peat to about 4 or more parts of perlite is suitable.

Foam Sponges: A range of ''sponges'' is becoming available to the propagator. These are sterile, of light weight and consistent quality. They offer good aeration, drainage, and water holding capacity. However, each type needs a different watering regime, and some offer fertilizer release. Propagators should experiment with their use, particularly as media in which to grow rooted cuttings for export.

Aeroponics: Fogging systems for humidifying cutting foliage are also being used to replace media. This method has been found successful for many aerial-rooting plants and is being trialled for plants which normally root in media. Fogging offers good aeration and sufficient water and humidity. Cuttings are stuck through holes in a plastic sheet supported by a frame. Very dilute concentrations of rooting hormones can be supplied in the fog underneath the cuttings on a regular basis. Fungicides and liquid fertilizers can be similarly supplied when needed. The root systems developed appear to be good. This technique needs a lot of experimentation and may be an ideal way of rooting cuttings for export.

CONCLUSIONS

The major conventional media ingredients, as well as some fairly new and innovative ones have been discussed. The message I would like to convey is that traditional media and methods can often be improved by thoughtful propagators who are willing to experiment.

ZANTEDESCHIAS AS FLOWERING POT PLANTS

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As many of you are aware, *Zantedeschia* is a flowering plant that has been talked about extensively over the last three to five years. Coloured hybrids have been selected by talented growers, resulting in a variety of new colours now being available. New Zealand growers have been at the forefront, but these plants are a relatively new crop in Australia.

Zantedeschias have been a very small part of the flower industry for many years. The traditional colours grown were white (arum lily) and yellow. In one state in Australia the arum lily has been declared a noxious weed, as it has escaped into native marshland.

Zantedeschias can be considered in two main groups: (1) "Zantz," the summer-flowering group that has the greatest marketability, and (2) the cool-temperature, late autumn to early spring flowering group, the "Kiwi Calla."

Both these groups have very distinctive behaviour. The summer-flowering group does not do well under wet conditions, and is deciduous in winter. The winter-flowering group is evergreen and tolerates a wide range of conditions, including "wet feet."

Plants of this winter-flowering group have only a limited flower colour range of which greens and whites are the most common forms. The "big" or old arum lily was grown extensively and flourished in the older gardens around Australia. These plants produced very large flowers on stems up to one metre high. They proved to be a quality plant that was very reliable.

'SNOW WHITE'

'Snow White' is a form released in Australia under the name "Kiwi Calla"; it is a dwarf selection of this reliable plant which has proven to be exceptionally adaptable for containers. It is an evergreen and its flower initiation responds as the temperature drops. Flowering will cease when the temperature exceeds 20 °C.

'Snow White' has white flowers on stems approximately 50cm tall. They can be used as a patio plant, pool side plant, or an indoor flowering plant once the flowers are initiated.

'Snow White' produces a large number of mini tubers which can be easily removed from the main tuber. They are transferred to trays and grown on until they are ready for transplanting. The main tubers are usually harvested in late spring.

Potting-on is done during late summer, and the plant puts on sufficient growth to be ready for sale the next spring. To date no colour form other than white has been produced, but it will only be time before colour introductions will occur.

"ZANTZ" GROUP

The summer-flowering "Zantz" group have an extensive range of colours, with new colours continually being selected. Flower colour occurs in a very wide range from almost white through to very dark purple and almost black.

These plants are very marketable as they can easily be manipulated into flowering whenever one wishes. Research indicates that they are programmable.

Plants in the "Zantz" group grow from a tuber and have a natural growing cycle commencing in spring, flowering for 4 to 6 weeks in early summer, then remaining vegetative until the cooler months when the foliage dies down and the tubers become dormant over winter.

The tubers multiply in the ground, and the ratio of multiplication varies from cultivar to cultivar. This ratio varies from 1:1 to 1:6 but is about 1:3 on average. Similar to other plants grown from tubers, the size of the tuber determines its ability to flower, the size of the flowers, the number of flowers and the stem length.

Pre-planting dips. To ensure flowering and success of establishment in pots, it is highly recommended that after six weeks storage and just prior to planting that tubers are dipped in a 50 to 100 ppm solution of GA_{4+7}. This dip assists in:

a. flower initiation.
b. stimulation of the development of lateral or mini buds.
c. speeding up the establishment of the tubers and reducing their mortality rate.

Tissue culture. Using plant tissue culture technology it is possible to build up the number of tubers relatively quickly. Once mother stock has been achieved natural multiplication will become the main technique to increase numbers. However, this is not the end of the use of tissue culture in the propagation of these plants as it will be used to multiply virus-free stock and to rapidly increase popular cultivars. It will continue to play an important role in the propagation of "Zantz."

Storage of tubers. The performance of tubers after lifting depends largely on storage. Current work has shown that a minimum of six weeks storage is necessary for flower initiation to be completed, but there is a lack of agreement at what temperature this should occur.

There are two main schools of thought that have any credibility. These suggest that for short and long term storage the temperature should be either 12 °C or 20 °C. It has been shown that storage at low temperatures—below 10 °C is not desirable, as it appears to lead to flower abortion during storage.

Tuber size. What is the minimum size for tubers before satisfactory results can be achieved for pot culture?

From work we have done this year it is suggested that satisfactory results are mainly obtained from the largest tubers. Our work indicates that the grade #2 tubers and above are the best suited for flower pot work, i.e. tubers of 4 cm in diameter and above. These tubers are usually two or three years old before they are suitable.

The average number of flowers per tuber in pots is two to three but with some cultivars it can be as many as eight to ten.

Having achieved the goals of growing quality plants, they should be shipped to the retail stores when the first flowers begin to show colour. This will ensure the longest shelf life and maximise the value to the customer.

"Zantz" will deteriorate quickly if stored in hot, closed boxes. They really need to be shipped in environmentally controlled vehicles where the temperature is controlled at 12° to 15 °C.

Once in the store they should be put in a well lit place, kept moist, and kept away from bright, HOT positions. Drying out is harmful, as this may induce dormancy in plants that are actively growing. Conditions of low light tend to etiolate the plants and should be avoided.

EFFECTS OF USING THE PLANT GROWTH REGULATOR, BONZI® ON THREE *EUCALYPTUS* SPECIES AND FOUR *CHAMELAUCIUM* CULTIVARS

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In recent years, the Australian nursery industry has witnessed the introduction of the ICI-developed product, Bonzi® (a.i. = 4g/l paclobutrazol). This is a new plant growth regulator with very broad spectrum growth retardant properties. The horticultural benefits of Bonzi® to the nursery industry include:

- Reduction in vegetative growth leading to a more compact plant.
- Reduction in numbers of treatments required compared to other products.
- Longer duration of control.
- Increased and earlier flowering.
- Improved colouration, including darker green foliage and improved flower colour (Pers.comm.ICI).

The objective of this experiment was to observe the effect of five Bonzi® treatments on three *Eucalyptus* species and four *Chamelaucium* cultivars.

MATERIALS AND METHODS

The species chosen for this experiment were:
(1) *Eucalyptus maculata*
(2) *E. microcorys*
(3) *E. nicholii*
(4) *Chamelaucium uncinatum* 'Early Pink'
(5) *Chamelaucium uncinatum* 'University'
(6) *Chamelaucium uncinatum* 'Album'
(7) *C.* 'Lady Stephanie'

Table 1. Treatments applied to each of the *Eucalyptus* species and *Chamelaucium* cultivars

Treatment No	Rate of Application*	Method of Application	Number of Applications
1		Control—no treatment	
2	50ml/liter 100ml soln POT	Soil drench	1
3	100ml/liter	Foliar spray	1
4	200ml/liter	Foliar spray	1
5	100ml/liter	Foliar spray	3 (14 day intervals)
6	200ml/liter	Foliar spray	3 (14 day intervals)

*Rate refers to—mls Bonzi® /liter

The treatments were unreplicated with ten plants per treatment.

Each of the experimental plants were potted into 140mm containers on the 21st December, 1988. The medium used was sand, peat, and milled pinebark in equal portions. The nutrition was supplied by Osmocote® (9 month plus) at 5 kg./m^3, plus Uramite® at 1 kg./m^3.

Using previous experience, the Bonzi® treatments were not applied until the plants had grown to an average height similar to the height of their container, e.g., 150mm from pot surface. Thus the chemical treatments were not applied until the 23rd January, 1989 with the follow-up treatment occurring at two week intervals after this date.

For foliar spray treatments, the Bonzi® was sprayed on until the foliage was just wet. No wetting agent was used. Normal nursery production procedures were carried out and the treatments were observed periodically for their growth and flowering responses.

RESULTS AND DISCUSSION

To prevent misunderstanding with the results, I will discuss the plant species separately. For *Eucalyptus*, the main aim of using a growth retardant was to control the speed of vegetative growth. The objective of this growth control was to extend the optimum economic life of the plant in a wholesale and retail nursery situation.

For the three species used, the responses to the treatments were quite variable. *E. maculata* showed no response to the foliar sprays and only little response to the soil drench. This response showed as a slight shortening of the stem internode length for approximately six weeks.

E. microcorys showed desirable responses to the foliar spray treatments. However, the soil drench treatment appeared to cause severe malformation of new growth. Subjectively, I would rate the

treatments in the order 4, 5, 6, 3, but there was not a marked visible difference between them and all plants are still saleable four months after application.

E. nicholii displayed dramatic response to all treatments. All plants exhibited severe growth malformation with only the control treatment saleable. I would suggest trying foliar spray treatments at rates lower than those used in this experiment.

Chamelaucium, particularly the cultivars of *C.uncinatum,* is very important, especially for the cut flower and nursery industries. Geraldton wax flower, as it is commonly known, flowers heavily through late autumn to early summer. One of the production problems with container-grown Geraldton wax flower is it tends to have a very open form and a straggly habit. To overcome this the plants require regular tip pruning and shaping. The main aims for trialling Bonzi® on this species is to shorten internode length thus creating a compact looking plant, and to observe flowering habits.

For the *Chamelaucium* cultivars tested in this experiment, the results were interesting, 'Early Pink' showed little or no response to the foliar spray treatments, but displayed a desirable growth response to the soil drench treatment. 'University' exhibited similar growth responses to those of 'Early Pink;' neither appeared to be forced into early flowering by the treatments.

Chamelaucium 'Lady Stephanie' and *C.uncinatum* 'Album' showed desirable growth responses to treatments 2,4,5, and 6. However, leaf disease led to a partial or total defoliation of some plants. Both these forms are noted for their disease sensitivity in summer conditions in Queensland nurseries. Personally I would not persist with the container growing of 'Album' in Queensland and would suggest treating 'Lady Stephanie' in drier winter months as it is one of the later flowering forms.

CONCLUSIONS

Bonzi® displays potential as a growth management aid in the production of container-grown ornamentals. However, users be warned: The plants' responses to treatment with this new plant growth regulator will vary dramatically depending on species, their stage of growth, and local environmental conditions, as highlighted by this observational trial. To gain the economic benefits of using Bonzi® , the user will need to spend time determining the optimum dosage, and method and time of application to suit his own specific requirements.

PROPAGATION FROM SPORE OF SELECTED TASMANIAN FERNS AND THEIR POTENTIAL FOR CULTIVATION

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A handful of fern species and cultivars is at present well entrenched in the trade as indoor ferns in Australia. Fewer however, are so widely known or used for culture out-of-doors. It seems only logical to look at Tasmania's own "bush ferns" as possible candidates to help fill this niche. They already suit the climatic conditions but particular attention should be paid to their other requirements. Unless otherwise stated, the ferns listed in this paper require some protection from exposure to harsh sun and wind, and require good drainage with an ample moisture supply. However, all ferns listed are selected because of their relative tolerance to the above conditions.

The majority of Tasmanian native ferns can be successfully raised from spore when it is available. By following the correct technique, thousands of fern plants can be ready for potting on within 8 to 12 months.

MATERIALS AND METHODS

Strict adherence to hygiene is most important during the collection of the spores, the preparation of the sowing medium, and the actual sowing. It is preferable that all spore be collected from plants in the wild, rather than from stock plants held within the nursery. There may be too much competition from other faster growing ferns (such as some *Pteris* and *Adiantum)* within the nursery, and it is hard to prevent contamination of stock plants with foreign spore. Even in the wild, some contamination with unwanted spore may occur—mainly from "weedy" species, such as *Histiopteris incisa* and *Hypolepis* spp.

Spore can be raised on almost any sort of medium—so long as it can be kept moist and is an easy medium for pricking out young plants (i.e., fine and separable but not clumpy). Ideally, a slightly acid medium of pH 5.5 to 6.5 is best.

Whatever the medium (usually sieved peat moss) it must be sterilized before sowing. Everything else involved in the sowing technique should also be sterilized—the water used to moisten the medium, all containers, glass, hands, and even any labels used. Without this detail to hygiene, the extremely slow growing prothallli

stand little chance against very invasive fungi, mosses, and sometimes liverworts.

Spore should be sown in an area free of draughts and mature ferns capable of shedding spore, as air-borne spore can contaminate the spore trays. After sowing, the container should be sealed as soon as possible—usually with clean glass. If the medium is sufficiently moistened before sowing, it may only need additional watering once or twice before the glass is removed in about 4 to 6 months.

Spores germinate soon after sowing, but the small green prothalli are not visible to the naked eye for 2 to 3 weeks. If the spore has been sown evenly and thinly, these will all have room to develop at the same rate to maturity. Depending on the species, sexually mature prothalli may take from 12 weeks to 9 months from sowing to develop. Some ferns (e.g. *Cheilanthes sieberi)* are apogamous—the prothalli do not need to be fertilized and sporophytes (actual fern stage) arise directly from each prothallus. However, most ferns require fertilization at the gametophyte (prothallus) stage. Misting or flooding the spore trays with water once the prothalli are mature will aid in fertilization.

From the initial sowing of spore and throughout the entire development of the prothalli, good light is essential. The use of bottom heat is not of paramount importance, but it will hasten the growth of some species and make them less susceptible to fungal attacks. In the case of some other ferns, it makes them more susceptible.

Hardening-off begins when there is a good showing of fronds. The glass covering can be tilted sideways to let some air movement in, then totally removed after about 1 week. After a further 2 to 6 weeks the young ferns should be large enough and hardy enough to be pricked out.

Even with the strictest hygiene, problems do occur. *Botrytis* is common, more particularly in the latter stages of prothallus growth, and one infection is capable of wiping out thousands of plants in the space of a couple of days. Spot spraying these outbreaks as they occur with an appropriate fungicide is usually successful, first making sure that the fungicide is not phytotoxic to the prothallus.

Water moulds, and mosses may become established in propagation trays—these are slower growing and may simply be dug out of the tray as they occur.

Slugs and snails will not usually attack prothalli, but have a feast on the fronds of some fern species. One slug can cause havoc if it gets into a spore tray. Bait scattered around the perimeter of the trays, rather than in them, should prevent entry.

The larvae of sciarid fly (fungus gnats) can be one of the most frustrating problems the spore grower can encounter. The flies

favour all the conditions provided for the germination and growth of the prothalli and, with a life cycle of 2 weeks during the summer months, can be present in plague proportions. The larvae feed on the 1 or 2 roots each of the prothalli possess, and the end result is whole "forests" of young ferns being "clear felled." To date, I know of no cure for this problem, except to have the prothalli developing as strongly and vigourously as possible.

SUGGESTED FERNS FOR CULTIVATION

Adiantum aethiopicum (maidenhair fern). This fern has already been released in Australia as a house plant. It is an easier subject to grow out-of-doors in soil where its almost insatiable thirst is more easily satisfied. It has a slow spreading habit with semi-erect fronds forming a tight clumpy plant. This species of maidenhair can withstand quite a deal of exposure to sun and wind.

Asplenium flabellifolium (necklace fern). Comparatively easy to raise from spore, necklace fern is a small quick growing plant suitable for rock gardens and an excellent candidate for hanging baskets. In nature, it is always found growing amongst rocks which helps prevent its root system from drying out. "Baby" plants are produced on the tips of older fronds.

Asplenium obtusatum (sea fern, shore spleenwort). This rates as one of the hardiest of all ferns—growing just above the high tide mark around the Tasmanian coastline. Here it receives the full brunt of strong, salt-laden winds. To withstand this normally desiccating effect, it has developed very thick plastic-like fronds. Under cultivation, fronds are dark green and naturally shiny and can reach 75cm in length.

Blechnum cartilagineum (gristle fern). This is a large, robust, slow-spreading fern that withstands quite a deal of exposure to the elements. New fronds are often tinged red and can reach close to a metre in height. This is perhaps one of the best larger ground ferns for cultivation.

Blechnum nudum (fishbone water fern). Young plants form a remarkably neat tussock of fronds—similar to that of a bird's nest fern. Fronds are always a fresh, light-green colour and can grow to 75cm in height. This is one of those amazing ferns that grow equally well in boggy, badly-drained sites, or in drier, sandy soils.

Blechnum wattsii (hard-water fern). A very common fern of southeast Australia, and one that deserves to be in cultivation. Its new fronds add a blaze of colour to the otherwise predominantly green world of ferns. These arise as various shades of bronze and red, and careful selection of stock plants for spore, should ensure a good colour range. *B. wattsii* has a slow, spreading habit, and its mature fronds are dark green and may reach a metre in height.

Cheilanthes austrotenuifolia (rock fern). This is a small, quick growing fern with fresh, green parsley-like fronds. In its natural habitat it grows in full sun or light shade in dry rocky ground. For this reason it adapts easily to cultivation and looks best planted amongst large slabs of rock that also give some protection against drying out. Being apogamous, a closely allied species *(C. sieberi)* is much easier to raise from spore, but is not quite so attractive as *C. austrotenuifolia.*

Culcita dubia (rainbow fern). Similar to the common bracken fern in its large scale spreading habit, this is an ideal fern for landscaping. Its fronds are fine and lacey, and in full sun take on an eye-catching yellowish-green appearance. Rainbow fern will grow well in sun or shade and will withstand periods of dryness, but has to have excellent drainage.

Cyathea australis (rough tree fern). Along with a few other species of tree ferns, this fern is already used in landscaping in southern Australia. Of all the approximately 800 species of *Cyathea,* it is one of the slowest growing, but is an excellent cool climate species for southern Australia. In contrast with the other cool climate favourite *(Dicksonia antarctica),* its trunk cannot be sawn off and transplanted, but it withstands more exposure to sun and wind, and it has a more attractive crown of fronds.

Dicksonia antarctica (man fern, soft tree fern). This fern is perhaps the most widely planted outdoor fern in southern Australia. However, all plants are harvested as 15 to 50 year old trunks from the wild. This resource will not last forever, and it may be time now to introduce young spore-grown plants to the public and nursery industry. This is the main reason for the inclusion of this plant here; besides, man fern makes a most attractive tub plant when young.

Pellaea falcata (sickle fern). Because of its very narrow glossy, dark green fronds, this fern is distinctive from other ferns listed. Its fronds stand upright from a short creeping rhizome, and a mature plant may cover a square metre in area. Sickle fern can withstand dry periods and makes a good contrast plant with other small shrubs or rockery plants.

Phymatosorus diversifolius (kangaroo fern). In nature, this fern occurs as an epiphyte on trees and rocks, but in cultivation adapts well to reasonably drained sites in the ground. As is implied by the specific name, fronds are variable in shape, from simple to multi-lobed. Its rhizome is thick and long creeping, making it a useful groundcover as well as hanging basket plant.

Polystichum proliferum (mother shield fern). A very common fern in Tasmania, this plant occurs from the salt spray zone on the coast all the way to sub-alpine areas. It proves just as hardy under

cultivation. It is a neatly-shaped, robust fern that is large enough to be planted amongst shrubs.

Pteris tremula (tender brake). This fern is already known and used within the nursery trade in Australia as an indoor plant. It is fast growing and easy to raise from spore but, as a pot plant, is often lanky and just grows too quickly for its own good. It is an easy fern to grow in the garden where it can withstand a good deal of exposure, but it does not do well in complete shade.

Todea barbara (king fern). Often classed as a tree fern, this is a large robust fern with a short, very thick trunk. It is slow growing but well worth the wait with its large glossy light green fronds. It needs ample moisture and does best in situations where it receives good light. King fern comes from a very ancient family of ferns; its spores are green and quickly lose their viability.

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BREEDING NEW CARNATION CULTIVARS

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Carnations are dichogamous, i.e. the male and female flower parts are present in the same flower, but they mature at different times, thus preventing self-pollination.

When the anthers ripen first it is known as protandry, and when the stigma is receptive first, it is known as protogyny. The carnation is protandrous as the pollen is mature when the flower opens.

When breeding anything, whether it is plant or animal it is generally accepted that the final result will be as in nature, that is the strongest will be more dominant and eventually the most successful. So the first lesson comes from nature.

Selection for breeding. When selecting carnations for breeding, pick strong and vigorous plants. Usually the pollen-bearing male plants contribute more to the physical make up than the female plants, but they both contribute to the progeny.

The things to look at in carnation parent stock are:

a. resistance to disease, particularly rust.
b. a strong and lengthy stem.
c. a flower to look you in the face.
d. bluish type greenery—this is generally healthier.
e. quality of plants.
f. flowers when YOU want it, e.g., I breed for winter flowering.

Cross-pollination. Once the parents have been selected it is essential to prevent interference from insects, such as bees. A tent or greenhouse is necessary for pollination, but I would recommend a glasshouse or polyhouse as it also aids in the ripening of the pollen. I have tried using pot covers and outside tents with little success compared to the process inside the glasshouse. Wind is a big factor when working outside as it blows the pollen around.

Inside the glasshouse the cross-pollination can be carried out in still air without fear of contamination.

I recommend that the stripping of most of the petals from the flowers be done, as this ensures that the ovaries area does not hold any excess moisture, as well as making the styles more accessible.

Collection of the pollen is best done in early morning from the just-opened flowers. The pollen is taken from the flowers by the fingers,

the last few days of the flower. Late morning or early afternoon are the best times to carry out the cross-pollination process.

A fine camel-hair brush is used to apply the pollen to the stigmas of the old blooms. The stigmas are located on the upper most ridge of the styles; generally there are two styles. Holding the stigmas uppermost, the pollen is applied to the very end which is curled. It is best to use one hand to straighten out both styles together so the pollen is applied evenly to both stigmas. More than two styles to a bloom generally does not give good seed.

After fertilisation, it helps to open out the calyx to allow the pod to ripen and to ensure it dries out particularly around its base, as any fungal infection in this area can damage all the seed in the pod.

Harvesting. The pods can be harvested when the top of the pod starts to split. The pod is allowed to dry out for a few weeks then the black, viable seeds are collected. Seeds will keep for six months or more in dry storage.

Seed germination. Seeds are sown into trays using a slightly acid, sterile, sandy U.C. mix. The mix is well watered before sowing, then, after sowing, the seed is covered with a light sprinkling of the same mix. The trays are then left for four or five days without any water. They are then placed under mist until the seed has germinated and the seedlings are growing well. They are then put under light mist before hardening-off a month later. The seedlings are ready for planting out after about two months.

Planting out. The seedlings are planted into the open ground about 2 in. apart, in rows about 18 in. apart. Unwanted plants are removed with a 2-in. hoe.

The testing process. Out of 5000 seedlings we get about 100 we consider worth testing further. Three replicates of these 100 selections are planted and grown for another year. Out of that 100 we may get about 12 that we will test the following year. From these 12 we may select three or four for final testing over the next three years. These are now tested in the glasshouse for duration of flowering, disease resistance, general appearance, etc.

The average successful carnation cultivar occurs about one in 30,000 seedlings, so patience is indeed a virtue for the successful breeder. The 'Granny Smith' apple would have taken around a million seedlings to produce, using this process, and the 'Sim' carnation even more.

The future. New cultivars will always be required, and genetic engineering may be used in this process. Tissue culture may be used to propagate huge numbers of a cultivar, but plant breeding to change the genetic make-up is essential to produce new ones.

"If I believed that I alone made this wonderful fruit, then, indeed, it would be for nought."

PRESIDENT BRUCE MACDONALD: It gives me great pleasure to welcome you to the Western Region's 30th annual meeting. I know that many of you have come a long way to be with us. We have people here from the Eastern Region, the Southern Region, G.B. & I., New Zealand, and Australia. So we have here a true representation of the IPPS.

I would like to introduce you to a special visitor from the G.B. & I. Region, Jonathan Allen. He was the first recipient of their newly-formed Richard Martyr Award. The first prize was a complimentary visit to the IPPS Western Region meeting. Jonathan, would you like to stand? Thank you.

The theme of our meeting this year is very appropriate—''Getting to the Root of the Problem.'' You will see that the program is full of all sorts of topics, perennials, ferns, propagation facilities, tissue culture, propagation of rare and endangered plants, etc.

We must thank your Vice-President here, Joe Solomone, and his committee for assembling such an interesting program. Joe, the Program is yours and your Moderators.

FERNS AND THEIR DIFFERENCES WITHIN THE PLANT KINGDOM

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There are different ways of propagating ferns. Some are multiplied by division or by ''pups,'' others by tissue culture or by spores.

We propagate using spores, not by seeds, but by spores. Here lies one of the most fascinating differences between flowering plants and ferns. A single seed is a composite of more cells, a momentarily dormant embryo, in many cases already a tiny, tiny plant, visible only under the microscope.

A spore is a single cell, not an embryo, just a single cell, which by itself is not able to develop into a plant, not even into an embryo. A group of many spores, with the help of one another, will go through a pro-embryo stage—the so-called prothallium. If collected successfully, spores are put down on a medium. We use straight peat moss. In a few days or weeks the whole surface will turn into a wondrous, beautiful, green moss-like carpet. This is the prothallia, which is the gametophyte stage in the alternation of generations.

One of my passions is to learn to collect spores. Spores are found, in most cases, on the underside of a frond (the leaf). They can be many sizes, different shapes, and even colors, but are always covered by capsules. In some cases, it has taken me years to collect spores successfully. I have watched spores developing for almost a year, during which I have collected at different times, only to find that it wasn't the right time yet. Then suddenly, I've lost the remaining spore on that plant to nature. So, spores are very valuable to me. It is a never ending curiosity, and sometimes an enormous sense of satisfaction to have discovered something new. No fern is alike. Each one has its own cycle.

Once collected and put on peat, the spores develop into prothallia. After further weeks, one can clearly recognize with the help of a microscope, a colony of flat kidney or heart-shaped leaves with tiny, hairlike roots, which keep them anchored to the soil surface. One can also see that the prothallia have both male and female organs, producing sperm and eggs, which will find a way to join with the help of water (not a lot of water, but the proper amount).

All of this does not happen overnight. It takes weeks and even months of waiting for a fern propagator. This is a time of patience, curiosity, and surprises. There are surprises of new discoveries, of losses, and of successes. Success is when one sees the first tiny frond, which later turns into a fully developed plant with roots, stems, and fronds with spores. In all these weeks and months, one tries to give proper conditions of medium, pH, water, fungicides, and even insecticides.

Another fascination of mine is the wealth of all the different sizes, shapes, and forms of fern fronds. A wonderful observation was written by Thoreau, "Nature made ferns for pure leaves, to show what she could do in that line." No matter how many the variations of design, the one constant characteristic is the uncoiling of each individual frond. I always enjoy observing the unfolding of a frond to an often symmetrical design. It is no surprise to me, that ferns have been mentioned in mythologies, in poems, and in literature as mystical and wondrous. I would like to mention Thoreau again, who said:

"It is the proudest of all plants in the structure of their leaves, it is Nature's lacework."

PROPAGATION: OLD, NEW, UNUSUAL: WITHOUT HORMONES, HEAT, OR MIST

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Our nursery was started by my father in 1937 as I entered high school. We grew bedding plants in wood flats using a sandy loam, leaf mold, and manure as a soil mix. After World War II, I became a partner with my father and a small general nursery evolved. In addition to annuals and perennials we grew ground covers and many of the common shrubs. Clay pots were still in general use for 6 in. and smaller material. Many trees were still field-grown and dug balled and burlapped (B & B) for sales to nurseries. This was about the time that nurseries began using discarded gallon cans from the canneries in the area as containers for nursery plants. Also about this time redwood sawdust came into general use for soil mixes. We were one of the first in the area to grow an assortment of perennial herbs in 3 in. clay pots which were sold with 5 or 6 cultivars to a flat.

In the late 1960's I became sole owner and in 1970 we moved our house and nursery 1½ miles to our present location on one acre. Here we specialize in perennials, rock garden plants, bonsai material, herbs, and other unusual items not seen in most garden centers. My wife does all of the bookkeeping. Our daughter works for us three days a week making most of the cuttings, potting-up, and much of the watering. We generally have a high school student after school to weed and clean up.

We have a 15 x 30 ft. glass propagation house, a 20 x 40 ft. plastic house, and saran cover for the small pot material and shade plants. Most plants are sold in 2, 3, and 4 in. pots and in #1 containers. The #1's are in the open and watered by Rainbird sprinklers on a timer. We also have overhead sprinklers on the benches of small pots that are hand operated. Our basic soil mix is 60% redwood sawdust, 20% sand, and 20% loam, mixed in a small concrete mixer. All containers 4 in. and up are top-dressed with Osmocote and the small pots liquid fed (30-10-10) during the year.

The basic rooting mix for our cuttings is ⅔ perlite and ⅓ sand by volume with the addition of peat for a few items. Most cuttings are stuck in wood flats 13 x 17 x 2½ in. that are placed on wooden benches in the glasshouse that has a Resnor heater to maintain a 50°F night temperature during the winter. The heater is not used from May to October. All cuttings and seedlings are hand-watered and generally kept on the dry side. Also we usually transplant as soon as the cutting is rooted. Since we grow many different kinds

of plants (Table 1) but in relatively few numbers we may have five or six items in one cutting flat.

In the seedling flats there may be as many as 20 kinds of seeds. If germination is going to take extra time we sow seeds in 5 in. pots. Most of our cuttings are softwood so can be taken any time of the year that the growth is at the right stage.

We have a small demonstration garden as well as the #1's that can be used for cutting. All of our softwood cuttings are stuck without hormone treatment, although we do use various rooting compounds for some of those plants we grow that are difficult to root, such as *Actinidia, Clematis*, conifers, *Daphne, Gypsophylla, Hydrangea*, and junipers. We seldom use any fungicides or insecticides.

Table 1. Some plants for which we use no heat, mist, or hormones in rooting cuttings

Plant	Family	Origin
* *Aquilegia formosa* 'Nana'	Ranunculaceae	n.w.N.America
* *Asimina triloba*	Annonaceae	U.S.A
Bergenia 'Rosy Red'		temp Asia
Bergenia,white form	Saxifragaceae	temp Asia
Calocephalus brownii	Compositae	s Australia
Campanula 'Dickson's Gold'	Campanulaceae	
Campanula isophylla	Campanulaceae	Italy
Campanula isophylla 'Mavi'	Campanulaceae	Italy
Chemaemelum nobile 'Plenum'		Compositaew Europe
Clianthus formosus	Leguminosae	Australia
Cosmos atrosanguineus	Compositae	Mexico
Dymondia margaretae	Compositae	South Africa
Fragaria vesca 'Semperflorens'	Rosaceae	Eurasia
Geranium maderense	Geraniaceae	Madeira
Helichrysum petiolatum	Compositae	South Africa
Helichrysum petiolatum 'Limelight'	Compositae	South Africa
* *Helleborous lividus* subsp. *corsicus*	Ranunculaceae	Corsica & Sardinia
* *Lapageria rosea*	Liliaceae	Chile
* *Lapageria rosea* 'White Cloud'	Liliaceae	Chile
Origanum 'Kent Beauty'	Labiatae	
Origanum libanoticum	Labiatae	Lebanon
Origanum rotundifolium	Labiatae	Mediterranean
Pelargonium tricolor	Geraniaceae	South Africa
Phlox paniculata 'Norah Leigh'	Polemoniaceae	U S.A.
Rehmannia elata	Scrophulariaceae	China
Rosmarinus officinalis 'Tuscan Blue'	Labiatae	Mediterranean
Russelia equisetiformis	Scrophulariaceae	Mexico
Sedum sieboldii	Crassulaceae	Japan
Senecio confusus	Compositae	Mexico
Thymus broussonetii	Labiatae	Morocco
Thymus membranaceus	Labiatae	Spain
Zauschneria 'Bowman Hybrid'	Onagraceae	w. U.S.A.

* These are seed-grown.

ALBERT NEWCOMB: I would like to ask Fritz Bieth how he measures ethylene sensitivity of his orchids.

FRITZ BIETH: Many plants are intolerant of ethylene, which will greatly shorten their life. For instance, ethylene-intolerant flowers, when exposed to 10 ppm ethylene for 12 hours will not be marketable after about 3 days. Ethylene-tolerant plants will be marketable for 30 days after the same exposure.

VOICE: This is for Edsal Wood. We use Wood's Rooting Compound on every cutting we make. Is there any new information on the EPA registration of IBA we are hearing so much about now?

EDSAL WOOD: Governmentese. I cannot understand what all the fuss in about. IBA has been in use for about 50 years, with no problems. It is going through an EPA registration, but there is nothing definite to report on just now.

THE LATEST IN GREENHOUSE CONSTRUCTION AND ENVIRONMENTAL CONTROLS

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Nine out of ten greenhouse construction projects that I have seen in the last 5 years in California have serious problems, and it is from a lack of proper planning. To give you an instance that happened about 2 years ago, a very well-respected foliage grower decided he wanted to build a 200 x 600 ft. addition to his greenhouse, so he called up three greenhouse manufacturers, saying he wanted a 200 x 600 greenhouse addition, with a glass covering, with 50% shade, (which he had used in his original house), what is your bid, and how soon can you build it? A week later he let the contract out, the following day he is all over the contractor to get it completed in a hurry. This sounds like a familiar scenario. After completion he puts his foliage plants in it. Three weeks later they all burn up. Obviously it seems to be fault of the greenhouse construction company. The glass was wrong. The shade wasn't right. What happened was his old 18 year old house had an acrylic covering, which had darkened over the years. If he had paid $39.95 for a light meter to compare the light inside and outside his old house, he would have found that he needed 85% shade. A simple thing, but an expensive problem, arose from a lack of planning.

How many of you know what the "kiss" principle is? A few. This was drilled into me by my dad. It is, "keep it simple, son." The simpler you can make things the better they are going to work for you. Yes, this is "high tech" today, but high tech does not have to be complex.

Secondly, you have the "4P" theorem—"prior planning precipitates performance," or the corollary, "poor planning precipitates problems." We have all been through that. Keep these two things in mind, please. If you are going to expand, or have the opportunity to build—it may be a once in a lifetime situation. You want to do it right. You want it to be profitable, and you want it to work the way it should. I guarantee you it will not work without proper planning.

The steps that we have followed are:

Firstly, know your needs and your wants. Differentiate between what you need (must have) and what you want (would like to have). What is important to you? For us, working with roses, it is light, ventilation, nutrition, temperature, and humidity. You have to

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[1]Projects Manager

separate things out and prioritize them. If you can first meet your needs, then you can consider your wants.

Secondly, after you have clearly defined your needs, figure out how far you can compromise those needs, if you have to. After you find your ideal, you still may not be able to reach it entirely, so know what your limits of compromise are. Question everything.

We moved from Pleasanton to Watsonville, California; the Watsonville-Salinas area has 40% of the U.S. cut flower rose production. It is very concentrated. So you would assume that everything is going to be great, no problems, for rose cut flowers. Such is not the case. Question everything that you have done in your own operation. Know why you are doing what you do.

Travel—get out and travel. Go to Holland, a lot of the new innovative ideas and equipment are coming out of Holland. They are ahead of us—new ideas are coming from there. See what is going on elsewhere, then pick and choose.

Use some common sense when you design your ideal greenhouse. There are a lot of manufacturers out there and they may tell you that you have your choice of greenhouse A, B, C, or D. They may try to sell you that way, but make them come up with a design for what you need and what you want in a greenhouse.

The same goes for the equipment you are going to put into the greenhouse. There will be times you are going to be better off buying the component parts of the equipment and putting it together yourself. Just remember, you are paying for this equipment. You should be able to get what you want.

Set up a master plan for your entire project. Sometimes this is difficult. A long-term planning horizon for us just now is 5 years. This is due to the international situation. A substantial number of roses are now being imported into the U.S. Ten years ago, it was 2% of the market—today 45% of the blooms are coming in from off-shore, from Mexico and from South America. But when we put in our new greenhouse we had a master plan for our entire 52 acres. We are now only using just 7 of those 52. But by doing that we could plan for our underground pipes for the remainder of the acreage without having pipes running under any greenhouses in our phase two or three.

Another thing, don't piece-meal what you are going to do today. Don't start a greenhouse with manufacturer X, then half-way through construction decide to add five more pieces of equipment. Plan the entire phase before you start construction. Again, limit your compromises. Your needs are out there. Just keep looking until you find them.

Try to have one piece of equipment do multiple tasks. An example with us is our mist system. We use it for mist but it can also spray pesticides early in the morning before people come to work. We also

use the same tank and pump to spray down the isles with hoses. We have a $7000 savings by using the same equipment for two operations. So try to get multiple uses out of the same equipment.

Do not be afraid to act as your own general contractor. There are some things you will not consider doing, such as building and putting up the greenhouse itself—but there are several things you can do yourself, probably better and cheaper than a lot of the contractors out there. But again, it takes planning, research, and perseverance to do it. One thing that really bit us was the time-frame. Give yourself plenty of time. We thought we would be done by the middle of July, but now we see it is going to be the end of October. Figure out your time frame, then add 50% to it to be safe.

One other part of this planning process—if you are going to move to a different region, as opposed to expanding in your present location, even though there are many other greenhouses in your new location, check out the climate, the soil, and water. But also think about transportation, the markets, customer accessibility—if this is important to you. Think about local regulations, codes, the local master plan, zoning, and neighbors.

What was important to Devor Nurseries and our rose production? First, light, ventilation, nutrition, temperature and humidity, soil and water, customer accessibility, all wrapped around economics of operation. Now, with all the other greenhouses in the Watsonville area, we find that there are numerous microclimates. There are greenhouses that literally hang onto the cliffs near the ocean, while others are up against the mountains; and within a 5-mile radius, it is not uncommon to have a 30° to 40°F temperature differential. Out on the Pajaro plan there is salt water intrusion. We are told by chemists analyzing our well water, that must add several elements for plant nutrition as our water alone is too pure for plant growth.

How do you get all this information? Start with data from any nearby U.S. Weather Service installation, look at other crops growing around you, look at USDA soil maps, get a back-hoe out and go down 10 or 12 ft. all over the parcel and see what you have underground. Take soil samples to your lab for analyses for minerals and pathogens, such as phytophthora and oak root fungus. Check wells on neighbors' property for amounts of water they can pump and for minerals in the water. Don't blow your whole enterprise for a $200 lab bill.

For the greenhouse structure itself, we wanted something that is wide and high. It is important to have a very stable, constant environment for roses. So our greenhouses are 276 ft. long and 50 ft. wide. The high peak on the roof gives us a constant environment down where the plants are. Changes occur slowly, and above the plant canopy.

Make sure your structure is strong. I guarantee you will add three times the iron on the structure that you thought you would need. So make sure your walls and your posts are ample. Doors, make sure you have enough and they are big. Our main doors will admit a one-ton truck. Aisles should be wide—yes, you will lose production space but if you are going to use carts crossing in the aisles, they must have room to do it.

The greenhouse covering, or "skin" is important. We put a lot of thought into it. We selected the Solatex, low iron, safety glass. Solatex glass was developed for solar hot water heaters you see on the roofs of houses. The advantage is that it lets in 6% more light at noon and 12% late or early in the day at a low sun angle, as compared to ordinary glass. And light is our No. 1 factor in growing roses. The low iron content gives a glass that diffuses light so we don't have strong shadows.

The other decision we made was to use safety glass, chiefly as a safeguard against earthquake tremors, that could cause ordinary glass to come down in sheets, injuring our workers. Safety glass just breaks into fine particles.

Our vent system is somewhat unique among rose growers. Mostly, large ranges of greenhouses will have houses side by side with top vents only. You really need side vents also, set up high to allow replacement air for hot air going out the top vents, giving a chimney effect.

We use shade curtains. We ordered a special curtain, using strips of reflective material, then an open strip. This allows hot air to escape through the open strips. When the shade curtains are closed it is often cooler in the greenhouse than outside.

To heat the greenhouse we are using a hot water system. The boilers work at 14 p.s.i. We selected it to give uniform heat throughout the greenhouse, as compared to steam heat. There are economic benefits, too--a 10% less installation cost and 10% less operating costs. We are using 3-way mixing valves, which gives us greater heating efficiency too.

Our mist system has intermediate size nozzles, so we can cool the plant leaf itself—not the air, yet we want to be able to spray with it from time to time, at 4:00 in the morning, set off by a computer. The advantage to this is that your crew does not have to be out of the greenhouse while spraying is going on, a labor savings practice.

Our fertilizer injectors—this is one of the examples of the "kiss" principle (keep it simple, son)—we looked at injector systems that cost from $4100 to $41,000 that basically do the same thing. We selected the first because it is a simple, positive, water-driven meter that has an injector stroke every time 4 gallons goes by the meter. The meter will work at a flow rate of 4 to 350 gallons per minute. It will be connected to the computer which will tell it when to come

on and for how long to be on. It has a high level EC (electrical conductivity) cut-out. We don't want the EC to climb up and burn the plants. The computer will also record the EC so we will know if the EC of the nutrient solution is climbing.

We have a drain system under each bed. Roses need to be leached occasionally. The solution is recirculated onto the landscape outside. We hope we never have a spill but if we do we want to be able to contain it.

In putting this altogether, it is going to be a computer-driven environment. Things we looked at in selecting a computer are: capability, flexibility, expandability, service to be expected, and the stability of the vendor. There have been many environmental computer companies lately that have not been able to stay in the market, because all this is very competitive and the technology is changing rapidly. Another thing to look at is scientific curiosity. The company we selected—Hoppman—has a sales rep. who excels in this.

Our packing shed is attached to the greenhouse so the product does not go outside. Ours is a rose hybridizing environment, so no plant material is ever exposed to unfavorable conditions. Our packing shed is designed for accessibility, 75 x 150 ft. but has seven outside doors.

Sanitation is very important. All concrete floors should be hosed down daily. Think about sanitation constantly.

Remember when you build or expand, you are doing it for yourself. Do it for economics and do it based on your needs, and do it so you can say, "this is my one opportunity and I have done it right."

PRACTICAL ASPECTS OF HIGH PRESSURE FOG SYSTEMS

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Abstract: It is the opinion of the author that one should decide how the fog system is to be used, whether for cooling or for the production of high humidity required for plant propagation. Furthermore, the greenhouse manager must realize that the system will require extensive maintenance, as well as having periods of downtime.

Mist propagation increases rooting percentages in cuttings of woody ornamentals. The reason for this is that by maintaining a humid atmosphere around a leaf, it will prevent the leaf from desiccating, thereby allowing the stomates to remain open, providing gaseous exchange, and subsequently, photosynthesis and growth. Intermittent mist is a tool for producing a water-saturated atmosphere, but it does have some disadvantages. The droplets produced by the mist system do not remain suspended in the atmosphere for a long period of time, thus increasing the transpirational loss from the plant. Furthermore, it has been noted by Good and Tukey (1) that large droplets are responsible for the foliar leaching of nutrients from the leaf, and subsequent lower rooting percentages.

With the development of fog systems, it has become possible to produce water droplets that are about 10 microns (10 μ) in diameter; these droplets are capable of remaining suspended in the atmosphere for long periods of time. Subsequently, the transpiration loss of the plant will be reduced to practically zero, and the foliage of the cutting will not be water saturated, thus reducing foliar leaching.

With some kinds of fog systems, one is working with high pressures (900 to 1,000 psi) and nozzles with small orifices. These two factors produce a system that is maintenance-intensive, and prone to have mechanical and electrical failures.

Perhaps, the most important component of a fog system is the water filtration. The nozzles that we have used have orifices that are very small (0.006 inch or 150 μ) in diameter, and are expensive (about $10.00 each). To prevent the orifices from becoming plugged, particulate matter suspended in the water must be removed. Different water filtrations systems have been designed; such designs include sand-media type filters, low-pressure cartridge filters, high pressure cartridge filters, and combinations of all the above. If materials such as disinfectants, fungicides, or fertilizers are injected into the fog system, they should be injected to the

upstream side of the filters to filter out any inert carrier ingredients or precipitates that form when salts in the water and injected chemicals react. Water quality is a factor which must be considered with some fog systems. The filtration system will filter out suspended solids but not the dissolved salts. In areas with high bicarbonates, carbonates, and chlorides, the nozzles will have to be cleaned periodically to eliminate the salt precipitates that form on the fog nozzles.

One chemical that we have been injecting into our system is Agribrom (1-bromo-3 chloro-5, 5 dimethyl—2,4-1 imidazolidinedone) which is a biocide that is active against algae, fungi, bacteria, viruses, and other microorganisms. Neither Agribrom, nor any of its residuals or breakdown products, are phytotoxic to plant materials. The recommended concentration of Agribrom used in a continuous injection program should be 0.25 ppm and, at this level, we have observed a decrease in algae production in the mist houses. By injecting Agribrom into the fog system, the routine maintenance of cleaning the benches and floors has been lessened.

To produce the high pressures (900 to 1,000 psi) required by the fog nozzles, an elaborate pump system is required. The pumps used are low gallonage (5 gpm) but produce high pressures, (1,000 psi). Such pumps require a high torque to produce high pressures. One consideration that must be taken into account is the source of electrical power available at the installation site, whether it be single-phase or three-phase. The high power requirement of the pumps make the use of the single phase motor impractical. If the only power source available is single phase, be ready to replace capacitors and centrifugal switches within the motor. With the constant on-off demand of the fog system, capacitors begin to leak and contacts on the centrifugal switch become burnt. To prevent any damage to the pump if the water supply is shut-off, there should be a low pressure cut-off switch to prevent the pump running dry when the water supply is shut down. Inherent with any motor-pump combination, vibration is a problem; rigid tubing under such conditions often breaks at fittings. To alleviate such problems, flexible tubing should be used on the low pressure side of the pump and hydraulic hose on the high pressure side.

To control the pump system, some form of controller is required; timers and humidistats are being used at this time. The normal timing circuit consists of an interval timer in series with a 24-hour time clock. This system allows the grower to select an "on" period during the day and/or night that satisfies the mist requirement of the plant material. Mechanical humidistats operate by the expansion and contraction of a fiber that is water sensitive; this motion of expansion and contraction is attached to a micro-

switch which opens and closes the circuit. It is my opinion that the reaction time of mechanical humidistats is too slow to react to the changes of the relative humidity within the greenhouse. Perhaps with the new generation of electronic environmental sensors, an electronic humidistat can be produced that has a rapid response time to changes in humidity.

At Moennig's Nursery, we have installed a high pressure fog system in our quonset-style mist houses (30 ft. by 70 ft.). To provide for more flexibility, two separate systems have been installed in each house; one system for cooling and one system for fog propagation. The fog propagation lines are installed overhead with each fog nozzle covering 50 sq. ft. of bench space, in a manner similar to the overhead mist system. The cooling system is designed as such: on one end wall (the intake side), two fog lines are run parallel to the ground behind the polywall (polyethylene connection tubing) which inflates and deflates upon temperature change. The opposite wall has a 48 in. exhaust fan that draws the fog through the house, cooling the air. Presently, we are using one controller to run all the fog houses. However, we are in the process of controlling each house and each system independently. Electric solenoid valves, capable of working under high pressures are available and are to be installed. Each house will then be controlled by a solid-state controller which has the capability for ''staging'' cool-hour times, warm-hour times, and transitional times. By implementing this system, we will have the flexibility of using each house for different purposes.

In conclusion, the fog system will become a more popular propagation tool in time. As with any new principle, there are engineering problems that must be overcome. The advantages of the fog system do outweigh the disadvantages.

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VOICE: Question for Bob Mazalewski. Does your rooting medium dry out more under fog than under mist and is your light intensity reduced under fog as compared to rust?

BOB MAZALEWSKI: Yes, the media does dry out faster under fog. And we do have a light intensity drop with a water-saturated atmosphere, as with fog.

BEV GREENWELL: At what humidity level are you setting your humidistat for in the fog on hot, sunny days?

BOB MAZALEWSKI: We are setting for 100%.

DON HERZOG: I would like to say that often we can get useful equipment from other industries. I have written to NASA about time clocks, etc. and they have responded with some useful information from their experiences, concerning environmental controlling devices.

MIKE EVANS: A few years ago a paper was presented by Phil Barker (Franklin, A.L. and P.A. Barker, 1985. An intermittent mist system with pressure boosted by continuous pumping. *Proc. Inter. Plant Prop. Soc.* 35:222-227) on high pressure mist or fog in which the pumps were allowed to run continuously. Two valves operated simultaneously to allow high pressure to enter the system. This would prevent damage to the motors from constantly starting and stopping. I am wondering if anyone has followed through on this, or is it still in the experimental stage?

BOB MAZALEWSKI: Any time you have motors starting and stopping continuously you are going to have burn-out problems. Continuously running motors might prove to be a very efficient system.

FRITZ BIETH: I am wondering if you have checked at all with the ultrasonic system of generating fog rather than the high pressure fog. In the ultrasonic system there is no pump and no high pressure lines, no motors, and it has large orifices, so there is no clogging.

BOB MAZALEWSKI: No. I haven't but I would like to talk to you about it.

FRITZ BIETH: This was described briefly by Natalie Peate from Australia in our meeting in Sacramento in 1986 (Peate, N.F. 1986. Plant Propagation in Australia. *Proc. Inter. Plant Prop. Soc.* 36:52-55).

(ED NOTE. See also Hartmann, H.T., D.E. Kester, and F.T. Davies, 1989. Plant Propagation: Principles and Practices, 5th ed., p. 294. Prentice-Hall, Englewood Cliffs, N.J. 07632).

TISSUE CULTURE PROPAGATION OF FRENCH HYBRID LILACS

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Lilacs have been propagated and grown by nurserymen in the United States and other countries for several centuries. They are truly an old fashioned shrub noted in particular for their spring blossom color and fragrance. Many lilacs in the nursery trade have been labeled as "French hybrids." This is somewhat a misnomer. Although several hundred excellent lilacs were hybridized and introduced by the Lemoine Nursery of Nancy, France, other fine lilacs have been developed by several Frenchmen, other Europeans, and other sources—including individuals in the United States.

Lilacs may be propagated several different ways. The methods used include: 1. seed (2); 2. layering (simple, stool) (2); 3. root suckers (2, 11); 4. softwood cuttings (2, 3, 4, 11); 5. Grafting and budding (2, 11); and 6. tissue culture.

There are several reports on tissue culture of lilacs (1,2,5,6,8,10). At Briggs Nursery, we have been micropropagating *Syringa* since 1982. We have propagated many hundreds of thousands of 20 or more cultivars of lilacs (Table 1). There are good reasons for tissue culturing lilacs. They include:

1. Microcuttings of lilacs are easy to root.
2. The plant is on its own root (suckering is true-to-type).
3. Production of large numbers of new or rare cultivars is possible
4. Tissue-cultured lilacs branch readily and can be grown into a high quality product.
5. Propagation is very reliable.
6. Cost-effective method of propagation.

Table 1. Lilac cultivars micropropagated by Briggs Nursery since 1982

Adelaide Dunbar	Ludwig Spaeth
Agincourt Beauty	*Madame Lemoine*
Annabel	Maiden's Blush
Belle de Nancy	Marie Finon
Capitaine Baltet	Michel Buchner
Charles Joly	Monge
Charm	Oliver de Serres
Clyde Heard	Paul Thirion
Congo	President Grevy
De Mirabel	President Lincoln
Edward J Gardner	Primrose
Hulda	Sensation
Katherine Havemeyer	Vestale
Krasavitsa Moskvy	Victor Lemoine
Lucie Baltet	*Syringa patula*

The remainder of this paper summarizes our experience in producing tissue-cultured lilacs.

Lilacs can be initiated from actively growing shoots, dormant buds, or meristems. We use any of these explants depending upon the condition of the stock plant or source of material. Actively growing shoots are carefully defoliated and washed in running water for up to 30 min. Next, 5 to 10 twigs are placed in glass jars filled with a detergent (Tween-20) and 0.5% sodium hypochlorite and agitated for 15 to 40 minutes. The explants are then transferred to 0.05% sodium hypochlorite. The shoots are then either trimmed into smaller nodal sections or the vegetative buds are dissected to remove the meristem.

Dormant buds may also be used. These dormant shoots are first washed and then disinfected in 0.5% sodium hypochlorite for 30 minutes or longer. They are then brought into a laminar flow hood and transferred to 0.05% sodium hypochlorite. Using sharp, sterile instruments, the bud scales are pulled and trimmed to expose the meristem and primordial leaves. The meristem may be cut, or a larger bud piece cut and placed on a shoot initiation medium. Generally contamination is very low, but it is a slow and tedious

Cultures are grown using cool-white fluorescent light (50 to 70 μ mol $S^{-1}m^{-2}$) with a 16 hr. light photoperiod. The culture room temperature is approximately 23 °C. Lilac shoots are grown in glass test tubes (25x150mm) or glass baby food jars (250ml). Lilacs can be grown and multiplied on a wide variety of media (1,5,10). We use the inorganic nutrients of Murashige and Skoog (MS) (9) supplemented with 0.4 mg/l thiamine-HC1, 100 mg/l myoinositol, 30 g/l sucrose and solidified with agar. The pH is adjusted with 10% KOH to 5.6.

As indicated previously by Pierik (10) and Einset (1) lilacs have been found to respond to a broad range of cytokinins. They include: N6-isopentenyladenine (2iP), N6-benzyladenine (BA), zeatin, zeatin riboside, kinetin, and thidiazuron. In our work, we have found the first three cytokinins mentioned of most benefit. We routinely use these cytokinins in combination or individually in range of 2 to 30 μ M. An excellent medium we have used for several lilacs is MS with 8 μ M BA and 8 μ M 2iP.

Shoot cultures are transferred to fresh media every 6 to 8 weeks. Multiplication rates vary with each cultivar but a 3x increase is common. Depending upon the cultivar, multiplication may be by either nodal (1,10) or axillary branching (5,6).

There are reports of curled leaves occurring on lilacs *in vitro* (10). We are not of the opinion that this is purely a response to cytokinin. Perhaps it may be due to varietal differences, nutrient or water

uptake, or the tightness of the seal on the culture vessel. We have not experienced any problem with acclimation or rooting of these curled leaved shoots. Once rooting occurs the new growth shows no leaf distortion.

Lilacs can be rooted in the laboratory or in the greenhouse. Initially we rooted our lilacs *in vitro*. Nodal cuttings were placed on ½ strength MS supplemented with naphthaleneacetic acid (NAA). Rooting occurred within two to four weeks and was best at a concentration of 0.15 μ M NAA.

Table 2. Effect of naphthaleneactic acid (NAA) concentration on the rooting of *Syringa* cvs *in vitro*[1]

NAA Concentration (μ M)	Percent rooted shoots of 'Victor Lemoine'	Percent rooted shoots of 'President Grevy'	Percent rooted shoots of 'Charles Joly'
0 05	52 4	81 3	62 5
0 15	95 8	100.0	93 8
0 25	66 7	68 0	75 0
0 5	78 1	68 8	56 3

[1] 24 microcuttings per treatment

Currently we root all our lilacs in the greenhouse. Sixteen nodal cuttings are stuck into a 10 cm square pot filled with 70% perlite and 30% peatmoss. The microcuttings are misted and placed into plastic covered mist tents with bottom heat to root. We root lilacs year 'round. In order to do this we use high pressure sodium vapor lights to supplement and extend the photoperiod. The juvenile lilac microcuttings root quickly—within 2 weeks. We expect 90 to 95% rooting. After 6 to 8 weeks the roots will reach the bottom of the 10 cm pot. Once this occurs, top growth is rapid, perhaps 2 to 3 cm per week.

Variation in rooting can be attributed to: the quality and size of the microcutting, timing and weather, a water or humidity problem, or poor soil aeration. When the plants are large enough they are potted and grow on into liners. As a liner, they grow continuously and respond well to shearing.

We have had our challenges with lilacs since 1982. Probably the most important observation is that lilac cultivars should be reinitiated periodically. This is especially true when growing chimeras like 'Sensation.' All white forms of 'Sensation' can be found growing on the same bush with the normal flowers of 'Sensation.' So care must be exercised in initiating true-to-type material.

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USE OF TISSUE CULTURE IN GERMPLASM MAINTENANCE PROGRAMS

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Conventional ex-situ germplasm storage is approached in two ways, via cold storage of seed or vegetative maintenance of plants in the field. Seed storage is used for most agronomic crops and annually propagated plants. However, a large class of plants with "recalcitrant," or difficult to store, seeds must be maintained vegetatively. Recalcitrant seeds, by definition, cannot be stored for long periods of time and are usually damaged by cold storage below 0 °C. Many tropical and temperate tree fruit and nut crop species have recalcitrant seed. These species are usually maintained through vegetative propagation, usually in the field. The U.S. National Plant Germplasm System has established clonal germplasm repositories to maintain germplasm of many of these crops (19, 20).

In-vitro germplasm maintenance is an alternative to field maintenance of clones (7,21). Germplasm can be maintained in-vitro as shoot tips or meristems, as callus, or as somatic embryos. Shoot tips or meristems are the preferred tissues for in-vitro germplasm maintenance (8). Regeneration into plants is usually easier from shoot tips than from other types of tissue, questions of genetic stability and somaclonal variation are minimized, and clonal genotypes can be maintained. Callus is usually considered to be a poor choice for germplasm maintenance due to the likelihood of somaclonal variation and the difficulty of converting the tissue into plants, especially where a variety of genotypes are to be stored (11). However, callus is a compact form of storage and is the easiest type of tissue to store at -196 °C in a viable condition because of the relative ease with which cryoprotectants may be introduced into the cells. Somatic embryos are a relatively new alternative for in-vitro maintenance. They could be ideal tissues for -196 °C storage because of their small size (making infiltration of cryoprotectants easier). Somatic embryos should be as genetically stable as seeds. However, somatic embryos are usually derived from some sort of induced callus so that potential questions of genetic stability may arise. Somatic embryos have been reported to be genetically similar (identical) to the parental tissue from which they were derived (5,9). Cotyledon tissue is generally used as a source tissue in fruit crops. Therefore, direct generation of cloned somatic embryos from a vegetative parent is not possible. Somatic embryos will probably be extensively used in genetic engineering applications since the

embryos can be transformed at the single cell level and grown into whole plants, limiting the problem of transformation chimeras.

In-vitro germplasm maintenance of clonal germplasm reduces difficulties associated with systemic diseases (mycoplasmas and viruses) that can be transmitted to uninfected accessions in the field. As a consequence of a curator's ability to maintain disease-free plants in culture, distribution of germplasm as cultures can facilitate exchange where quarantine restrictions would otherwise prohibit passage of the materials. Obviously, germplasm recipients must have tissue culture facilities available to them to receive this type of material. In-vitro distribution has been successfully applied to banana, potato, and peach.

Some practical limitations to in-vitro storage as described above include the problem of genotype-media specificity. Different genotypes often have specific media requirements. Thus, for large collections with a variety of diverse genotypes, numerous media formulations may be required. This is probably the most serious limitation to in-vitro germplasm maintenance today. Reasonably broad spectrum media can be developed for species with low levels of genetic diversity (15). A question of similar importance is the genetic stability of the cultures. In-vitro maintenance procedures should be sufficient for maintenance of specific genotypes, without change, indefinitely. Any procedure involving generation of callus prior to plant regeneration has the potential for inducing or propagating genetic changes (1,6,11,17).

Although in-vitro culture has the potential for reducing environmental hazards from disease, insects, frost, etc., other risks must be considered. Power or equipment failure in storage facilities can destroy entire collections if not immediately detected. Fire, earthquake, or flood could have similarly disastrous consequences for in-vitro collections maintained in vulnerable structures. Large scale contamination through undetected sterile transfer hood failures, contaminated media, or culture mite infestations are potentially serious problems. Knowledgeable staff can minimize the latter concerns.

Discontinuities in program funding could have especially severe consequences for in-vitro maintenance programs. These programs require regular maintenance and transfer of the cultures for all nonfreezing storage temperatures. Thus, a one-year program suspension due to short term administrative decisions could result in major germplasm losses. Cultures maintained at -196 °C (liquid nitrogen temperature) are likely to be relatively secure as long as liquid nitrogen (LN_2) and minimal labor to monitor storage conditions are available.

In-vitro germplasm maintenance could be less expensive than field maintenance and, if field space is a limitation (often the case

for large tree crops), tissue culture storage may permit maintenance of a larger number of clones than field maintenance. Using eight culture tubes (20mm x 100mm) per cultivar, about 10,100 cultivars could be maintained in a 3.6m by 4.6m room (4 °C cold room for example). Assumptions: seven levels of shelving would be used with a 1.2m center aisle. With a transfer interval of one year, a technician should be able to reculture a collection of about 12,000 cultivars annually (48 cultivars recultured per day).

The cost of an in-vitro germplasm preservation program will be closely related to the frequency of transfer needed to maintain the cultures. Several possibilities for extending culture intervals have been suggested. These include storage at reduced temperature, reduction of carbon source levels (sugars), growth at reduced light levels, and addition of growth retardants to the medium.

Temperature is one of the most easily controlled variables in a tissue culture system. Tissue cultures are normally maintained at about 25 °C which is a good temperature for shoot multiplication and growth. Cultures can be maintained for four to eight weeks between transfers at this temperature; 4 °C is another common temperature for tissue culture maintenance. Fourteen examples of shoot tip or meristem derived explant maintenance for one or more years are given by Kartha (8). Several crops show improved survival at 6 °C to 9 °C (2,13,14). Cultures of mint have been successfully maintained at 2 °C in the National Clonal Germplasm Respository, Corvallis, Oregon (10). However, 0 °C to 2 °C temperatures are relatively difficult to maintain with normal refrigeration or freezer equipment (too low for refrigeration and too high for freezers).

Reduction of light levels has been suggested as a method for reduction of growth in culture. However, our experience has indicated that maintenance of peach shoot tip cultures in the dark at 25 °C results in a severe decline in vigor as well as growth. Reduced light levels had no effect when cultures were maintained at 4 °C, probably since no growth was occurring. Work by Marino *et al.* (12) has shown similar results.

Limitation of the carbon source in the media (sugars) may be expected to have results similar to reduction of light levels (which prevents CO_2). Since active growth will continue at 25 °C, tissue decline may occur. Japanese researchers have developed protocols for sugar-free media using high CO_2 and light levels to compensate for the lack of carbon in the media, demonstrating the relationship between light, CO_2, and carbon source in tissue culture systems. An alternative to using sugar-free media might be to limit CO_2 exchange. The benefits of using this approach are unknown.

The use of growth regulators in-vitro for growth restriction have not been studied to any great extent. The general emphasis in tissue culture research has been to find growth regulator combinations

that promote rather than retard various aspects of tissue growth. Abscisic acid has been reported as a growth control factor. It seems reasonable to believe that reduction of growth regulator concentrations in tissue culture media, in appropriate combinations, could effectively limit tissue growth at a variety of temperatures.

Buffered media could permit extended growth of cultures without transfer to new media by making nutrients available to the explants for a longer period before transfer to a new medium is needed. An effective nontoxic buffer (MES) is available and has been tested with several crops and tissue types (16). The effectiveness of MES buffers for extending transfer intervals has not been proven and additional work is needed to test this hypothesis.

Work in our own lab has indicated that maintenance at 4 °C could be effectively used to suspend the growth of in-vitro cultured peaches for more than 40 weeks and almonds for more than 33 weeks. Twenty-four peach cultivars were tested and although substantial variability for cultivar effects was observed, no significant declines in viability were observed. Effects of light and dark treatments were evaluated for Lovell peach after 16 weeks and a significant decline in tissue health was noted at 25 °C for the dark treatment although no differences were found at 4 °C for the two treatments. These results were generally consistent with those from Marino, *et al.* (12) with three *Prunus* rootstocks. They observed substantial loss of viability at 24 weeks in 4 °C conditions.

An ancillary experiment using three antibiotics to control bacteria inside the shoot tips demonstrated that two of these compounds, polymyxin B and rifampicin, could have significant growth limiting effects on peach shoots. Tetracycline at 6.5 mg/l did not inhibit plant growth (and was also less effective as an antibiotic). Antibiotics have previously been reported to retard shoot growth (3,4). Other compounds that could restrict tissue growth and permit extended storage are compounds such as mannitol or cryoprotectants such as sucrose or polyethylene glycol which act by changing the osmotic potential of the medium.

All of the procedures described previously for in-vitro germplasm maintenance can be classified as short to medium term methods. Periodic maintenance of the cultures is required and there is some risk of genetic change occurring during maintenance. The only technology available for truly long-term maintenance of germplasm in-vitro is cryogenic storage at or near the temperature of liquid nitrogen (-196 °C). Storage above liquid nitrogen provides a storage temperature of -130 °C to -150 °C. Metabolic activity ceases at LN_2 temperatures and the only source for mutations would be ionizing radiation or cosmic rays. Such mutational events would be

cumulative and would only be significant over a long period of time. LN_2 storage of germplasm should permit permanent storage in-vitro, without transfers or genetic changes. The technology has been tested with more than nine crop species (8). Specialized pretreatments, addition of cryoprotectants and prefreezing, are usually required for successful storage (18).

A prerequisite to the application of LN_2 preservation strategies is the ability to handle the subject tissue in-vitro, either as shoot tips, callus, or cell suspensions. Systems must also be available for generating plants from tissue-cell systems. In-vitro systems permit the introduction of cryoprotectant compounds into the tissues to prevent freezing injury.

From the preceding discussion it is apparent that the development of effective in-vitro systems will become increasingly important for germplasm maintenance programs. We must also recognize that in-vitro systems may not be appropriate for all germplasm objectives.

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PRODUCTION OF FORSYTHIA PLANTS FOR FORCING

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Developing a program for the production of forsythia as a pot plant started at North Willamette Research and Extension Center in 1980. Forsythia branches have been cut and forced for indoor use in early January for decades but many people prefer pot plants. An ideal forsythia pot plant would have many heavily flower-budded branches starting near the soil line. Stinson (7) also had this idea but his report was not brought to our attention until 1987.

Normally hardwood cuttings are used for propagation of forsythia and these were used in 1980 by graduate student, Robert Staton, to produce plants for evaluation of Dikegulac sodium (Atramec, Atrinal) to induce branching. Atrinal was used at 1000, 2000, and 3000 ppm, with 1000 ppm applied twice—April 15 and June 26—producing the best branching and flower bud formation. In later trials, softwood cuttings (2 to 3 nodes in length), obtained from forced stock plants during January and March, produced better plants.

'Lynwood' and 'Spring Glory' used in the first trial both flowered well, however the flower buds of some other cultivars are hardier (2, 3, 4, 5, 6, 9). Hardier cultivars could be used for dual purpose pot plants over a wider area. Cultivars tested include: 'Gold Zauber', 'Karl Sax', 'Lynwood', 'Meadowlark', 'Mr. K', 'Northern Sun', 'Ottawa', 'Spring Glory', 'Sunrise', 'Tetragold' and 'Vermont Sun'. 'Mr. K' is a selection by Klehm nursery of Illinois from plants they received without a name and it is very similar to 'Lynwood'. Best cultivars for pot plant use have been 'Lynwood', 'Mr. K', 'Ottawa', and 'Spring Glory'.

The days to first open flower, to full bloom, and the time plants are most attractive varies. The earlier the plants are brought into warmth, and the cooler the temperature, the longer it takes for flowers to open, but the longer they last. Starting January 5, 1987, 'Spring Glory' averaged 15 days to first flower, 21 days to full bloom, and 22 days of attractive display in a north window, and 11, 14, and 21 days, respectively, in a south window. Days for 'Ottawa' were 20.5, 25, and 25 in a north window, and 16, 19, and 21 in a south window. Starting February 16, 1987, the days were 3.0, 4.5, and 19.5 in a north window, and 3.0, 4.0, and 18.0 days in a south window for 'Spring Glory'. 'Ottawa' took 4.5, 8.0, and 19.5 days in a north window, and 5.0, 6.5, and 18.0 days in a south window. Performance of 'Mr. K' is close to 'Spring Glory'.

PRODUCTION PROCEDURES

Initial trials used Osmocote 18-6-12 at 2 lbs. nitrogen (N) per cu. yd. of ½ in. minus fir bark 9:fine sand 1; however, growth continued into the late fall. These plants had to be cut back before forcing. Six fertilizers rated at 3 to 4 month release were tested in 1983 with Osmocote 19-6-12 at 2 lbs. N/cu.yd., producing the most branches and flower buds. All subsequent trials have used 19-6-12.

All trials through 1983 used nursery gallon (2.7 liter) pots that are not accepted in the florist market. In 1984 plants were grown in 6x5 in. and 4¼x4 in. pots. Plants were larger and had more flower buds in the larger pots, but when test-marketed through a wholesale florist it was found the 4¼ in. pots sold better.

When plants were grown in 4¼ in. pots a new problem developed. The roots coil in the bottom of the pot and push the root ball above the pot rim. Bovre (1) reported that the root coils developed in 0.46 liter pots, but not in 1 liter pots. This root mass can be trimmed off and the plant flowers normally when forced; however this is an extra operation.

Struve's (8) work on root control of red oak seedling roots with copper carbonate in exterior latex house paint applied to the inside of pots suggested an answer to the root coil problem. Copper carbonate, basic copper carbonate (a mixture of copper carbonate and copper hydroxide), and Kocide 101 as fungicides, whose active ingredient is copper hydroxide, were evaluated at our Station during the 1988 growing season.

All three products were used at 1000 grams of product per liter of exterior latex house paint. We also had a control and oryzalin (surflan 75W), mixed with paint at the herbicide rate of 4 lbs active ingredient per acre, or 6 grams per liter; however the latter was not as effective on forsythias as the copper products.

All three copper products eliminated the root coil problem without causing adverse effects on growth, flower bud formation, or flowering time (Table 1). Since it takes time and expense to treat the pots, more than one use after treatment would be desirable. Root and top growth in pots painted with Kocide 101 in 1989 is being compared to growth in pots painted with the three compounds in 1988. All three compounds appear to be effective for at least two years. The test will continue in future years to determine the longevity of the treatments.

Table 1. Growth and development of three forsythia cultivars as influenced by interior coating 10.8 cm (4¼ ″) pots to control excessive root growth Trial started May 4, 1988. Data recorded December 29, 1988.

Tr No.[1]	Height, (cm)	Width, (cm)	Number branches	Number flower nodes	Root coil depth (cm)	Soil Level, Above +, or Below -, pot rim (cm).
			SPRING GLORY			
1	35.1	14 9	7 0	53 9	2.2	+1.5
2	34.0	13.4	7.9	49.1	1.5	+0 5
3	33.6	16.0	8.1	61.6	0	-1.0
4	31.3	16.2	7.2	60.8	0	-0.9
5	30.7	14.0	7.3	56 8	0	-1.0
6	33.3	14 1	6 8	51 3	1 4	+0.6
LSD 5%	N.S.	N.S.	N.S.	N S.	0.3	0 4
LSD 1%					0.4	0.5
			OTTAWA			
1	29.3	12.8	5.8	39.6	2 9	+2 0
2	30.9	14.6	6.5	46 5	2 0	+0 9
3	32.4	13 8	5.8	46.5	0	-1 1
4	29	14.1	5.9	48.3	0	-1.1
5	22.6	6.6	4 8	24.6	0	-1.2
6	30.1	9 6	4.6	32.1	2.7	+1.7
LSD 5%	N S.	4.1	N.S.	10.0	0.4	0.6
LSD 1%		5 5		13.3	0.5	0 8
			MR. K			
1	32.4	11.3	5 9	37.8	3.4	+2.5
2	30.6	11.1	6 3	40.6	2.9	+1.7
3	31.3	12 5	6.7	45.5	0	-1.0
4	33.2	15.5	6 8	54.2	0	-1.0
5	32.5	13.1	6.8	50 0	0	-0.9
6	31.8	13.0	6.3	45.0	2.5	+1.5
LSD 5%	N S.	N.S.	N.S.	8 7	0.6	0.6
LSD 1%				11 6	.7	

[1] Tr. No
1 None
2 Exterior latex paint
3 Exterior latex paint with Kocide 101 at 100 grams per liter
4 Exterior latex paint with copper carbonate at 100 grams per liter
5 Exterior latex paint with basic copper carbonate at 100 grams per liter
6 Exterior latex paint with oryzalin (Surflan) at 6 grams per liter

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MEDITERRANEAN-CLIMATE BULBS: PROPAGATING FOR CONTAINER PRODUCTION

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Wintergreen Nursery is a small wholesale nursery devoted to the new and unusual, particularly among blooming perennials of Mediterranean climate areas. One of my special interests within this diverse group has been the plants commonly lumped together as ''bulbs''; these include some of the showiest and, for the gardener, most rewarding of all perennials. I have been pleased to find that many personal favorites, especially South African and Pacific Coast natives can be economically propagated and presented for sale in ordinary nursery containers, from 4 in. pots to 2-gal. cans, during growth and bloom. Unlike florist crops, these are specifically grown and presented for outdoor garden use.

A variety of ''low-tech'' strategies have been followed, reflecting both our own goals and the reproductive features of particular plants. I would like to briefly share some of our experiences here.

PLANT FEATURES AND PROPAGATING OPPORTUNITIES

The most distinctive features of the ''bulbs'' in general, regardless of plant family, are vegetative structures adapted for storage of water and nutrients during times of climatic stress. In many cases they also serve as important instruments for natural increase. Differences in these structures have a direct bearing on strategies for commercial propagation.

True *bulbs*, such as those of the lilies and narcissus, are contracted stems crowded with fleshy, reduced leaves known as *scales*. Generally they persist for many years, increasing in size over time. Many have incipient growth buds, or tissue capable of producing them, at the base. These may naturally produce offsets, which can be separated from the main bulb, or they may form bulblets along the basal plate in response to injury to the main bulb. In some cases individual scales are capable of generating whole new plants, as described below.

Corms are common structures in the Iris Family (*Gladiolus* and *Freesia* are familiar examples) and West Coast representatives of the Amaryllis Family (*Brodiaea* and others). They are basically swollen stem-bases, with apical buds for next season's shoots and often with accessory shoot-buds at basal and intermediate nodes. Corms are more transitory structures than true bulbs, often

lasting only a single season but sometimes producing large quantities of new corms and smaller *cormlets* in the process. This provides us a means of rapid increase.

Tubers are a little more confusing, since many plants refuse to fit the textbook definition. In general, they are swollen underground stems, or portions of stems, with solid cores and incipient shoot-buds at various points (the zantedeschias, or calla lilies, are good examples); however, we may also speak, as in the case of the alstroemerias (Peru lilies), of *tuberous roots* associated with a comparatively reduced shoot-crown.

Seeding habits and structures are also important with many species. Many "bulbs" are prodigious setters of seed—either through sheer numbers of flowers, as in *Crocosmia* and some other South African irids, or through large seed vessels with dozens or hundreds of seeds, as in the lilies. Structure of the seed pods in many members of the Lily, Amaryllis, and Iris Families make the seeds easy to collect and separate, and their viability tends to be quite high. Further, we have found it surprisingly easy, through moderate isolation, to develop and maintain superior seed strains with respect to such features as overall vigor, flower size, and color.

Below are some examples of the techniques we use.

SEEDING TECHNIQUES

Part of the definition of a Mediterranean climate (including that of much of California) is a combination of cool, moist winters and warm, dry summers. Thus plants of these climates are generally adapted to germination and growth of seeds during the winter and early spring, when a supply of moisture is assured. We have two alternative techniques for exploiting this habit in seeding of Mediterranean-climate bulbs. Most are simply sown in fall, with the onset of cool weather. We scatt them rather densely in flats of a light, porous medium and barely cover them with more of the same (there is no magic in a particular formula, but ours includes 1 part of a redwood sawdust/sand UC-type mix, 2 parts medium grade perlite, and 0.5 to 1 part screened peat moss, with 3 oz. per yard Truban as a damping-off preventive). Large, fleshy seeds like those of *Crinum* (the corn lilies) are left partly or completely exposed; covering them only encourages fungus decay. The flats are placed either outdoors in a small shade house, or on a shady bench within a large unheated greenhouse. In either case they receive midwinter night temperatures from 30 to 40 °F but little or no direct frost. Most species are ready to transplant to 2 in. pots or open flats by mid-spring, though a few, like the *Calochortus* (maiposa lilies) remain too small and delicate and are held over for a second season.

The second alternative, which seems to give more consistent germination for native lilies and certain others, is to stratify the seeds in Ziploc bags containing a moist cutting medium (3 parts perlite, 1 part screened peat moss). This method also permits an early start and extended first growing season, which minimizes growing time to first bloom. The bags are refrigerated at around 40 °F until germination begins, usually at 2 to 3 months. Then they are flatted and treated like dry seeds.

DIVISION

Since we are interested in a number of specific clones selected for vigor and floral features, and since the structures themselves are so amenable to simple division and some more brutal variations, these are our most common techniques for bulbs. Usually we save plants from one year's mature crop and divide the bulbs, corms, or tubers into appropriately-sized clusters, replanting these in the same size containers. This oversimplifies things a bit, since there is no easy formula for the "appropriate" number of units per container; bulb genera, species, and even individual clones vary enormously in profuseness of growth and minimum age of structures for onset of bloom. Our object is, wherever possible, to have blooming plants of salable size in the next blooming season after division.

There are various cases of special interest. Some bulbs, like *Zephyranthes* and *Habranthus* (rain lilies) in the Amaryllis family, have essentially no dormancy in our climate and are dividied almost anytime (though with care to keep root masses reasonably intact). Others, like the *Rhodohypoxis*, have a seasonal dormancy but also an extended growing season, and may be divided during active growth. Some of the South African irids permit a sort of two-fold division. Cormlets which have formed either along last years growing stems (as in the babianas, or baboon-flowers) or on the surface of the old main corm can be stripped away, often in large numbers, and planted in flats for a later year's crop.

Some features call for special caution on our part. Many cormous plants, like the brodiaeas, begin their fall or winter growth season with delicate rhizome-like pegs radiating in all directions from an old corm; these should not be disturbed until new corms have formed at their tips. Some of the summer-dormant alstroemerias are especially troublesome: Their tangled masses of tuberous roots must be carefully teased apart, leaving the rather delicate growth-crowns intact.

There are some species, too, which do not separate neatly and ned some encouragement from a hatchet or large knife; *Crinum* (corn lily) and *Eucomis* are good examples. Fortunately, most of

these heal rapidly, and the injury to older bulbs may even encourage production of offsets along wounded surfaces. Many solid-cored tubers must be subjected to chopping, slicing, or a variety of other abuse to make appropriate pieces for planting. The zantedeschias, or callas, are a good example of plants which take this sort of indignity in stride.

SCALE CUTTINGS

Among our bulb techniques, probably the most interesting is that of bulb scale cuttings. Unfortunately, this technique is difficult to apply to any but the most loosely knit true bulbs. With selected clones of our California native lilies, we knock out and wash off large stock bulbs and break off a number of scales, trying to get a bit of the basal plate with each scale. The scales are dipped in a mild rooting powder (Hormex #3) and inserted in flats like stem cuttigns, with at least half of each scale showing above the medium. Within two or three months bulblets form at the base of each scale; then one or more leaves will appear. At this point the plants are potted up. This often promotes a second growth cycle. The most virgorous species, like *Lilium pardalinum,* will produce flowering plants in the second summer.

Certain other relatively large, loose bulbs can be given some variation of this treatment. The broad scales of *Urginea maritima,* the sea onion, will produce multiple plantlets from each scale base. We have also experimented haphazardly with various *Crinum* species and hybrids, with mixed results.

All of these techniques have proven commercially viable for container plant production and offer a welcome break from more conventional routines.

MIKE EVANS: A question for Ellen Sutter. In the plants you have worked with or observed, in the roots transformed by bacterial action, will they be mycorrhizal, or will they later become mycorrhizal on their own?

ELLEN SUTTER: We did not deal with that question in our work, so I do not know.

GARY MATSON: Does forsythia have fully differentiated flowers when cuttings are taken and will it still root after the flowers have formed?

BOB TICKNOR: The flower buds are visible now (September) but, normally, hardwood cuttings are taken in winter when the flower buds are fully developed, and they root very easily.

SOURCE SELECTION OF VEGETATIVELY PROPAGATED CULTIVARS

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The *clone* is a primary concept in horticulture, with vegetative propagation (cloning) being one of our most important procedures (4,6). Most cultivars propagated by nurseries today are clones. Success in propagation depends upon maintaining trueness-to-cultivar and trueness-to-type. Research in this area, however, has emphasized the detection and elimination of viruses in clonal materials (2,10,11).

The purpose of this paper is to discuss some basic concepts of source selection from a genetic standpoint and to describe some unique problems with clonal variability. Emphasis will be given to the propagation of fruit and nut crops, particularly California almonds.

Most clones originate as selections of superior individuals from seedling populations. Selections are vegetatively propagated for test plantings. Figure 8-17 in Hartmann, et al. (4) outlines the basic steps in the development and subsequent propagation sequences. An alternative approach is selection of bud-sports (bud-mutations) from within the clone. All but a few almond cultivars originated by the selection of individual plants from seedling populations. Some, including 'Nonpareil', 'Mission', 'Ne Plus Ultra', 'Peerless', 'Drake', and 'I.X.L.', originated over a hundred years ago and have a long history of consecutive generations of propagations. Others, such as 'Merced', 'Carmel', and 'Thompson', originated more recently, either from chance seedlings in commercial orchards, roadsides, etc., or from public and private breeding programs.

Individual trees of the clone are selected to be the *source* to begin a sequence of propagation. Most commercial propagation of fruit and nut trees in California is by T-budding cultivar material to seedling or clonal rootstocks. Individual vegetative buds are taken from a budstick of 8 to 10 buds. The related lines of descent through propagations from the original selection constitute the *pedigree* of the cultivar. In some of the younger almond cultivars, the original trees and representatives of all the intervening generations of the propagation sequence are in existence.

PEDIGREE SYSTEM OF SELECTION

Most commercial nurseries for fruit and nut trees in California have utilized the *pedigree system.* Commercial orchards are used as *source blocks* for collecting propagation material. Budwood is collected from bearing trees after *visual inspection*, avoiding individual trees which do not appear *true-to-type.* Identity with the source orchard, and often with the individual source trees, are maintained into the nursery row. When the nursery trees are dug in the fall, the trees are graded by size and any relationship to specific source trees, or even orchards, may be lost.

The same orchard source may be used for a number of years until the trees lose vigor and produce reduced amounts of suitable budwood. New budwood sources are then chosen which are invariably the vegetative progeny of previously used orchards. As this: source > > nursery > > progeny orchard cycle is repeated, a series of vegetative generations of individual ''budlines'' evolve from separate nurseries, each with a unique propagation history or pedigree.

NUCLEAR STOCK (OR SOURCE-CLONE) SYSTEMS

This system starts with a single source plant (or even a bud) which then provides a ''nucleus'' for all subsequent propagations (2,3). This plant essentially creates a ''new'' clone selected from the original clone. The primary reason for this procedure has been to clone a source plant found to be free of specific viruses. It is assumed that the new plants will have the same genotype as the original clone. (Use of the term ''source-clone'' distinguishes these special kinds of ''clones'' from traditional new clones that are chosen because of a mutation that actually changes the genotype.)

The *source-clone* is subsequently maintained in a special *scion orchard* for budwood production rather than for a crop. Trees usually need to be multiplied in an *increase block* in order to provide sufficient volume of budwood for nursery propagation.

Nuclear Stock System

In the mid-1960's a nuclear stock system involving *Registration* and *Certification* was introduced by the California Department of Food and Agriculture to distribute selected indexed source-clones of grape, fruit, and nut tree species. There are three general phases (4).

Phase I. Selection of specific source-clones which had been indexed, found to be free of specific viruses, and appeared to be true-to-type.

Phase II. Maintenance of trees (2 or more) in a *Foundation Orchard* under protected conditions to prevent reinfection and to retain their genetic identity. This function was carried out by the *Foundation Seed and Plant Materials Service (FSPMS)* of the University of California.

Phase III. Distribution of ''registered budwood'' to commercial nurseries who would establish scion orchards and produce ''certified nursery stock'' under the regulations and supervision of the California Department of Food and Agriculture.

Some attempts were made at the time by the commercial fruit and nut tree industry to adopt this program but very little material was actually distributed and the program was poorly utilized. Several reasons can be cited:

a. Recovery of the added cost of the operation in the sale price of the tree was not possible.
b. Inspections and cumbersome management practices were required.
c. Some nurseries had more confidence in their own material obtained by pedigree selection,
d. Problems arose with genetic disorders, trueness-to-type, and knowledge of horticultural quality, which reduced industry confidence in not only specific source-clones but also in the program.
e. Many important cultivars, particularly those newly patented by commercial firms were not included in the program.

Scion Orchard Production Systems

Consequently, some commercial nurseries began to incorporate virus testing into their own programs and to develop scion orchards to manage their own sources. Registered source-clones were sometimes used but other sources were also included, such as privately patented cultivars. These sources often did not have the level of virus testing to which registered stock was subjected.

In the past few years, there has been renewed interest by commercial nurserymen in California to reestablish a Registration and Certification program for fruit and nut crops as a basic tool for nursery source management. This trend has been fostered by the following reasons:

a. Problems arose with virus infections and associated threats of litigation.
b. A program to provide financial support for a ''clean stock'' program from fees on commercial nursery stock was instigated.

c. Competition developed from certified stock production from other states.
d. There was improved understanding of genetic problems within clones leading to potentially more effective practices for maintaining trueness-to-type (1,7).

SOME BASIC PRINCIPLES OF SOURCE SELECTION

The model: PHENOTYPE = GENOTYPE + ENVIRONMENT states that the appearance and performance of any individual plant is a function of its genes interacting with the environment. What we perceive is the *phenotype*. What is propagated is the *genotype*. A high correlation exists in clones between the genotype and associated phenotype. This means that the phenotype of the offspring should be very similar to the phenotype of the source plant since their genotypes are identical.

Two basic terms have been used to describe phenotypes in relation to source selection:

Trueness-to-cultivar means that a specific identified cultivar is being reproduced and not some other cultivar that has been propagated by error.

Trueness-to-type means that not only is the correct cultivar being introduced but also that the plants being produced are typical for that cultivar and meet standards for performance and appearance. In practice, the two terms are often used interchangeably but the two are fundamentally different.

Trueness-to-type applies both to *source* plants and to *vegetative progeny* plants. If the two are different, then change has occurred in the cultivar, (a) in the source plant (or its antecedents), (b) during the propagation process, or (c) in the vegetative progeny. In dealing with deviations from ''trueness-to-type'', one first needs to be able to determine the cause of the variation and then to identify the exact time in the propagation sequence when the variant appeared. Variation may result from three basic causes: pathogen-induced (primarily viruses), genetic changes, or environmental effects. In addition, there may be unique *species or cultivar-specific genetic disorders*, as described later in this paper.

Three standard procedures are used to determine the causes of variation:

Virus Indexing. This procedure includes various types of tests, including transmission, biochemical, and other procedures, and provides direct evidence for the presence of specific systemic viruses within individual plants (8,10). A full range of tests are specified in the Registration and Certification regulations for fruit and nut trees in California. These tests provide a category of *indexed* source plants that are available for propagation. In our

model, the virus combines with the environment to affect the phenotype expression:

phenotype = genotype + (virus + environment)

The effect on the phenotype varies by virus, cultivar, and environment. Sometimes the combination can kill plants. In other combinations, the effect may be severe and result in decline, yield reduction, or poor quality. However, in some combinations, the phenotypic effect is not readily apparent and not easily measured.

Nevertheless, the trend is for the elimination of identified viruses from propagation stock when it is possible. Plant pathologists and propagators, however, are careful not to use the term ''virus-free'' in referring to such plants. The term should only apply towards those viruses for which the test has been made. A more appropriate term is ''indexed-stock'' which refers to source plants in which the absence of specific viruses and other systemic pathogens has been verified by specific indexing methods.

Phenotypic Selection. This term refers to selection of trueness-to-type by VISUAL INSPECTION of the source plants. Most organisms have species- or cultivar-specific characteristics that an experienced evaluator can recognize, providing that the inspection is made under proper environment and management conditions. A high correlation between the morphological characteristics of a source plant and its vegetative progeny is expected. Consequently, visual inspection of the source plants becomes an essential part of any selection process and, for some plant cultivars, may be the only procedure available. The procedure can be effective, providing that the inspection is carried out under the right conditions, done by knowledgeable persons and utilizes specific standards of identification.

Phenotypic selection has important limitations, however. Some traits—e.g., health, yield potential, and vigor—may not be readily evaluated or can be strongly influenced by the environment, age, location, or management of the source plant. Fruit and nut trees grown for budwood are pruned severely to increase new growth and reduce flowering. Under these conditions, fruit and nut characteristics invariably are atypical and observations may be misleading. Visual inspections may thus result in ''false readings'' and misdiagnosis of genetic ''problems.''

Visual inspections may not detect viruses, latent mutations, yield reduction, or susceptibility to latent disorders, such as *noninfectious bud-failure* in almonds.

Genotype selection. This procedure is based on *visual inspection* of the *vegetative progeny* and provides a test for the actual type of plants that the source will produce. Important uses of a vegetative progeny test include:

a. the screening of sources for latent genetic mutations, such as nonproductive syndrome in almond, and other disorders, including noninfectious bud-failure (almond), crinkle (cherry), etc.
b. the testing of yield performance and horticultural quality.
c. establishing whether a perceived abnormality is due to environmental or genetic causes.

For these reasons, genotypic selection should be incorporated into source selection programs whenever possible.

SPECIFIC PROBLEMS AFFECTING SOURCE SELECTION IN ALMOND

This section illustrates the concepts and application of source selection by describing experiences we have had with the almond.

1. Virus problems. The almond is susceptible to the same range of viruses affecting other stone fruit species. General procedures for viral elimination and maintenance of source materials are available. Most almond cultivars do not appear to have as great a phenotypic response to some common viruses as other stone fruits. Nevertheless, the use of ''clean'' material is desirable.

2. Genetic problems: mutations, chimeras, budsports. These terms refer to discrete changes in the genes, chromosomes, or other genetic units in single cells somewhere in a growing point (4). Normally mutations are rare and the probability of one occurring in a selected source plant is low. Mutations in a cell in a growing point may lead to a *chimera*, which may then encompass a sizable part of a plant and affect a number of buds. The chimeric shoot may be latent and not easily identified by visual inspection. If such an undetected chimeric shoot is used as a source of single bud propagules, the probability of off-type progeny plants being produced is high.

This type of single mutation will be referred to as Type I. In the 1950's, a late-blooming mutant of the 'Nonpareil' cultivar was discovered which involved several entire trees and single limbs of others (8). Evidently a single gene mutation had occurred but was not detectable until after propagation. The mutant became the patented cultivar, 'Tardy Nonpareil'. In this case, the genetic change affected few trees, and proved economically useful. In another example, a heavy producing 'Nonpareil' limb was discovered which became the patented 'Jeffries'. It was later found that the pollination requirements of the budsport were unique (9) and resulted in economic problems when planted in commercial orchards.

Nonproductive syndrome or ''bull'' trees (a second type of mutation problem—referred to as Type II) reduced productivity,

increased vigor, and produced morphological aberrations of the fruit and foliage (7). Trees with this condition began to appear in commercial orchards in the late 1960's and early 1970's and were associated with specific nursery sources and cultivars. After considerable research, we were able to trace the origin of the problem through several vegetative generations to two nursery sources. Our research did not indicate a pathogen problem but rather some earlier "event" which resulted in an "explosion" of mutations that appear to affect a number of traits. The incidence of these characteristics was associated with exposure to certain agricultural chemicals, although this relationship has not been experimentally tested. The key point is that this problem was not detected in the primary source plants where it was initiated but only in secondary progeny plants after several generations of consecutive propagation.

3. Species or cultivar-specific "genetic disorders." In almond a genetic disorder called *noninfectious bud-failure* (BF) falls into this category (5,9). This condition does not have a known virus etiology but develops in a regular pattern within specific cultivars (1). Its primary action involves the necrosis of vegetative buds and consequently dieback, which after consecutive years, results in a BF-induced phenotype called "crazy-top." Physiologically, the disorder appears to involve the loss of resistance to stress (high temperatures, low moisture) with prior growth required for expression. Variation in the potential for BF is shown by different propagation sources. Thus, the primary method of control has been through source selection, though subsequent conditions at the progeny orchard site may also be important. Selection cannot be based upon the phenotypic selection of the source but requires information from progeny testing.

4. Nongenetic causes. These produce only temporary effects and are not heritable. These can lead to false readings. For example, in the investigations on the *nonproductive syndrome*, source trees growing in a scion orchard, which were heavily pruned for budwood, showed low crops, extra vigor, and abnormal nut morphology. Visual inspection of these plants led to the misdiagnosis of a Type II disorder. This error was only revealed by conducting vegetative progeny tests of the sources involved.

SUMMARY AND CONCLUSIONS

In the selection of propagation sources for vegetative propagation, testing for viruses, trueness-to-cultivar, and trueness-to-type are required. These tests are particularly important for source-clones since all subsequent propagules will inherit identical

genetic factors. Our studies indicate that visual inspections under proper growing conditions are essential. Visual inspections of the source plants (phenotypic selection), however, are not always adequate. Additional visual inspections of the progeny plants (genotypic selection) are necessary particularly when dealing with latent disorders.

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BENCH GRAFTING COLORADO BLUE SPRUCE—CRITERIA FOR SUCCESS

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Picea pungens (Colorado blue spruce) cultivars are one of the most important bench-grafted crops in both North America and Europe. A number of superior, glaucous, blue forms have been selected and named during the last few decades, including *P. pungens* 'Hoopsii', 'Thomsen', and 'Baby Blue Eyes'. There have also been selections based on their varied growth habit, e.g., the weeping 'Glauca Pendula', and the compact 'Glauca Compacta'. The aim of this paper is to summarize a number of the important criteria necessary for successful bench grafting of this crop.

Rootstock Production. A quality rootstock should have a pencil-thickness caliper (6mm;1/4in.), a straight stem, and a well-developed rootball. These are major criteria for success. The production or purchase of under-sized rootstocks with a poor root system results not only in low grafting success but also in poor subsequent scion growth. Quality rootstocks can be produced by using 2-year, graded, transplanted, or undercut open-ground seedlings of *Picea abies,* which are then potted into 10 cm (4 in.) containers. Attention to control of red spider mite, spruce aphid, and root aphid, together with adequate nutrition and irrigation, is particularly important after potting. Mulching the pot-grown rootstocks with peat moss reduces weed germination and also reduces the need for irrigation.

Time of Year. There are two optimum periods for grafting blue spruce. The first is in late July to early August, when there is a natural lowering of growth processes, and the second is during December to early February, when the rootstocks are still fully dormant. One advantage of late summer grafting is that the vascular tissue between scion and rootstock unites prior to the winter and this subsequently often results in improved scion growth the following season, as compared to winter grafting. The majority of propagators prefer winter grafting. It is important not to graft late, particularly after a mild winter.

Rootstock Preparation. Correct preparation of the rootstocks just prior to grafting is often overlooked. Inspect the rootstock

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[1] Director

plants 2 to 3 weeks prior to grafting and bring them into a greenhouse with an optimum air temperature of 10 to 12 °C (50 to 54 °F) to reduce the rootball moisture level to 50 to 60% in order to initiate physiological activity. Less drying-off is required for late summer grafting. A small amount of white root growth should be visible after this procedure. Excessive moisture in the rootball at grafting time will encourage "flooding of the union" (excessive sap accumulating around the union following grafting) and results in poor success. Conversely, excessive drying-out kills the newly formed roots, resulting in little or no subsequent scion growth.

Selection and Collection of Scionwood. The propagator must collect 1-year, vigorous, terminal scions, 10 to 15 cm (4 to 6 in.) long, with a dominant terminal bud and not less than three radial buds. Scions prepared from non-vigorous wood lacking dominant terminal buds result in plants with lack of symmetry in whorls and in reduced vigour. The slower growing cultivars often require scions prepared by cutting into 2- or 3-year old wood and these normally have side shoots. Collection of scionwood should be geared to having sufficient scions available to supply one-half to one full day of grafting. If storage is necessary, the scions should be placed in a polyethylene bag and put in a refrigerator at 4 °C (39 °F).

Method of Grafting and Tying-in. Blue spruce must be side-grafted because a considerable degree of control of the sap rise is required during the aftercare procedures. The two methods principally used are the side veneer and the apical wedge grafts. The key points for success, apart from developing a proficient skill by continuous practice, are:—

1. Use a sharp knife. I like the pointed blade of the Tina 606 because I find that it allows greater precision.
2. Clean the knife blade after each graft to remove the resin. Wipe the blade on a pad dampened with white or methylated spirits.
3. Do not tear the stem tissue when removing the needles from the scion at the point where the cuts will be made.
4. Ensure the cuts on the scion are shallow to expose the cambium—the wood is often relatively pithy so good knife control is important.
5. Make sure that the cut surfaces are in close contact when matching the scion and rootstock. Smaller caliper scions should be matched on one side only of the cut surfaces.
6. Tying-in should be firm, begin above the upper cut surface and end well below the base of the cut on the rootstock. The base of the veneer on a side veneer graft must be left uncovered by the tie. One common fault of beginners is to pay insufficient attention to tying-in—particularly at the start and end of the operation.

Waxing. Waxing of the cut surfaces is necessary when humidity and air temperatures are low and movement of air is encouraged, e.g., on an open bench or in a polyethylene tent facility. Waxing is not necessary if the unions are covered with moist peat moss in a grafting case. It is better to wax the unions if in any doubt. The best types of waxes are either the cold latex waxes (e.g., Farwells Tree Doc® —Yellow or Green Cap), or the hot waxes that cool rapidly when brushed onto the cut surfaces of the grafts.

Aftercare. Correct aftercare procedures for the grafts are essential. Perfect carpentry is useless if the principles of aftercare are neglected.

A heated aftercare facility, grafting or closed case, is normally designed as a tent, drape, or tunnel. An open bench in the greenhouse is used sometimes providing there is limited air movement. A shaded coldframe is a very effective aftercare facility for summer grafting.

Very accurate temperature control is not vital, but a useful guide to optimum temperatures is to have a base temperature of 18 to 20 °C (65 to 68 °F) and an air temperature of 15.5 to 18 °C (60 to 65 °F), combined with a minimum humidity of 80%. It is important to provide sufficient shading to reduce temperature build-up and retain sufficient humidity—a rise in temperature will reduce the humidity unless precautions are taken. Excessive extremes of temperature and humidity cause severe stress to the rootstocks and result in poor success. A guideline is to have 50 to 70% shading for winter grafting and 80% for summer grafting.

Watering is another important consideration. The commencement of watering depends on the moisture level of the rootball at the time of grafting and on the environment within the grafting facility. The rootballs *must* be inspected regularly for excessive dryness and root development. The first thorough watering should take place when callus tissue has formed between the scion and rootstock, although some propagators prefer to wait until the terminal bud on the scion begins to swell. Excessive watering during the first 2 to 3 weeks after grafting leads to excessive sap rise and results in lost grafts due to ''flooding of the union''. Stress or loss of newly developing roots caused by either over- or under-watering will also cause poor results. Watering should be increased gradually as the grafts are hardened-off.

The application of a fine spray of water over the grafts is beneficial in several circumstances, e.g., the morning after the polyethylene cover was removed overnight, when the grafts have been left uncovered on a dull day to encourage some air movement, and during hardening-off. Such spraying helps to reduce stress by quickly raising the humidity levels around the needles.

Ventilation of the grafts begins 3 to 6 weeks after grafting to start the hardening-off process and is normally concluded by 8 to 12 weeks after grafting. Shade cloth should replace the polyethylene at this point.

Attention to pest and disease control is very important. The major pests for blue spruce are red spider mite, spruce aphid and root aphid. *Botrytis cinerea* infection of the soft growth results from infection of the scion buds.

Heading-back (snagging back) of the rootstock to the apex of the union is best done in three stages. Reduce the rootstock (''sap drawer'') to half its length 6 to 8 weeks after grafting. Repeat 6 weeks later to 2.5 cm (1 in.) above the union. The third stage is the final removal of the snag in the following August for winter grafting and in early March for summer grafting. Earlier removal of this final snag, particularly for winter grafting, results in poor scion growth.

CONCLUSIONS

In this paper I have attempted to relate the major criteria for successful grafting of blue spruce. Successful bench grafting should result from adherence to these principles, especially if the propagator is willing to adapt his/her technique in response to experience with successes and failures. As in many aspects of propagation, observation, dedication, and enthusiasm are essential, and bench grafting of *Picea pungens* cvs. will challenge all three of these powers.

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BENEFITS OF GOOD RECORD KEEPING IN PROPAGATION

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There are many factors that go into the making of a good propagator: education, training, personal interest, a keen eye, and the ability to learn from success and failure—to name a few. Another element that can aid the propagator to hone skills and reduce failures is that of good record keeping.

The average propagator is dealing with several hundred plant cultivars. When items such as: propagation medium, hormone concentration, size and maturity of cuttings, flat density, and timing are all considered, this produces thousands of bits of information to remember. As years go by and crops are repeated, it becomes more difficult to remember the details of producing a particular crop.

Personal experience with these problems led me to develop a record keeping system and subsequent forms which can be used by the beginning and experienced propagator alike.

METHODS

Table 1 shows a form which is the initial step in the process. One should start by logging each day's production. Show the quantity produced, name of plant, a description of activity performed, the date and the number of people involved in production for the day. As the log is continued, it produces a chronological listing of propagation by the week and month for the year.

Table 1. (Daily Propagation record sheet)

QUANTITY	CULTIVAR	DESCRIPTION	NO. OF PEOPLE	DATE

Tables 2 and 3 are forms for recording all pertinent information pertaining to the propagation of a particular crop by either seed or cuttings. These cards are designed to fit a standard 8 x 5 in. index file box. The card is filled out and filed alphabetically in the index box. Later as changes occur in the crop the card is retrieved and details added. Finally as the plants are potted and counted the results are noted and the card is moved to a non-active file.

Table 2. (Record card for Cutting Propagation)

CUTTINGS

Botanical Name· _____

Common Name. _____

Date Propagated _____ Rooted _____

Cutting Method _____ Size _____

Medium Mist _____ Bottom _____ Heat _____

Treatment· _____

Hormone. Type _____ *Conc* _____

No of cuttings per flat· _____

Date potted up _____ No of liners _____

Area to be placed _____ Prop Initials _____

Source of cutting _____

Results % notes _____

The non-active file becomes a collection of all the propagation over a period of several years. Numerous cards may accumulate for one cultivar. At this point a "Master Card" can be developed, gleaning all the details of successes and failures to establish a program for the future production of each particular plant.

Table 3. (Record card for Seed Propagation)

SEED

Botanical Name _____

Common Name _____

Date Propagated _____ Breaking _____

Area to be placed _____ Rooted _____

Medium _____ Top Dress _____ Bottom Heat _____

Treatment _____

_____

No of seed per flat _____

Cleaning Instr _____

Source of seed _____

Results. % notes _____

BENEFITS OF RECORD KEEPING

The benefits of a record keeping system will be immediate as well as long term. Short term it forces the propagator to keep a close watch on the crop for subtle changes such as callusing, rooting, and germination. It is during these inspections that disease and pest problems are discovered and can be dealt with prior to a major disaster. The propagator also learns the type of cuttings that can be produced rapidly and those that are more time consuming. Details about the variation in greenhouse environments and differences in media become apparent and useful. This system also becomes an excellent method to track the progress of small scale experimentation which leads to improved techniques.

Long-term, the possibilities are nearly endless. The details on the record cards become the raw data to develop a wide variety of lists and schedules.

Information gathered on the form in Figure 1 can be utilized to make lists of plants to be propagated each month. It can help with scheduling when greenhouse space is critical. Further use of this form can assist in budgeting and lining up supplies and labor needs. Calculations made using this same data can lead to establishing daily propagation quotas.

The detailed data collected on forms in Tables 2 and 3 can be consolidated to produce lists of very specific information. An example of this: ripening dates for seed collection, seed treatments, reliable seed suppliers, and alphabetical listing of plant cultivars with addresses where seed, cutting, or scionwood can be collected.

CONCLUSIONS

This record keeping system and its results are only as good as the effort put into it.

The propagator must be diligent in making proper and timely entries.

The rewards of a good system can result in substantially improved stands in the cutting flat, seed bed, or grafting tent. Ultimately this results in a more efficient operation and greater profitability.

Many propagators today have access to a computer. This system would easily lend itself to computerization.

PROPAGATION OF RARE AND ENDANGERED SPECIES FOR RESTORATION

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INTRODUCTION

Certain plant species that are now or may become threatened with extinction are protected under one or several, international, federal, state, or local laws. These laws place restrictions on certain activities such as import, export, foreign or interstate commerce, and removal from areas under agency or governmental jurisdiction. The purpose of this paper is to outline the legal protection, explain the terminology, and mention certain programs regarding endangered plant species. A list of ten principles for propagation of endangered species is offered as a guide for restorationists and nursery professionals.

LEGAL PROTECTION FOR PLANTS (INTERNATIONAL LEVEL)

IUCN. The International Union for Conservation of Nature and Natural Resources (IUCN) is an international, non-governmental organization based in Gland, Switzerland, whose goal it is to aid all countries in their efforts for detailed documentation and preservation of their threatened native plant resources. The Threatened Plants Unit of IUCN's Conservation Monitoring Center has undertaken to monitor and, where appropriate, to coordinate and advise on the documentation and preservation of threatened plant species throughout the world. Recently, the Conservation Monitoring Center prepared a Plants Conservation Program. A few of the many projects in this program are: 1) sponsorship of several books on plant conservation, including Anthony Huxley's ''Green Inheritance,'' and David Given's forthcoming ''Plant Conservation: Principles and Practice''; 2) promote stronger legal and planning tools for international and local plant conservation; 3) help increase *in situ* preservation, especially of primitive cultivars and races of economically important plants; 4) increase coordination among botanic gardens and others for carrying out *ex situ* conservation of plants critically threatened in the wild.

CITES. The Convention of International Trade in Endangered Species (of Fauna and Flora), (CITES) was established in 1977. The main focus of the rules of this convention is on international trade; import and export. The United States and more than 90 other

nations are party to the convention, which was created in order to regulate ''import and export of imperiled species covered by the treaty.'' Permits are required from the Management Authorities (U.S. Fish and Wildlife Service in the United States) of both the importing and exporting countries. The import permit must be obtained prior to requesting the export permit (from the country of origin. Seeds, parts and products, and hybrids are afforded full protection as Appendix I specimens. Artificially propagated Appendix I plants are given special consideration, depending on whether they were propagated for commercial purposes. They may be imported to the U.S. with a certificate of exception issued from the country of export.

LEGAL PROTECTION FOR PLANTS (FEDERAL LEVEL)

Endangered Species Act—Background. The Senate and House of the 93rd Congress of the United States passed the ''Endangered Species Act'' on the 19th and 20th of December 1973, respectively. Signed by then President Nixon eight days later, the Endangered Species Act of 1973 repealed much of the ''Endangered Species Conservation Act of 1969,'' which replaced the ''Endangered Species Preservation Act of 1966.'' The ESA affords protection to various species of fish, wildlife, and plants (animals other than vertebrates, mollusks, crustaceans, and plants for the first time) threatened to extinction by both human and non-human causes. Some foreign species are also protected. The ESA places restrictions on import, export, interstate and foreign commerce of listed species.

Endangered Species Act—Terminology. The words ''endangered'' and ''threatened'' are often used interchangeably as pronouns and adjectives in conservation or written material about unusual plants or species whose future survival is in jeopardy. It should be noted that crucial legal differences exist in the meaning of these words under the provisions of the ESA. Brief definitions of some of the important terms are given below.

''Endangered Species''—Any species, including subspecies (U.S. Fish and Wildlife service considers ''varieties'' to be ''subspecies''), in danger of extinction throughout all or a significant portion of its range.

''Threatened Species''—Any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

''Listed'' or ''Federally Listed Species''—Terms often used in conjunction with endangered or threatened; they indicate that a species has been the subject of a proposed and final rule or regulation published in the Federal Register.

''Proposed Species''—Endangered or threatened species for which a proposed regulation has been published in the Federal Register, but not a final rule.

''Candidate Species''—Taxa the Service is considering for listing as endangered or threatened species, but not yet subjects of a proposed rule.

Category 1—Taxa for which the Service currently has on file substantial information on biological vulnerability and threat(s) to support the appropriateness of proposing to list the taxon as an endangered or threatened species. Development and publication of proposed rules for such plants takes several years.

Category 2—candidates are those taxa for which information now in possession of the Service indicates that proposing to list them as endangered or threatened species is possibly appropriate, but for which substantial data on biological vulnerability and threat(s) are not currently known or on file to support the immediate preparation of rules.

Category 3—(Non)-candidates are former candidate plants grouped into three subcategories: 3A) extinct; 3B) taxonomically invalid or not meeting the Service's definition of a ''species''; 3C) too widespread or not threatened at this time.

Endangered Species Act—Protection. Listed endangered and threatened plants receive full protection and authority of the ESA. Section 4 of the ESA requires the Service to develop recovery plans and directs Service recovery monies to help procure the services of appropriate public and private agencies in an effort to recover listed species. Section 5 permits federal agencies within the Department of the Interior and the Forest Service to conserve listed plants by land (habitat) acquisition. Section 6 enables the Service to enter into management and conservation agreements with state agencies (including research), species management and recovery plans. Twenty-one states, including California, have cooperative agreements for plants. Section 7 provides the most significant protection of the 14 sections of the Act by regulating the activities of federal agencies toward recovery and conservation of plants on their lands or impacted by their activities. Section 9 prohibits removal, collection and possession of listed plants from lands under federal jurisdiction. This section makes illegal the international and interstate transport, import, export, and sale or offer for sale of endangered and threatened plants.

Proposed species are granted limited protection under the ESA. Federal agencies must address these taxa in biological assessments and the Service typically reviews project plans and makes (non-binding) accommodations for the protection of the proposed species.

Candidates species do not enjoy any protection under the Endangered Species Act. Some federal agencies accord some level of protection or management consideration to candidates. Such federal policies are not mandatory under the ESA.

LEGAL PROTECTION OF PLANTS (STATE LEVEL—CALIFORNIA)

As a result of the endeavors of many farsighted people, and as concern for preserving California natural heritage has grown over the past several decades, the State has an exemplary program to protect the future of its endangered plants. Three different pieces of legislation have emerged as part of this program.

California Native Plant Protection Act (NPPA). The NPPA was passed in 1977. This act gave the power to the California Department of Fish and Game (CDFG) to ''preserve, protect and enhance endangered plants in this state.'' The CDFG can designate native plants as endangered or rare. The Act prohibits the taking of the plants from the wild and requires salvage of state-listed species on impacted private land Under this act, permits are required for collecting, transporting, or selling such plants.

California Endangered Species Act (CESA). The CESA was passed in 1984. The major intent of this legislation was threefold: 1) to unite various sections of the Fish and Game Code and the NPPA which deal with endangered species and to align state laws as closely as possible with federal laws; 2) to provide formal public opportunity to add, delete, or change the listing status of a species; and 3) to provide a consultation process whereby potential impacts to species and habitats can be determined in light of the California Environmental Quality Act (CEQA).

There are three categories for listing plants in California:

''Rare''— Species although not presently threatened with extinction, are in such small numbers throughout their ranges that they may become endangered if their present environment worsens.

''Threatened''—Plants likely to become endangered species in the foreseeable future.

''Endangered''—Plants whose prospects of survival and reproduction are in immediate jeopardy.

A ''candidate'' species category exists for taxa under review for possible addition to the Threatened or Endangered list. Rare, threatened, endangered and candidate species are all protected from taking. All are subject to the code sections of the CESA concerning preservation, recovery and management.

California Environmental Quality Act (CEQA). CEQA is a piece of legislation which provides protection for listed species by enforcing native habitat protection. Under CEQA, a project cannot have a significant impact upon the environment without adequate mitigation or compensation.

STATE PROJECTS AND PROGRAMS (CALIFORNIA)

In addition to, and in support of state law, there are several programs of interest to anyone concerned about rare plants.

The Endangered Plant Project (EPP) was created by the CDFG in 1977 to carry out listing, protection, and education activities for plants. It is the EPP's responsibility to direct protection efforts and conduct reviews of species status.

The Natural Diversity Data Base (NDDB) is a CDFG program which inventories the locations of the State's rarest species and natural communities. With extensive computer files, the NDDB records can be accessed as a planning tool in order to avoid conflicts between environmental and developmental interests. Within the structure of the NDDB, the Natural Communities Program documents the occurrence of the State's rare plant communities; essential information for the preservation, management and recovery of critical species.

The California Native Plant Society (CNPS) is a private, nonprofit conservation and education-oriented group dedicated to furthering the awareness of the State's rich botanical resources. A major work of the Society's Rare Plant Program is the publication of the CNPS ''Inventory of Rare and Endangered Vascular Plants of California,'' the fourth edition of which was released in September, 1988. The accuracy and credibility of this model publication is evidenced by statements and land-planning documents. In fact, CEQA recognizes many plants listed in the CNPS Inventory, even though they may have no other legal protection under the CESA. Plants in the CNPS inventory are listed alphabetically by botanical name; federal and state status (if any) are indicated and each plant is segregated into one of five CNPS lists:

List 1A—Plants presumed extinct in California.

List 1B—Plants rare, threatened or endangered in California and elsewhere.

List 2—Plants rare, threatened or endangered in California, but more common elsewhere.

List 3—Plants about which we need more information—a review list.

List 4—Plants of limited distribution—a watch list.

All of the plants on lists 1A, 1B and 2 meet the criteria and are eligible for state listing under the Native Plant Protection Act. Furthermore, each entry in the CNPS Inventory is rated as to its degree of ''rarity,'' ''endangerment,'' and ''distribution.''

BOTANIC GARDENS

The role of the botanic garden in handling rare and endangered species is key in terms of taxonomy, identification, research, preservation *(ex situ)*, propagation, education, and display. Storage of pollen, seed, herbarium specimens and vital information on the status of critical species, and making those resources available to researchers is an important facet of rare plant preservation and management. Especially useful are herbarium specimens, as changes in range and distribution can be documented from old collections. Several major botanic gardens in North America have very active rare plant programs.

LEGAL RAMIFICATIONS OF PROPAGATION

The propagator interested in rare plants should look first to laws and regulations concerning the same, obtain the proper permits, and proceed in accordance with federal, state and local laws.

International Level—For obtaining ''Import Permit for Plants and Plant Products'' to be imported into the U.S.:

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
Hyattsville, Maryland 20782

For import permit to import Appendix I CITES plants into the U.S. (plant list as published in the Federal Register; 50CFR 23.23, also available from the same address):

U.S. Fish and Wildlife Service, Wildlife Permit
U.S. Department of Interior
1000 N. Glebe Road
Arlington, Virginia 22203

Request Fact Sheet FWS F-018 for permit procedure. Request Fact Sheet FWS F-006 for CITES information.

Federal Level—For a list of plants protected by the U.S. Endangered Species Act:

Federal Wildlife Permit Office
U.S. Fish and Wildlife Service
U.S. Department of Interior
Washington, D.C. 20240 (703) 235-1903

For a permit application for interstate commerce or export of artificially propagated Endangered/Threatened plants:
Federal Wildlife Permit Office
1000 N. Glebe Road, Room 611
Arlington, Virginia 22201

Request Fact Sheet FWS F-037 for Endangered Species Act information.

For information on Federally listed plants in California:
Fish and Wildlife Service
Sacramento Endangered Species Officer
2800 Cottage Way, Room E-1823
Sacramento, California 95825
Attn.: Staff Botanist

State Level (California). For inquiries and permits on state-listed plants and information on the Natural Diversity Data Base:
Department of Fish and Game
Nongame-Heritage Program
1416 Ninth Street, Twelfth Floor
Sacramento, California 95814

Non-governmental State Level (California). For information on the California Native Plant Society, Rare Plant Program, and Inventory of Rare and Endangered Plants in California:
California Native Plant Society
909 Twelfth Street, Suite 116
Sacramento, California 95814

PRINCIPLES OF PROPAGATION

The principles of nursery plant propagation and restoration with Rare and Endangered Plants are as follows:

1. A permit from the U.S. Fish and Wildlife Service and/or state or local agencies is required.
2. Field trips for collection of propagation materials must be planned carefully to obtain ripe seed and good cutting wood. Gathering material of poor quality will result in propagation failure and negative impact to the plants in their native habitat.
3. Many species have never been grown in cultivation. Research is often required to determine the best propagation and production methods. Consult botanic gardens and conduct tests on sample quantities of seeds or cuttings.
4. The propagator/collector should never deplete the natural supply of rare plant propagation material by collecting all the seeds or cuttings available. This is especially true for species of limited distribution and unknown horticultural requirements.

5. The nursery site used for growing rare plants for revegetation should have a climate similar to that of the native ''field'' site of the plants.
6. Given sufficient time for ''subsequent generation'' propagation, seed and/or cuttings may be obtained from cultivated ''mother'' plants *(ex situ)* which were grown from seed or cuttings collected from plants in nature *(in situ)*. This is a very effective method to secure high quality seed and cuttings from plants in a controlled environment. Extra care should be taken with regards to labeling. This technique will not provide guaranteed pure seed if related plant species can be found in or near the nursery, as cross-pollination and hybridization are possible. By observing the plants in a cultivated setting, the grower can learn how susceptible the plants are to disease and insect damage and determine the proper handling methods in the nursery as well as on the out-planting site.
7. Preparation of nursery-grown plants for out-planting includes the total elimination of all exotic weed, pest and disease organisms from the plants. Introduction of harmful organisms to the native site would be completely contrary to the goals of revegetation and restoration.
8. Phytosanitary precautions in preparation for out-planting on the project site include insect pest and disease prevention and control, weed control in the containers, natural plant vigor and non-dependence on residual influence of agricultural chemicals. It should be noted that the high percentage of success in seed and cutting propagation of dry-land plants can be attributed to modern agricultural ''tools'' including equipment and chemicals. Pathogenic fungi (damping-off, water molds, etc.) which plagued native plant propagators in earlier years, can be prevented or controlled, to a large degree, with the use of fungicides. The propagator/grower of endangered species is presented the challenge of raising healthy plants and preparing them for reintroduction to the native site, ''weaned'' of their nursery treatment and capable of unimpaired establishment in their ''new'' home. This is done by maintaining healthy standards in nursery production and reducing the frequency of chemical treatment on the plants as they grow older.
9. It is necessary to keep accurate records of all field collections, nursery production methods, crops and crop failures, and subsequent seed and cutting collection from plants of nursery provenance.
10. Eventually, plants with ornamental or useful qualities may be introduced into the horticultural trade. This can only be done under provisions of the permit, using seed and cuttings from

nursery-grown plants (the new plants are considered ''artificially propagated.'')

CONCLUSIONS

While the programs for the management and preservation of rare and endangered plants may include nursery propagation, it should be noted that the mere preservation of the species is not the main issue. Artificial propagation and garden cultivation of sensitive species could never replace their existence in the wild state, nor justify the total destruction of their natural habitats.

The Franklin tree *(Franklinia alatamaha Marsh.)*, a North American species, serves to remind us of the loss of a beautiful flowering tree, extinct in the wild, and today known only in cultivation.

Let us hope that the rare plants in California will be preserved in the wild, and when necessary, their populations enhanced by carefully planned revegetation and restoration programs.

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PROPAGATION OF NATIVE PLANTS FOR THE WESTERN STATES

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There are a vast array of plant communities within the western states. Plant communities within this region are diverse, ranging from the great basin plateaus, to the mountain coniferous forests, to foothill woodlands with their oak parklands and spring wildflowers, and to the riperian wetlands. Each plant community within these areas have specific requirements for soil type, nutrition, moisture, and reproduction. Discovering the specific requirements for each native species can challenge the propagator. It is particularly valuable for the propagator to visit these native plant communities and become an open observer of all the interacting forces of nature in order to better understand the requirements of each plant.

Propagation of natives can be valuable for several reasons. One is to restore disrupted sites, caused by natural disasters or by human development, to its natural condition so that wildlife can continue to be supported in that area. Another is the value of ornamental native species that enhance our variety of landscape material selections. While offering year-round displays in color and form, other reasons to plant natives include low water requirements, the ability to recreate natural settings in order to draw wildlife into small urban landscapes, as well as offering hardy low maintenance landscapes for large scapes such as large commercial developments and highway plantings.

Propagation can be done from hardwood, semi-hardwood, or softwood cuttings, or from seed. Material being propagated for a specific revegetation project is preferably taken from site specific collections of either the seed or cuttings. Hiking through your collection areas in the spring when the plants are in bloom allows one to make mental or written notes for collection the following fall.

SEED COLLECTION METHODS

Timing in seed collection is important in order to catch the seed when it is in its prime but before it becomes dispersed. Every year offers new surprises, from plants that have not borne in recent years to discoveries along the trail such as Indian grinding rocks set below ancient oaks, to those hidden "leaves of three," poison oak, *Rhus diversiloba.*

The proper conditions to collect seed vary considerably. The pods of redbud, *Cercis occidentalis*, need to be dry but remain on the shrub so collection is easier. The seed clusters on the blue elderberry, *Sambucus caerulea*, will develop at different times on the same bush. Those for collection should be deep blue with the white coating forming on the clusters to the point that they are beginning to slightly lose moisture. The snowdrop bush, *Styrax officinalis* var. *californicus*, will form a fleshy coating over a large, hard seed. This seed should be collected when the coating is just beginning to split at the bottom but before the seed falls out. The seed should then be dried on screens and the outer shell removed. The Western dogwood, *Cornus nuttallii*, forms a cluster of drupes with interior stones. The completeness of pollination of these clusters will vary from tree to tree. It always seems that the largest cluster of seeds are always on the tallest branch hanging over a near-vertical grade. If you are on a trail several miles in, you are not likely to be carrying pole pruners. This is when on the trail "creativity" comes in. A medium sized rock can be covered with a piece of fabric and tied to a thin rope and tossed over the overhanging branch so the rock circles and catches on the branch. The branch can then be gently pulled into your reach, seeds collected, the rope slackened, and the branch released.

SMALL BATCH SEED CLEANING METHODS

Basic tools for cleaning seed can be found in most households and consist of: a selection of bowls, food processor or blender, window screens, straws, plastic bags, hair dryer, colanders, and strainers. Nothing too elaborate is needed for cleaning small batches—just a good imagination. Seed is first correctly identified and then assigned a record number by which to track them through all stages of cleaning, stratification, sowing, etc. Seeds with a fleshy exterior and small seeds inside, such as *Sambucus spp.* or *Vitis spp.* can be pureed in either a blender or a food processor. This is then put into a tall container and filled with water to separate the non-viable seeds and pulp, which float on the surface, from the viable seed, which sinks to the bottom. With several decantings you can end up with clean seed that is ready to go into stratification. Fleshy seeds with a larger seed such as *Rhamnus spp.* or *Cornus spp.* can be fermented in water then cleaned by rubbing against a coarse meshed sieve to remove the outer pulp. Some seeds need after-drying so the capsules will dehisce, letting out the seed. These are placed into paper bags, labeled, and allowed to sit at room temperature until they are dry. Some seed such as *Alnus rhombifolia, Carpenteria californica,* and *Heuchera spp.* will open and the seed can be collected from the bottom of the bag. Others

such as *Ceanothus spp. Heteromeles* berries, *Fremontodendron spp.* and *Rosa californica* need to be opened physically and the seed separated with a blower, water separation, or screens to remove the chaff from the seed. A simple box lined with ribbed non-skid rubber matting on the bottom and a covered hand-held block works well for most seeds to crush the seed pods apart. The entire crushed contents can be put into a bowl and a hairdryer (set on cool) can be used to carefully separate the chaff from the seed. It is advisable to put a tarp below the bowl to check that the seeds are not being thrown out.

AFTER TREATMENTS AND STORAGE OF SEEDS

Some seeds such as *Heteromeles arbutifolia* are ready to be directly sown. Others may need a 30 to 60 day stratification period at 35° to 40°F. Information on various seeds can be found in several source books, such as *Seeds of Woody Plants in the United States*, USDA, Forest Service. 1974 Agricultural Handbook No. 450. Sometimes no information can be found so you have to think about what natural conditions do to the plant and try to artificially create those conditions. Those that need treatment are either soaked overnight in warm water, given a hot water treatment, or an acid soak if it has an impermeable seed coat, such as *Arctostaphylos* species. Seeds are then mixed with medium grade perlite in a 50/50 ratio. Then moisture is added (but not until it is soggy) and put into a plastic bag. The bag is closed off with a straw so that the seed is vented to the atmosphere. They are then put into a refrigerator for the required amount of time. The bags should be checked every couple of weeks to check the moisture, watch for mold, and to look for the emergence of the radical. They can be directly sown into individual containers or into seed flats at this time, depending on the size and character of the seed.

CUTTING PRODUCTION

Cutting stock can be taken from on-site mother beds or in the wild. You have more control of the vigor of the tissue if it is taken from your own mother beds. Using *Ceanothus* as a general example for natives, we take a basic 3-in. cutting with the lower inch stripped and a node included. It is rinsed in a 2 to 5% chlorine/water bath. The very bottom of the cutting is then dipped into a commercial hormone. (Hormodin #3) It is then stuck into a cutting flat that has a 90% perlite and 10% peat medium. The mix being high in perlite is important because most roots of most natives need good aeration and drainage in the rootzone to keep them from rotting, especially when being put under intermittent mist. The bottom of the stuck

cutting should be kept about an inch from the bottom of the flat to keep it out of the water saturation zone. A definite sign that they are too deep is when you see the bottom ½ in. of the cutting rotting off and the roots developing above it. The spacing between cuttings of native plants is important and should be adjusted for each species, taking into consideration their leaf size and form in order to maintain good aeration within the flat.

GROWING CONDITIONS

Every greenhouse has a different environment overall and many micro climates within the same house. You need to become aware of these and what each species need. Selection of our propagation house was important. Growing predominately native and drought tolerant species, we looked for a house that was tall and had good circulation with minimal problems of condensation drip. The overhead fact fan is kept running at all times except when the exhaust fans are on. The holes are kept in the 10 o'clock and 2 o'clock position so the air will circle down the sides of the plastic and reduce the condensation. The double poly covering and the type of plastic affect the interior conditions. We are currently using Monsanto "Cloud Nine" poly which seems to diffuse the light differently and not be as harsh on the newly stuck cuttings.

Our benches were constructed at ground level so we can conserve our bottom heat and give more air space above the cutting. Each bench is insulated with 2 in. styrofoam on the bottom and 1 in. on the sides. The mist heads arise from the bottom of the bench so there are no problems associated with an overhead drip line. Each table has its own zone on the mist timer so it can be customized for the plants placed upon it. The time and intervals of the mist is watched daily in order to make changes due to temperature and daylength. The mist turns off by the afternoon so that the tops of the plants can dry before night, thereby reducing fungal problems. If the water conditions are kept balanced you will eliminate the need to do costly drenches.

TRANSPLANTING

When the cuttings or the seedlings are ready to be transplanted we use different containers depending where the plant is going to be planted. Those used for transplanting into 1 gallons are potted into rose pots so that they can adapt to other nurseries planting systems. Those going to be outplanted in a revegetation planting will use containers whose root systems are deeper and have ribs that guide the roots down to the bottom drain holes where root pruning occurs. The liners are all grown on raised open benches or raised tube racks in order to get the maximum air pruning and drainage. The finished product is then shipped out to be planted into containers or sent to a revegetation site where it is planted back into the wild.

CUTTING PROPAGATION OF *CUPRESSUS* AND × *CUPRESSOCYPARIS*

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Abstract. The rooting of selected cultivars of *Cupressus* and × *Cupressocyparis leylandii* was evaluated utilizing various cutting treatments. Cuttings of *Cupressus glabra* rooted best with the use of an 8,000 ppm IBA dip and a 6,000 ppm IBA + 6,000 ppm NAA dip; 6,000 ppm IBA was the optimal treatment for *Cupressus macrocarpa* 'Donard Gold'. *Cupressus sempervirens* 'Glauca' produced the highest rooting percentages when cuttings were treated with 8,000 ppm IBA, 6,000 ppm IBA was optimal for rooting cuttings of × *Cupressocyparis leylandii* Clone 121 tended to root the most readily of the three clones tested.

INTRODUCTION

Cupressus and × *Cupressocyparis* are two genera of evergreen conifers widely used in the landscape and produced in the nursery trade in California and the U.S. Southwest. There are some twenty species of *Cupressus*, primarily trees, originating in North America, the Mediterranean, the Himalayas, and eastern Asia. Their appearance may add a bold, yet graceful effect to the landscape, or they may provide a strongly rigid and formal effect. × *Cupressocyparis leylandii*, a bigeneric hybrid between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*, is valued in the landscape for its rapid growth and graceful form (2).

Selected cultivars of *Cupressus* and × *Cupressocyparis* are propagated vegetatively to avoid the variation found in seedling plants. As with many other conifers, some *Cupressus* and × *Cupressocyparis* cultivars root readily from cuttings, while many offer a challenge to the commercial propagator.

Dirr and Heuser (1) indicate that rooting of *Cupressus glabra* is dependent upon juvenility, while clonal rootability is a factor with *Cupressus macrocarpa* cultivars. They also mention the advantage of an IBA treatment for the rooting of *Cupressus sempervirens*. With cuttings of × *Cupressocyparis*, Whalley (4) emphasized the importance of selecting easier-to-root clones, while Howard (3) notes that a basal wound is of advantage.

MATERIALS AND METHODS

Experiments centered on the effects of selected types and on concentrations of rooting hormones and other cutting treatments on the rooting of *Cupressus glabra* 'Blue Pyramid', *Cupressus macrocarpa* 'Donald Gold', *Cupressus sempervirens* 'Glauca', and × *Cupressocyparis leylandii*.

The rooting hormones utilized were the auxins, indole-3-butyric acid (IBA), naphthaleneacetic acid (NAA), and combinations of IBA and NAA. The auxin were generally prepared as solutions containing 55% methanol and 45% water. Some treatments involved the use of the potassium salt of IBA (designated as KIB) or the use of the methylated salt of IBA in a dry talc powder (designated as IBA powder)

Propagation material was collected from vigorous stock plants (approximately five to ten-years-old) during the early winter. Cuttings were prepared approximately 4 to 5 in. in length, such that the outer tissue on the main stem of the cutting was brown at the base and green above. Side branchlets on the cuttings were trimmed as needed so that all cuttings were of an overall uniform size.

Prepared cuttings were washed and disinfected by immersing them for five seconds in a water bath containing 15 ppm chlorine followed by five seconds in 200 ppm Physan disinfectant. Cuttings then received a quick basal dip in their respective hormone treatments and were stuck into pasteurized flats of a rooting medium consisting of 90% coarse perlite and 10% peat moss. Cutting flats were placed on outdoor heated concrete rooting beds in full sun with an average bottom heat temperature of 62 °F. Intermittent mist was provided during the daytime for 10 sec. every 12 to 30 min., depending on weather conditions.

In addition to the standard treatment described above for general rooting hormone experimentation, other specialized cutting treatments were examined. Some cuttings were soaked for 24 hours in a 5% sucrose solution prior to the standard washing and hormone treatment in an attempt to stimulate additional rooting by increasing the carbohydrate content of the cutting tissue. Other cuttings received a quick-dip in acetone prior to a dip in a hormone powder, the theory behind this treatment being that a portion of the IBA in the powder will be redissolved to provide a quick effect on the cutting, while some IBA will remain undissolved in the powder for subsequent effect. Another treatment involved the inclusion of 200 ppm (a.i.) Captan in the IBA solution. Some cuttings of × *Cupressocyparis leylandii* received a basal wound such that a ½ in. slice of bark was removed from one side of the cutting base. One experiment with × *Cupressocyparis* involved the use of a heavier rooting medium (70% fine perlite and 30% peat moss) in an effort to reduce heavy callusing by reducing the air space (and available oxygen) in the rooting medium. Finally, three clones of × *Cupressocyparis leylandii* (one from Monrovia Nursery and two obtained from the Glasshouse Crops Research Institute in England) were tested with 6,000 ppm IBA to compare their rootability.

After a rooting period of four to five months, bottom heat was discontinued and the mist frequency was gradually reduced during a two-week period to harden-off the rooted cutting flats. The cuttings were then removed from the flats and the number of rooted cuttings and the rooting percentages determined.

RESULTS

The treatments given and results obtained are given in tables 1 through 9.

Table 1. Effects of selected treatments on the rooting of *Cupressus glabra* 'Blue Pyramid' (Experiment 1)

Treatment	Average No Rooted Per Flat ± Std. Error[1]	Percent Rooted
3,000 ppm IBA	82.0± 3.2a[2]	41.0%
6,000 ppm IBA	108.0±15.8ab	54 0
8,000 ppm IBA	122.8± 3 3b	61.4
16,000 ppm IBA powder	99.8± 7.7ab	49.9
45,000 ppm IBA powder	83 0± 9.5a	41.5
6,000 ppm NAA	101.3±17 3ab	50.6
6,000 ppm IBA + 5% sucrose soak	121 3± 9 3b	60.3

[1] 200 cuttings per flat. Four flats per treatment.

[2] Means followed by the same letter or letters are not significantly different at the 5% level (Duncan's Multiple Range Test)

Table 2. Effects of selected treatments on the rooting of *Cupressus glabra* 'Blue Pyramid' (Experiment 2).

Treatment	Average No. Rooted Per Flat± Std. Error[1]	Percent Rooted
8,000 ppm IBA	50.7±5.4a	25.4%
8,000 ppm IBA ± 200 ppm Captan	62.3±6.7ab	31.2
3,000 ppm IBA ± 3,000 ppm NAA	43.7±9.7a	21.8
6,000 ppm IBA ± 6,000 ppm NAA	88.7±9.2b	44 4
5% sucrose soak, 8,000 ppm IBA	76 3±3.8ab	38.2
5% sucrose soak, 8,000 ppm IBA ± 200 ppm Captan	78.7±9.8ab	39 4

[1] 200 cuttings per flat. Three flats per treatment.

Table 3. Effects of selected treatments on the rooting of *Cupressus macrocarpa* 'Donard Gold' (Experiment 1).

Treatment	Average No. Rooted Per Flat ± Std. Error[1]	Percent Rooted
3,000 ppm IBA	58.4±6.5ab	22 9%
6,000 ppm IBA	72.5±5.6a	28.4
8,000 ppm IBA	25.0±1.6cd	9 8
16,000 ppm IBA powder	36.5±1.2bcd	14.3
45,000 ppm IBA powder	21 8±2.7cd	8.5
6,000 ppm NAA	37.8±4.4bcd	14 8
6,000 ppm IBA ± 6,000 ppm NAA	7.3±1.3d	2.8

[1] 225 cuttings per flat. Four flats per treatment

Table 4. Effects of selected treatments on the rooting of *Cupressus macrocarpa* 'Donard Gold' (Experiment 2)

Treatment	Average No Rooted Per Flat ± Std. Error[1]	Percent Rooted
6,000 ppm IBA	101.5±16 6ab	39.8%
acetone ± 3,000 ppm IBA powder	111.0± 10 7a	43 5
acetone ± 6,000 ppm IBA powder	94 8±10 7b	37 2

[1] 255 cuttings per flat Four flats per treatment

Table 5. Effects of selected treatments on the rooting of *Cupressus sempervirens* 'Glauca'.

Treatment	Average No Rooted Per Flat ± Std Error[1]	Percent Rooted
3,000 ppm IBA	176 6± 12.3a	78 5%
6,000 ppm IBA	186.0 ± 10 3ab	82 6
8,000 ppm IBA	202 6 ± 6.0c	90.0
16,000 ppm IBA powder	145 2 ±11.2	64 5
acetone ± 3,000 ppm IBA powder	195 6±10.3bc	86.9
acetone ± 6,000 ppm IBA powder	158.6±20 9	70.5

[1] 225 cuttings per flat Five flats per treatment

Table 6. Effects of selected treatments on the rooting of × *Cupressocyparis leylandii* (Experiment 1)

Treatment	Average No Rooted Per Flat ± Std Error[1]	Percent Rooted
6,000 ppm IBA	141 8±12 9abc	56 7%
6,000 ppm IBA ± 200 ppm Captan	177 3±9.7a	70 9
6,000 ppm KIB	173 3±10.3a	69 3
12,000 ppm KIB	160 3±11 6ab	64 1
16,000 ppm KIB	162 8±11.4ab	65 1
3,000 ppm NAA	146 8±4.9abc	58 7
3,000 ppm IBA ± 3,000 ppm NAA	160 0±8 1ab	64 1
6,000 ppm IBA ± 6,000 ppm NAA	116 5±10 4c	44 4
5% sucrose soak, 8,000 ppm IBA	129 5±10 1bc	51 8

[1] 250 cuttings per flat Four flats per treatment

Table 7. Effects of selected treatments on the rooting of × *Cupressocyparis leylandii.* (Experiment 2).

Treatment	Average No Rooted Per Flat ± Std Error[1]	Percent Rooted
6,000 ppm IBA	109.6±6 8a	54 8%
6,000 ppm IBA ± 200 ppm Captan	98 2±5 6a	49.1
3,000 ppm IBA ± 3,000 ppm NAA	96.4±7 0a	43.2

[1] 200 cuttings per flat Fifty two flats per treatment

Table 8. Effects of selected treatments on the rooting of × *Cupressocyparis leylandii* (Experiment 3)

Treatment	Average No Rooted Per Flat ± Std Error[1]	Percent Rooted
6,000 ppm IBA, standard medium	108 2±6.6a	54 1%
6,000 ppm IBA, heavier medium	93 0±8 0ab	46 5
16,000 ppm IBA powder; heavier medium	57 2±6 6c	28 6
acetone ± 3,000 ppm IBA powder; standard medium	76 2±8 6bc	38 1
acetone ± 3,000 ppm IBA powder, heavier medium	68 2±5 7bc	34 1
acetone ± 6,000 ppm IBA powder, standard medium	61 8±11 0c	30.9

Table 8. *Continued*

acetone ± 6,000 ppm IBA powder, heavier medium	74.3±12.8bc	37.2
basal wound 6,000 ppm IBA powder; standard medium	72 7±6.5bc	36.4
basal wound 6,000 ppm IBA powder, heavier medium	61 2±9.0c	30.6

[1] 200 cuttings per flat Six flats per treatment.

Table 9. Rooting percentages of selected clones of × *Cupressocyparis leylandii.*

Clone	Year	No Rooted/No Stuck	Percent Rooted
MN Clone	1987	804/2,000	40.2%
Clone 21	1987	45/70	64.3
Clone 121	1987	54/65	83.1
MN Clone	1988	738/2,000	36.9
Clone 21	1988	86/170	50.6
Clone 121	1988	112/170	65 9

DISCUSSION

The initial experiment with *Cupressus glabra* 'Blue Pyramid' showed 8,000 ppm IBA to be the optimal hormone treatment, but with the sucrose soak showing some promise. A subsequent experiment with this cultivar showed 6,000 ppm IBA + 6,000 ppm NAA to be a preferable hormone treatment over 8,000 ppm IBA, with the sucrose soak continuing to show promise.

In a comparison of hormone treatments on *Cupressus macrocarpa* 'Donard Gold', 6,000 ppm IBA resulted as the optimal hormone treatment. Treatment with acetone and IBA powder was not shown to be of benefit.

Cuttings of *Cupressus sempervirens* 'Glauca' produced the highest rooting percentages when cuttings were treated with 8,000 ppm IBA.

× *Cupressocyparis leylandii* cuttings rooted best when treated with 6,000 ppm IBA in the standard rooting medium. Clone 121 tended to root the most readily of the three clones tested.

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BRUCE BRIGGS: Mike Evans, a question for you. How do we manage to preserve the germplasm for the woody ornamental plant material when we have over eight times the number of kinds of plants of all the others put together? How can we preserve the germplasm and make it more useful to all?

MIKE EVANS: In the earlier talk at this meeting by Dan Parfitt on the use of tissue culture for germplasm maintenance, the principles he outlined would hold true here.

California has an extensive computer search system called the ''natural diversity data base''. This can serve to locate plant material in the state. I don't know if it exists in other states or at the federal level. The California Native Plant Society has prepared an inventory of rare and endangered native species. California has been exemplary in this area and, in many ways, could be a model for tracking the location of plant material in the U.S. and throughout the world.

VOICE: For Eugene Blythe, is light intensity much of a factor in rooting cuttings of your *Cupressus* cultivars?

EUGENE BLYTHE: The major effect of increasing light intensity is to reduce disease incidence. When we try to propagate many conifers inside the greenhouse we may have fungus problems, so we root cuttings outdoors in the full sun under mist, where we get good air circulation.

VOICE: For Ann Fisher: working inside a closed house in rooting cuttings of native plants, what mist intervals do you use?

ANN FISHER: Our mist is on about 4 sec. every 5 min. initially, then we cut it back; but it is changed quite a bit depending upon conditions, cool and rainy or windy and hot.

GERMINATION REQUIREMENTS FOR SEEDS OF SOME AUSTRALIAN NATIVE PLANTS

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Australia boasts well over 20,000 species of plants, thousands of which have exciting horticultural potential because of their unusual and colourful flowers and/or peculiar vegetative form. Comparatively few are in cultivation and, in fact, some beautiful plants are known to only a handful of enthusiasts.

The seed of some of these species often proves difficult to germinate, either failing completely or yielding a very poor and irregular percentage. In nature, such species may germinate only under very specific weather conditions or a sequence of weather conditions that may occur very infrequently, perhaps years apart. These specialised germination requirements have developed to enable those plants to survive in our extremes of climate.

Australia has an area of nearly three million square miles, almost equal in area to the U.S.A., and lays claim to being the driest continent. Only one-third of the continent receives 20 in. or more of rain per year, one-third 10 to 20 in., and one-third less than 10 in.

Rainfall has a tremendous influence on the development of vegetation, but in Australia it is only half the story. The whole of Australia has an annual deficit of rainfall to evaporation. For 70% of Australia, there is not one month in which rainfall exceeds evaporation. In India, for instance, 38% of the rainfall enters the rivers, compared with the Australian figure of 5% to 10%. Mountains are rainmakers, and our dry climate is a reflection of our very old, eroded, and flat land form. Our highest mountain reaches only 7316 ft., and the whole continent averages only 900 feet above sea level. The central area known as Lake Eyre is actually about 39 ft. below sea level.

Certainly there are areas of very high rainfall in Australia, such as parts of the west coast of Tasmania and a narrow strip of the northeast coast of Queensland. Both areas receive between 100 and 200 in. or more of rain annually. However, even there some plants show adaptations that indicate that somewhere in their past their parents suffered periods of severely dry conditions. The adaptations that evolved then are still evident today in the germination of the seed.

The very harsh conditions that have such a profound influence on the development of our plants resulted from both droughts and fires. The plants are both tenacious and persistent, as any farmer

who has ever cleared land will vouch. They can grow very rapidly and flower prolifically when conditions are favourable, and hang on to life, if necessary, through many years with little or no rainfall.

Australia has both a pyrophylic or fire-loving flora and a desert flora which each containing plants with specialised germination requirements that may pose difficulties for would-be growers.

PYROPHYLIC PLANTS

Pyrophylic plants have developed fire-resistant fruits, fire-resistant seeds, or fire-resistant vegetative organs. Some difficulties experienced in germinating seeds of these plants result from a lack of understanding of the phenomena of seed release and pre-germination requirements.

Fire-resistant fruits are hard, woody structures, large or small, that may persist on the plant for many years, thus building up successive crops of fruit. They persist until a bushfire razes the area and, in fact, such species generally occur in a highly flammable type of bushland. Fruit which has been severely charred by fire will often open quite rapidly as the fire cools, releasing the seed, some of which may be several years old.

Species with fire-resistant fruits include eucalyptus, leptospermum, melaleuca, and callistemon, as well as hakea, banksia and xylomelum. There are practical advantages for these plants in releasing their seed on to freshly burnt soils. These include elimination of competition, elimination of pests such as borers that become active in the period between fires, partial sterilisation of the seed bed, provision of a loose ash seed bed, and release of basic nutrients in the ash.

The seed of species such as most of the banksias which hold the seed very securely in the fruit can be damaged by physical attempts to extract it. It will fall out quite freely within a few hours of the fruit being charred in a flame.

Fire-resistant seeds, on the other hand, generally have an extremely hard seed coat. This is characteristic of the seeds of most of our acacia, cassia, our huge range of brilliant peaflowered plants such as oxylobium, bossiaea, gompholobium, mirbelia, and hardenbergia, and other showy plants such as boronia, eriostemon, and the dodonaea or hop bushes. These seeds ripen and are dropped or thrown onto the ground each year, but because of the hard, impermeable seed coat, little germination takes place until the area is burnt. Heat cracks the hard seed coat, and subsequent germination is usually prolific.

Growers need to treat seed to ensure germination. Although elaborate methods such as acid treatments have been devised, filing each seed with a small three-cornered file is the most positive

treatment, but is too tedious to be practicable for other than very small batches. Boiling water treatment is simple, and good enough give an acceptable level of germination. It consists of placing the seed in a suitable container, pouring in boiling water, allowing it to cool in the water overnight and then planting it without drying.

Fire-resistant vegetative parts are another adaptation I should mention. In addition to either fire-resistant fruit or seed, some of the pyrophylic plants have also developed fire-resistant organs called lignotubers. These are woody tuber-like structures at the base of the stem and just below ground level. A bushfire may severely scorch or completely burn off the above-ground plant parts, but the lignotuber is safely insulated in the soil. Soon after a fire, vigorous shoots appear from the lignotuber and develop very quickly.

Species that regenerate from lignotubers include many of the Myrtaceae, such as eucalyptus, leptospermum, melaleuca, and baeckea; in Proteacea, banksia and some hakea; and in Rutaceae, boronia and eriostemon. I can think of only one showy acacia, *A. complanata*, that regenerates from the base.

Pyrophylic plants generally grow in dense mixed populations in areas subject to burning every few years. Such areas are usually spectacular natural wildflower areas, and are at their showiest for three or four years after burning. In following years, plants gradually become leggy and less floriferous, building up fruits and pests such as borers. Some of the weaker hard-seeded species such as boronia may, depending on the time between fires, become over-shaded and die out. However, they usually reappear vigorously after fire.

DESERT PLANTS

It has been stated that more than half of Australia at the present time is either continuously or seasonally arid. Many plants from the arid and semi-arid areas have developed very specialized fruit or seed structures to ensure seed resists the heat and desiccation. Some have highly complex inhibitors to ensure the seed germinates only when there is sufficient rain or soil moisture to allow the establishment of young plants.

Some species have dense or leathery and impermeable seed coats or indehiscent fruit, and include the ubiquitous acacia (of which we have some 835 species), cassia, pea-flowered plants, dodonaea, and some pimelea, and some grevillea. Other species have woolly or papery covers enclosing the seed, such as the indehiscent dried flowers, or else woolly seed coats. Such seed usually requires at least one summer baking in the scorching soil surface—or is it to partially decompose the covering or seed coat so that germination can take place? There is no doubt that some of these are even more complex,

and actually contain a chemical germination inhibitor that has to be leached away by repeated or substantial falls of rain.

These kinds of fruit or seed will often respond to alternate periods of wet and dry. This is achieved by keeping seed pans moist for some weeks or months, and then placing them out in the scorching sun to dry and bake for weeks or months before returning to moisture. Germination in the open sunlight is quite important in any case. I know of seed pans of verticordia that continued to yield seedlings by this method for well over a decade.

Perhaps the most complex genus is eremophila, our beautiful so-called native fuchsia. All species are restricted to arid and semi-arid areas. They have physical, chemical and temperature barriers to germination, and have successfully frustrated most attempts at germination. The seed is enclosed in a tough, leathery, indehiscent fruit, and a hard, bony endocarp. There is also a strong chemical inhibitor that takes time to leach away and, in addition, the one species that has been intensively studied would germinate only on substantial winter rainfall. No amount of summer rainfall would cause germination, and only fruit that had lain in the soil for more than 2 years would respond to winter rain. Presumably, seedlings would scorch if they germinated in summer or after light rain.

Some small successes in germinating eremophila seed have been achieved by using old fruit that had accumulated under plants, soaking them for 2 to 3 weeks, and then storing in a household refrigerator for 4 to 6 weeks before sowing.

Perhaps suspending fruit in a cloth bag in a toilet cistern for a period would be a useful leaching treatment. I know of one instance where a quantity of eremophila seed was inadvertently left in a wheelbarrow of water for 2 weeks after a storm. Some germination occurred after the barrow was emptied on a garden bed.

OTHER GERMINATION FACTORS

After-ripening is a requirement of some species of eucalypt, and may be an unrecognised factor in other genera. Freshly extracted eucalyptus seed often gives a very poor germination, or may not germinate at all. However, if the seed is stored for some months, the germination percentage will rise dramatically and, depending on storage conditions, will remain high for several years.

Small seeds are a characteristic of genera such as callistemon, melaleuca, baeckea, leptospermum, and some eucalyptus. Some of these plants have seed as fine as dust, quite remarkable for woody plants. Such small seed is unlikely to germinate and survive unless kept continually moist for periods of at least several weeks. We are unlikely to see spontaneous seedlings of these plants in the garden even though they produce large quantities of seed, unless there is

a dripping tap in the area. This is probably quite fortunate for us in Australia, otherwise we would long ago have been smothered by these plants.

The natural germination of these small-seeded plants is associated with floods and droughts. Drought often triggers a heavy release of seed, and this, falling on the band of wet soil or sand along the receding water line of a river or dam, produces a forest of tiny seedlings. Fortunately, nearly all are washed away in the flood that eventually follows.

Moving seeds are characteristic of a few plants with seed (actually fruit) that moves in response to moisture or wind, and literally buries itself in the soil.

Our various spear grasses are examples where the awn or awns on the seed twist and untwist with alternating moisture and dryness, pushing the seed along to an obstruction or soil crevice and then down into the soil.

The beautiful genus, *Calytrix*, has dart-like fruit with long hairs on the persistent calyx lobes. These hairs are moved by the wind and twist the seeds into the soil.

RAINFOREST PLANTS

I referred earlier to the fact that some rainforest plants show adaptations that suggest their evolution was influenced by drought. It is an involved story that encompasses continental drift, the Gondwana origin of Australia, dramatic changes in climate, the migration to Australia of successive waves of primitive people—the aborigines—and their intensive use of fire in land management. More parts of the story are the shrinking of previously extensive rainforests to refuge areas and, starting well before Captain Cook discovered the east coast, a return to a wetter climate and the expansion once again of rainforests.

Some rainforest plants such as ceratopetalum and syzygium have seeds with a very short viability that will not survive drying. Others such as aceratium and some cryptocarya have relatively large seeds that take 4 years to germinate. Some seeds will send down a root and establish a woody crown deep in the soil, but the plumule does not appear until about the fourth year. Little has been devised yet that will speed up the germination of these seeds.

As you can see, the germination of some Australian native plants is quite complex, but an understanding of the factors involved assists in overcoming the problems.

BREEDING AND PROPAGATION OF *ALSTROEMERIA* FOR POTTED FLOWING PLANT PRODUCTION

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Alstroemerias are familiar to many as cut flowers or landscape plants. They have been domesticated and hybridized to produce a group of generally tall, herbaceous perennials often regarded as half-hardy or tender. The genus *Alstroemeria* is classified in the family *Alstroemeriaceae.* Uphof (4) described 62 species in the genus which consists entirely of plants native to the South American continent, specifically the countries of Argentina, Brazil, Bolivia, Chile, Ecuador, Paraguay, and Peru. Alstroemerias successfully exploit a wide variety of environmental conditions. Indigenous species are locally used for decoration as well as harvested for food, since dry, fleshy roots can be milled to produce flour.

Modern commercial cultivars of *Alstroemeria* are interspecific hybrids, containing genes from at least two species (1). Cultivars are usually propagated by rhizome division (2). The subterranean rhizome bears numerous buds which gives rise to both vegetative and reproductive shoots throughout the growing season. The rhizome also produces roots, some of which become swollen and develop into tuberous storage organs. A typical propagule consists of a rhizome segment containing shoot buds and possessing both fibrous and tuberous roots.

During 1986 a program to develop and produce alstroemerias for the potted plant industry was initiated. Collection of plants, hybridization, selection and propagation were identified as key components of the program. Plants and seeds, as foundation materials, were collected from both public and private sources A population of dwarf hybrids was obtained from a breeder in California, and several species were bought from commercial seedsmen. Seeds and plants of Chilean species were collected from natural populations. Seeds of Brazilian species were procured through a collaboration with Brazilian scientists. A list of species currently in our collection is presented in Table 1. The collection serves as a source of genetic variation for future improvement of alstroemeria hybrids and as a repository for conservation of germplasm.

Table 1. List of alstroemeria species procured for development program

Name	Source	Origin
A aurea (A aurantiaca)	P	Chile
A. caryophyllaea	P	Brazil
A diluta ssp. *chrysantha*	C	Chile
A magnifica	C	Chile
A. pelegrina	C	Chile
A. psittacina	P	Brazil
A pulchra	C	Chile
A. angustifolia ssp *angustifolia*	C	Chile
A. hookeri ssp *hookeri*	C	Chile
A ligtu ssp *simsii*	C	Chile
A paupercula	C	Chile
A revoluta	C	Chile

Legend P = Purchased from seedsmen, C = Collected

The breeding effort was directed at creation of plants with the following characteristics: a) dwarf habit, short flower stems, b) many flowers per stalk, c) many flowering stalks per plant, d) long-lived flowers, e) bright attractive color, f) year-round performance, g) predictable flowering, and, h) sterility or reduced seed set.

Fertilization is achieved by transfer of pollen from anther to stigma. In fertile crosses, 6 to 8 weeks is required for seed maturation. Seeds dehisce with a sharp 'crack', as the segments of the dry wall of the capsule explode. In the breeding program capsules are generally collected prior to dehiscence of seed. Plants in the hybrid population obtained from California were mostly cross and self fertile. Practically no seed was produced when such plants were crossed with the species or when crosses were interspecific.

A technique was developed for excision of ovules from developing capsules and subsequent in vitro culture of such ovules. The method was used successfully with a variety of parental lines. The overall efficiency in conversion of excised ovules to plants was between 2 and 5%. In general, four months of in vitro culture involving at least 2 culture cycles were required to complete plant formation.

Seeds produced as a result of the hybridization program were subjected to dry heat (32.2 °C) for 28 days. Heat treated seed were sown in a commercial Peat-Lite mix and placed in a greenhouse for germination. Seedling emergence was observed after 4 weeks and was generally complete after 8 weeks. Seedlings were transplanted to either 4 or 6 in. pots when at least three shoots were developed. Depending on time of year, 10 to 14 weeks after transplanting, the flowering plants were evaluated. Plants received 240 ppm N from a commercial 20-10-20 fertilizer. From a population of approximately 25,000 seedlings 20 individual plants were selected as suitable for pot plant production. These select individuals were

numbered and when large enough were divided to produce two plants. One plant was maintained in the breeding program for further hybridization and the other was retained as a stock plant for propagation.

Since large numbers of high quality, uniform plants will be required by finished product producers, we chose to develop a micropropagation method for *Alstroemeria*. Initially following leads from the literature (5), various explants such as leaf pieces, pedicel, peduncle, and stem segments were transferred to media enriched with various concentrations of cytokinins and auxins in factorial combinations. In one case out of over 500, a pedicel segment regenerated into a single shoot, which on further culture was observed to be incapable of rhizome formation. Callus growth was observed on some explants in some media but no adventitious rhizome buds were produced. The pursuit of adventitious regeneration was discontinued due to a lack of positive results and micropropagation through culture of totipotent buds was investigated (3). Rhizome tips were excised from vigorous greenhouse grown plants and sterilized by immersion in a 10% dilution of commercial bleach for 25 min. Buds on the rhizome were dissected out with the aid of a microscope, and transferred to test tubes containing medium gelled with agar. After approximately four months of culture, multiplication was observed. Explants, made up of a rhizome segment and 2 or 3 shoots, were induced to root by transfer to and culture on a medium containing indolebutyric acid. Plantlets were established in soil by transfer to a commercial Peat-Lite medium contained in plastic trays which were placed in a greenhouse equipped with a high pressure fog humidification system. After 2 weeks in fog, plantlets were transferred to ambient greenhouse conditions.

Two-year-old multiplying cultures of *Alstroemeria* are maintained in our laboratory and have regularly supplied plants for finished-pot production. No variations in the propagules have appeared to date Flowering was observed to be uniform within clones and no treatments were required for flower induction.

Although our experience is limited, it seems that alstroemerias appear to be ideal for exploitation as a potted flowering plant. There is a very large pool of variability in the genus and it is possible using current technology to overcome natural barriers to sexual reproduction. We are confident that we have only just begun to develop plants suited to the needs of the US market.

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ROOTS FOR THE FUTURE

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We root cuttings routinely. We plant seeds, they germinate and develop roots. Everyone knows that roots are important, so why all the fuss about roots? It appears there are efficient and inefficient roots. There are aggressive roots that secure and establish the plant quickly and there are the ''welfare'' roots that wander aimlessly doing just enough to get by.

Conducting research is a bit like being a sleuth, in that you are always probing and looking for clues. There had been clues suggesting a variation in root efficiency, but they could not be confirmed. In the fall of 1985, a total of 720 trees were excavated to try to determine why some had grown well while others grew poorly. All of the trees (180 of each of four species) were the same age, had been grown the same way and on the same soil for two years. The procedure used was to sharpen the teeth and sides of a 24-inch backhoe bucket and dig every tree. Before all the trees were dug it was clear that a wide variation in root systems existed. But could the roots be correlated with the growth of the top? The answer was a dramatic, yes!

Every tree that had grown well had a very fibrous root system with many roots arising at the root/stem junction. Trees with a limited number of roots at this junction were always medium or small, even if those roots were well branched several inches from the stem. All trees with a poor root system were small (Figure 1).

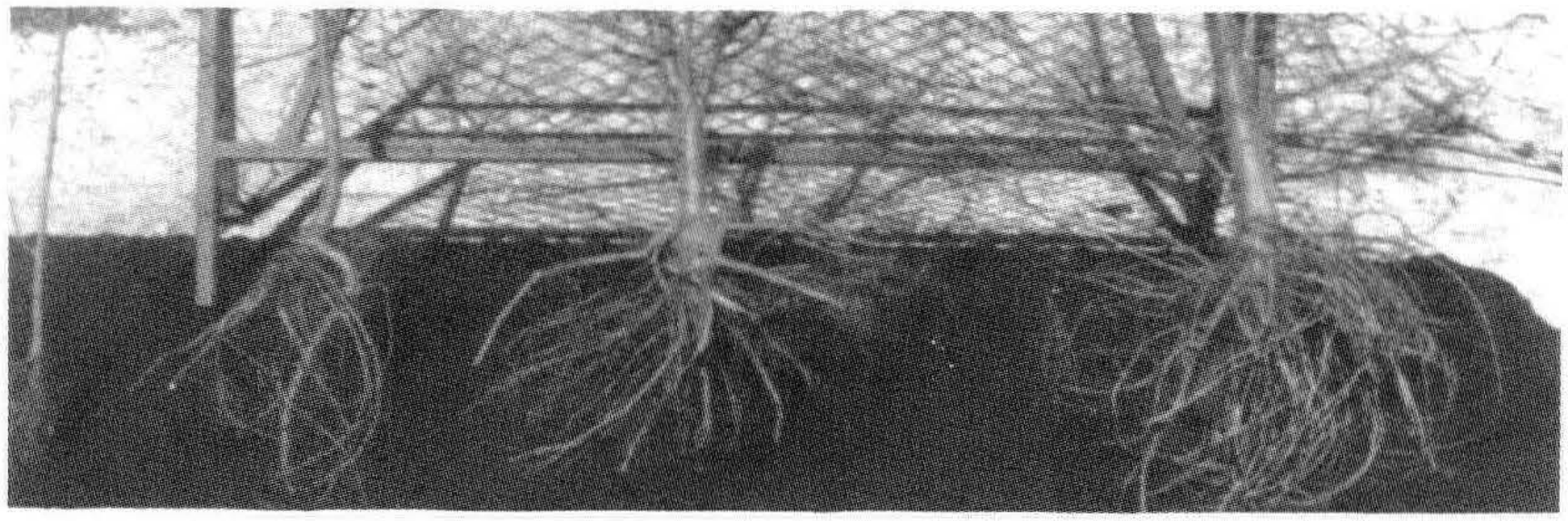
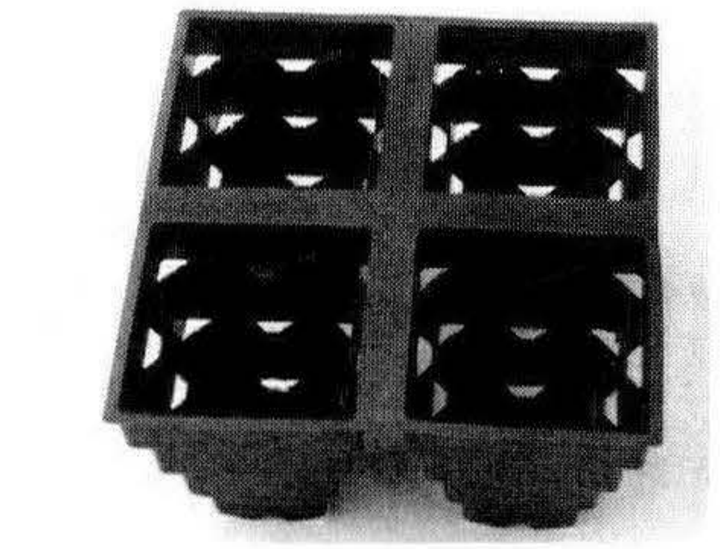


Figure 1. (Above) Roots of lacebark elm, *Ulmus parvifolia*, following two growing seasons in the field. Some of the trees had grown very little while others had reached 2.5-inch stem diameter. Every tree that had many secondary root rising from the base of the stem was a large tree. Trees with a few large roots that then branched, were always of moderate size. (Below) Aggressive roots (with branching) and welfare roots (no branching). When transplanting from a container into the field or landscape, the aggressive roots establish the tree and provide for its health.

This leads to the age-old question: Did the roots make the top grow or did the top make the roots grow? My present view is the roots enabled the top to grow. The roots originating at or near the root/stem junction were more efficient than roots originating further away. This led to the burning question, "If this observation is correct, how can it be utilized effectively?"

Beginning on January 6, 1986, a determined effort was begun to design a propagation container to force roots to develop at the key root/stem junction. A review of old research data and masses of photos suggested that 4 in. was the maximum depth for effective branch root stimulation as a result of air-root-pruning. One opening at the base of the container was unsatisfactory and led to a cluster of root tips. One day while "dreaming" during a coffee break, I looked up at the roof on our house. A north/south roof over the garage intersects with the east/west roof over the main house thus creating the sloping V. I climbed onto the roof and stood atop the intersecting roof lines. It would work for a bottom in a container, thus directing roots to four air-root-pruning holes and increasing the volume of mix at the bottom of the container. This same roof design also led to the sawtooth undulations in the side wall of what

is now known as the "RootMaker Propagation Container." Air-root-pruning can occur at the bottom of every tooth. The other key design aspect added later was an outward slope to the ledges created by the sawtooth undulations around the container (Figure 2).



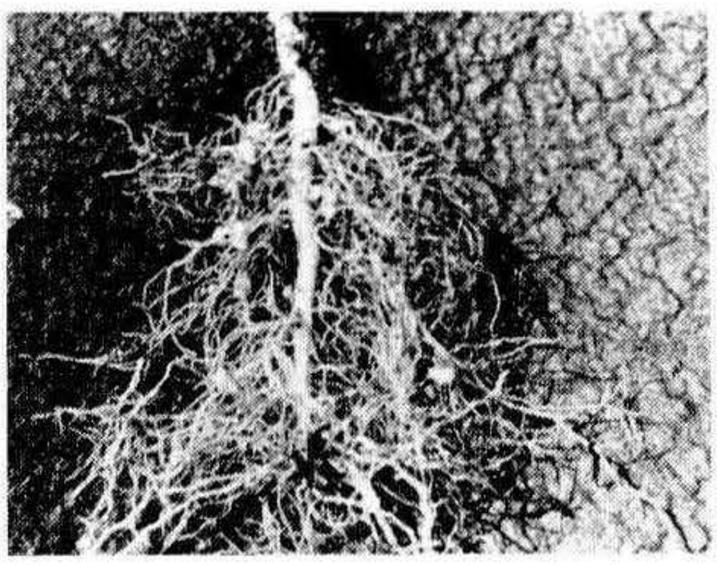


Figure 2. (Above) The Rootmaker propagation container is designed to air-prune the taproot of a seedling at a depth so that secondary roots will form back to the base of the stem. The secondary roots are then air-pruned on the sides of the containers to stimulate further root branching. The design of the container with 24 air-root-pruning openings prevents entanglement of the roots as occurs with conventional containers. Thus at transplanting, roots grow in many directions to quickly establish and anchor the plant. (Below) The tree seedling is a green ash, *Fraxinus pennsylvanica*, that had been grown in the container for three months.

When a seed or seedling is placed in this container, the taproot is directed into one of the four openings at the bottom. When the root tip is air-pruned, secondary roots form through the vertical length of the tap root, not just at the bottom. These secondary roots grow mostly horizontally and strike the side wall of the container where they are guided to one of 24 openings for air-pruning. This, in turn, stimulates tertiary branch roots and so on.

This container is designed to stimulate root branching and create a more efficient root system. With the air-pruning on the sides, the aimless "welfare" roots that typically circle conventional round containers and contribute little to plant health are eliminated.

This container has only been manufactured since January, 1989. Thus far it has worked well on seedlings of all test genera including *Carya* (pecan), *Quercus*, *Cercis*, *Platanus*, *Betula*, *Pinus*, *Pyrus*,

Myrica cerifera, and *Eucalyptus*. It may also be useful in the stimulation of roots on rooted cuttings, especially on those species that develop few secondary roots prior to transplanting.

It also appears that early root branching complements the further development of roots and tops. Thus, if a tree with many roots at the root/stem junction is placed in an in-ground fabric container, the resulting root multiplication and growth stimulation will proceed more rapidly than normal.

The influence of root system quality on plant growth also became clear while trying to solve problems with the old style (Root Control) fabric containers with the polyethylene bottoms. Some nurserymen would be happy with the ''bags'' while another, growing the same species, would report problems. The difference would be the branching of the root system on the original liner. It appears that if a tree has five major roots at the root/stem junction, each one will grow much larger in diameter and exert much more expansion pressure on the fabric compared to the roots on a tree with 25 or 50 major roots.

Another interesting aspect of root response resulted from a series of studies to try to determine if there is an optimum time or diameter to restrict a root. A series of different size holes were drilled in the bottom of small plastic ''funnels''. The funnels were positioned such that the tap root of a seedling would grow down and through the opening. If the root was not restricted by the plastic until it was about 3/16 in. in diameter, few secondary roots formed behind the restriction. In contrast, if the opening was about 2/16 in., the number of secondary roots increased by a factor of five to seven times.

We can now grow trees with more fibrous and compact root systems. These trees will perform better in restricted spaces in the landscapes of the future. How much better? No one knows. Will these trees be sufficiently well-anchored to remain upright and not pose a hazard? Thus far, trees grown with this type of root system have been more tolerant to wind than conventionally-grown trees. Circling roots, especially on trees and other species grown from seed, slow establishment, increase stress, shorten the life of the plant, and contribute to a host of related problems. We can do better and it is up to us as plant propagators to set the stage for other aspects of the nursery industry.

I believe that trees grown using techniques that stimulate efficient roots will grow faster, transplant easier, be healthier longer, and adapt better to restricted root spaces than trees grown conventionally. How fast will these changes occur? Very slowly, because, unfortunately, the more difficult thing to change is tradition.

SOME PLANTS FOR DRY CALIFORNIA CONDITIONS

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Dry, very dry, and getting drier describes most of California. Our climate and geography, expanding population and diminishing resources, regulations, and politics are telling us to use less water just when we would like to use more. We want all-year-green landscapes, but there is not much to water them with. Can we "have our cake and eat it too" in California? Maybe, but only if we choose our landscape plants carefully and propagate, establish, and maintain them properly. For more than fifty-three years we have been working on this at The University Arboretum at the University of California at Davis, and we have had some successes.

Careful observation is the first step in choosing which plants look good with little or no irrigation. We must observe them in all seasons. The best place to look for appropriate plants is in the dry landscapes within our own area, or in places with very similar conditions. The best candidates for the green-but-dry landscapes that we want are plants that look bright or dark green and good all year, need little or no irrigation aside from that required to establish them, be easy to propagate, no trouble to maintain, and long-lasting. We also look for plants that are free of pests and diseases and those that are neither invasive nor dangerous. For nursery production they should be easy to propagate and produce and have plenty of customer appeal. We have found that all plants in these categories look better, stay healthier, and grow faster if they are watered well once every two or four weeks during the dry season, even after they are established. The drier the climate, the fewer successful candidates; but at Davis with its moderate climate (17 inches of rain in the cool season, none in the hot season, and temperature extremes of 18 to 112 °F) we have found that the following species work well.

[1] Superintendent

Drought-tolerant, all-year-green-foliaged plants for summer dry landscapes:

Ground-covers:

Aptenia cordifolia ×
Platythyra haeckeliana,
often called *Aptenia*
'Red Apple'
Baccharis pilularis
'Pigeon Point'
Ephedra chilensis
Eriogonum fasciculatum
Theodore Payne'
Heuchera maxima,
(shade only)
Horkelia spp., (best with
some shade)
Iva haysiana
Juniperus sabina
Lavandula angustifolia ×
L. dentata
Polygonum paronychia,
(best with some shade)
Rhagodia nutans
Ribes viburnifolium,
(shade only)
Rosmarinus officinalis, (low-
growing forms)
Viguiera deltoidea
var. *parishii*

Shrubs:

Acacia hemiteles
Acacia rotundifolia
Adenostoma fasciculatum,
(dwarf form)
Arctostaphylos densiflorus
Arctostaphylos manzanita
Arctostaphylos pajaroensis
Bupleurum fruticosum,
(best with some shade)
Buxus balearica
Callistemon brachyandrus
Callistemon macropunctatus
Cassia nemophila
Cassia oligophylla
Cercocarpus betuloides
var. *blancheae*
Cneorum tricoccon
Comarostaphylis diversifolia
var. *planifolius*
Dendromecon rigida
subsp. *harfordii*
Encelia californica
Ephedra distachya
Ephedra tweediana
Ephedra viridis
Garrya fromontii
Genista aethnensis
Isomeris arborea
Hesperaloe parviflora
Larrea tridentata
Leucophyllum laevigatum
Nolina bigelovii
Phillyrea latifolia var. *media*
Prunus ilicifolia
Quercus coccifera
Quercus parvula
Quercus phillyraeoides
Rhus integrifolia
Rhus laurina
Rhus ovata
Rhus standleyi
Rhus virens
Rosmarinus officinalis,
(taller forms)
Simmondsia chinensis
Vauquelinia californica

Vines:

Billardiera bicolor
Clematis flammula
Macfedyena unguis-cati

Trees:

Abies pinsapo
Acacia blakei
Arbutus andrachne
Callitris preissii
Casuarina cunninghamiana
Cedrus libani
Cupressus dupreziana
Cupressus forbesii
Cupressus sempervirens
Laurus nobilis
Lyonothamnus floribundus subsp. *asplenifolius*
Olea europaea, fruitless forms, e.g. 'Swan Hill'
Pinus canariensis
Pinus jeffreyi
Pinus ponderosa
Prunus ilicifolia
Prunus lyonii
Pseudotsuga macrocarpa
Quercus agrifolia
Quercus calliprinos
Quercus ilex
Quercus suber
Quercus tomentella
Tetraclinis articulata
Umbellularia californica

VOICE: Dr. Whitcomb, would you comment on staking trees.

CARL WHITCOMB: I would rather not stake trees but it is something you may have to do to get a strong trunk with a good taper. The trunk must have some freedom to move, however.

STEVE McCULLOCH: Carl, what feeling do you have about the color of the container pots?

CARL WHITCOMB: I have worked with an assortment of colored pots. I believe shading the exposed side of the pots is best to reduce the temperature so the roots can function. The color really does not make much difference in my opinion.

VOICE: In the slide of root variability you showed among seedling trees, how much of that variability is just due to genetic differences?

CARL WHITCOMB: My feeling is that a big portion of that difference is due to root system quality, not genetic. I think that we have used genetic variability as a crutch in alibiing for poor performance in certain plants.

VOICE: For Stephen Garton: Do you find a difference in cold tolerance of *Alstroemeria* species and cultivars?

STEPHEN GARTON: Yes, there is a difference in cold tolerance, depending upon the genetic background of the cross. We have grown some outside in Salt Lake City, where last winter (1988-89), we had 20°F below zero. The plants were in pots plunged in the ground, with good survival. Alstroemerias planted in people's gardens survived and grew in the spring.

MICHAEL SMITH: David, we have had problems in germinating boronia seeds, an Australia native. Can you shed some light on this?

DAVID HOCKINGS: Germination of boronia seed is difficult if it has been stored for any length of time. It is best to get mature fruit, and then use seed where the seed coat is starting to darken but the seed is still large and soft—then it will germinate readily. If it is put in storage and the seed coat hardens, then germination is poor. Giving a hot water treatment will help, not boiling water, but as it comes out of the hot water tap.

NEW PLANT FORUM—WESTERN REGION

BRUCE BRIGGS, MODERATOR

STEVE MCCULLOCH: *Magnolia acuminata* var. *cordata* 'Miss Honeybee' was introduced to the trade by Jim Merrill of Painesville, Ohio. It originated as a chance seedling of *Magnolia acuminata* var. *cordata*. The bloom size is approximately 10 cm in diameter and is a light to medium yellow color. The plant blooms and leafs out at the same time. Plant size is approximately 25-30 feet tall. This plant is rather difficult to propagate. Plants can be grafted with some success, whereas cuttings are virtually impossible to root. 'Miss Honeybee' is now successfully being micropropagated.

Vaccinium crassifolium 'Wells Delight' is an ornamental form of creeping blueberry (*Vaccinium crassifolium*) selected from native stands in North Carolina. This selection was named and introduced to the trade by the North Carolina State University Breeders Release Board and Agriculture Research Service to honor the late Dr. Bertram W. Wells, former head of the N.C. State Department of Botany and renowned plant ecologist. The plant is a low (12 to 16 cm) creeping broadleaf evergreen groundcover. The leaves are a lustrous dark green color. The blueberry-shaped flowers are white to pink in color. The fruit is a black to purplish-black berry from 3 to 9 mm in diameter. 'Wells Delight' should provide an effective groundcover tolerant to heat and drought and adapted to full sun or partial shade. It is hardy to at least Zone 7. It is propagated by stem cuttings and tissue culture.

HUDSON HARTMANN: *Olea europaea* 'Swan Hill'. This is a fruitless olive tree discovered by me in a planting of seedling olive trees near Swan Hill, Victoria, Australia in 1960. Vegetative growth is similar to the common cultivated fruiting olives. 'Swan Hill' blooms heavily but sets little, if any, fruit. Abnormalities in the development of the embryo sac are the main cause of unfruitfulness. The anthers contain very little pollen that clumps rather than dispersing, a bonus for persons allergic to olive pollen. Cuttings are very difficult to root, even under mist and with IBA treatments, in contrast to most other olive cultivars whose cuttings root easily. Propagation of 'Swan Hill' is generally done commercially by grafting onto easily-rooted cuttings of the cultivar 'Oblonga', which is resistant to verticillilum wilt, although rooted cuttings of 'Swan Hill' itself are resistant to verticillium. At present (1989), 'Swan Hill' is used commercially as an ornamental, non-fruiting olive tree mainly in Arizona, and to a lesser extent, in California. 'Swan Hill' is subject to winter-killing at temperatures below about 15 °F.

RANDY BALDWIN: *Casuarina torulosa,* forest-oak. A small decorative tree to 25+ ft. tall with deeply furrowed corky bark and delicate weepy dark purple foliage. Tolerant of most soils, dry conditions and frost. A choice specimen tree for foliage color and texture with the beautiful bark as a bonus. Propagation by seed. Our thanks to the University of California, Berkeley, Botanic Gardens, whose magnificent 15 ft. specimen inspired us to grow this tree. (A nice grove of young trees is planted in the Santa Cruz, California Arboretum).

Elymus condensatus 'Canyon Prince'. A selected form of the California native giant wild rye, *Elymus condensatus*, that has been recently introduced by the Santa Barbara Botanic Gardens. This selection was made in 1968 by Ralph Philbrick from wild-collected material off of Prince Island, a small island to the west of Santa Rosa Island in the Channel Island chain. It is a medium sized evergreen (semperglauca) grass that, when grown on the dry side, only grows 2-4 ft. tall, about 1/3 the size of typical *E. condensatus.* Although this grass is rhizomatous, the vegetative shoots are short and mostly up-right; forming a dense clump. The short upright stems bear 12 to 18 in. long by ½ in. wide chalky grey-green leaves. Flowering commences in the fall with dense erect spikes shooting up over 18 in. above the foliage. Propagation is by divisions taken fall through spring. Our thanks to the Santa Barbara Botanic Gardens for this plant.

Myoporum floribundum. A picturesque sprawling shrub from New South Wales and Victoria, Australia, reaching to 9 ft. tall with an equal spread. This shrub has drooping linear leaves along horizontal branches that are covered with small white flowers in spring. A very showy plant for specimen plantings. Give this plan well-drained soil in full sun to light shade with average garden watering and plenty of room for best results. Propagation is by cuttings taken in the fall. Our thanks to the University of California, Santa Cruz, Arboretum for this plant.

Oxera pulchella, royal climber. A tender evergreen climber from New Caledonia with dark green leathery leaves and showy ivory white slightly fragrant flowers that can appear for long periods any time of the year. This plant deserves to be in gardens wehre there is little or no frost and a sheltered, well-drained planting site can be offered. Propagation is by cuttings in the summer. Our thanks to University of California, Santa Barbara, Biological Studies Dept. for this plant.

Pachystegia insignis, Marlborough rock daisy. A dense, 3-4 ft., slow-growing shrub from Marlborough, New Zealand, where it inhabits harsh coastal rock crevices. The large thick leathery leaves

that are borne on the tips of the stout, densely tomentose branches, are clad in silver or rust hairs when young and become glaborous on the upper surface and tomentose on the lower with age. The summer 2-3 in. wide "daisy" flowers are a composite of white ray flowers and yellow disc flowers. Useful as a specimen shrub, container plant, or in a mixed border in full sun or light shade. Plants will take both garden conditions, or can be used in xerophytic plantings. Spent flower heads are useful in flower arrangements. Propagation by seed. Our thanks to many people for the stock plants for our crops, including UCSB Biological Studies Dept. (A 20 year old specimen plant at UCSB died this year); the late Austin Griffith (Native Son's Nursery), who gave us our first stock plant; Ed Carmen (Carmen's Nursery) for our second stock plant; Saratoga Horticultural Foundation for enough plants to finally get us started into production.

Scabiosa sp. (*S. crenata*?). A small tight shrub to 2 ft. with glossy dark green leaves having crenate margins and pale lavender pincushion flowers rising 6 in. or better above the foliage. This plant is possibly *Scabiosa crenata* but confirmation has not yet been made. The seed came to John Bleck at the University of California, Santa Barbara, from Coimbra Botanic Gardens in Portugal in 1982, identified as *Scabiosa cretica. S. cretica* is a coarser grey-leaved plant, however, and it is possible that the seed was mixed with *S. crenata,* another plant that was on the Coimbra Seed list that year. In any case, we like this plant. It takes dry hot conditions, forming dense, dark-green mounds with its pale pincushions appearing year-round. Hardy to at least 26 °F. Propagation is from softwood cuttings in spring. Our thanks to John Bleck for this plant.

Westringia linifolia. A tough fine-textured medium-sized shrub 6-8 ft. tall with equal spread, from New South Wales, Australia. The pale lavender flowers, which are borne in profusion throughout the year, seem to hang in the delicate foliage.

ALAN SHIMAMOTO: *Pittosporum tobira* 'Cream de Mint'. U.S. Plant Patent 6449. 'Cream de Mint' is a new and improved compact dwarf variegated, pittosporum that was discovered as a sport from the popular *Pittosporum* 'Wheeler's Dwarf.' 'Cream de Mint' is principally distinguishable by: a) being resistant to leaf spot and reversion; b) venation is distinct, pronounced, and uniform between edge of leaf blade and center of leaf blade; c) color of mature leaf blade is medium-green, edged in creamy white; d) ultimate height has been determined to be approximately ½ to ¾ meters.

SEEDLING PRODUCTION—A CURRENT PERSPECTIVE

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INTRODUCTION

Seedling production in the hardy ornamental stock industry in the U.K. has made dramatic steps forward in the last 15 years or so; previously it had been almost the exclusive prerogative of the European Continental nurseryman.

Seedling production, as a component of hardy ornamental plant production, however, is still a relatively minor sector. The vast majority of such plants, both in numbers and value, is still being produced by vegetative means. Nevertheless, the propagation of plants from seed in the U.K. has very rapidly developed a sophistication in terms of logistics, science, and economics which is comparable with the best conventional operations of vegetative propagation.

The production of seedlings falls into a series of categories, classified by the end product—none of these are mutually exclusive—but can be designated largely on the sophistication of production technique; for example: hedging plants, urban/amenity forestry, rootstocks, landscape uses, and specimen subjects.

The financial ''intensity'' of production is determined by the value of the product and the scale of production. The business is to produce a crop of seedlings of a sufficient quality on a profitable basis and this requires attention to a series of factors.

In an ideal world we would be able to understand each subject sufficiently to ''blueprint'' seedling production on the basis of:

(i) date of required seed germination
(ii) period or type of treatment to encourage germination of ''unencumbered'' seed
(iii) treatment of seed to remove dormancy constraints
(iv) storage conditions
(v) collection and subsequent treatment
(vi) source plant

It is not difficult to determine accurately for a fully imbibed and ''unencumbered'' seed, the period required for germination to occur under specified environmental conditions. Most seeds, however, are ''encumbered'' and require some form of treatment to release them from these constraints.

It may simply be a question of treating the seedcoat to allow imbibition but such techniques are still primitive and coarsely managed. No significant advances have been made in the treatment of such seeds since scarification and acid digestion were recommended.

Seeds may then require a period of chilling but what is known of threshold temperatures and periods of exposure? Even the physiology is not well understood. Despite literally thousands of papers on this subject, virtually no practically useful recommendations can be extracted and despite the tremendous advances in cellular and molecular biology, as well as concurrent promises that it is only a matter of time—that's what it is!

To a lesser degree, but still significantly, some subjects exhibit ''immature'' embryo conditions.

SEED SOURCES

Vast improvement in the collection, extraction, storage, and distribution of commercial seeds has been experienced in recent years and suppliers nowadays are becoming more concerned, for the consumer standards have risen world-wide in :

Identification (reliability/provenance/selection),
Reliability of supply—or communication of crop failures,
Maintenance of viability/storage, and
Season of delivery.

This is not to suggest that the present situation is in any way approaching perfection but it does recognise that the interests of the consumer are being recognised by the supplier.

SEED COLLECTION

The local collection of seed by the propagator is still a major contributor to production and, provided that it is economically managed and costed effectively, then its place is assured. Local collection allows for sure identification, parental selection, optimal season of collection, rapid processing and storage, and hence reliability of supply.

SEED STORAGE AND VIABILITY

The successful storage of seeds depends on maintaining the highest levels of viability for the required storage period. This requires knowledge of suitable storage conditions for the duration envisaged and must be related to the condition, composition and physiology of each individual subject: generalisations are suspect and rarely provide a satisfactory answer.

However, the greatest signficant feature contributing to successful storage is to commence the storage treatment as soon after collection as is feasible, so that the attenuation of viability begins at the highest level and with the greatest potential (i.e. before any significant deterioration in viability has occurred) thus giving the longest period of storage life.

CHILLING AS A DORMANCY BREAKING TECHNIQUE

The need for the cold stratification of seeds of plants of temperate region origins has long been a subject for discussion and the fact that such seeds require to be exposed to 'cold' in an imbibed condition has been well known.

The physiological encumbrance which prevents seed germination can only be eliminated once a critical pathway in the seed's metabolism is available and this requires a knowledge of the threshold temperature at which this becomes available. No one temperature is critical, each subject has its own and there is evidence to suggest that some subtropical plants require a "chill" (at about 15 °C). Chilling is, therefore, a relative phenomenon and this response criterion usually reflects the particular climate experienced naturally by a particular subject.

Once a suitable threshold temperature has been established, the length (time) of chill is relatively constant with little variation within a taxon (unless climatic provenances are existing). Reported variations among samples can usually be attributed to incomplete imbibition, restriction of oxygen permeability, other seedcoat conditions, etc.

Temperatures below the threshold do not accelerate the process but similarly do not hinder unless sufficiently low to cause freezing of intracellular water, thus it is possible to select chilling temperatures to suit a collection of subjects (all responding below a particular threshold temperature).

SUMMARY

Seedling production, despite considerable practical advances in recent years still remains a system largely based on empirical and traditional approaches. The vast array of scientific literature on seed physiology has yielded little of practical significance to the propagator and the major breakthrough is still awaited.

BED DENSITY—ITS SIGNIFICANCE IN SEEDLING PRODUCTION

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The achievement of producing a consistent objective density is the single most important factor in the production of field-grown seedlings. I propose to deal with this subject under three headings:

1. Production objectives—what are you trying to do?
2. Minimising the variables—seed testing, organisation, and field factor.
3. Securing the crop—Good husbandry.

There are cultural operations that can minimise errors but in both objective and economic terms if the correct number of seedlings are not in the right place at the right time that the seeds germinate there is little that can be done to achieve the target or objective.

There is one exception: the potted seedling liner crop. These are often sown densely, pricked or potted off on germination and can be roomed out in a way similar to normal potted or container production so as to achieve the size and type of plant that is required.

PRODUCTION OBJECTIVES

We must set firm, specific objectives. Do we want: a one-year or a two-year crop, feathered or single-stemmed plants; are the plants required for potting-off or growing-on in the field; and what size, height, and girth constitutes the specifications?

There are many tables with recommended sowing density rates. Most give the maximum number that can be achieved per square metre but without considering what the plants are to be used for. This is of little value. The Forestry Commission in its *Nursery Practice Bulletin* (1) gives good recommendations for a specific crop and these provide a useful guideline when assessing bed density for forestry purposes. However, in my opinion it is better to use the simple formula as detailed on page 36 in Philip McMillan Browse's book, *Hardy Woody Plants from Seed* (2), provided always that you can decide the final plant population, as this is the vital factor in the equation.

As a general rule, when deciding plant populations the leaf size will determine the maximum number of plants. Large-leaved plants can only be grown at fairly low densities, whereas finer-leaved and needled plants can have substantially higher densities and still produce a satisfactory result. Some typical examples are shown in Table 1.

Table 1. Densities for the production of transplants as understocks

Plant		Plants per sq metre
Aesculus, Juglans, Ailanthus, Catalpa		50-180
Castanea	as a 2yr crop	80-100
Robinia, Laburnum	as a 1yr crop	100-150
Robinia, Laburnum	as a 2yr crop	150-180
Quercus	as a 2yr crop	120-150
Sorbus intermedia	as a 1yr crop	120-150
Fagus, Fraxinus, Corylus	as a 2yr crop	150-180
Crataegus, Tilia	as a 1yr crop	180-200
Betula, Alnus, Sorbus aucuparia	as a 1yr crop	200-220
Rosa spp	as a 1yr crop	250
Small conifers, *Picea* and *Pinus*	as a 1yr crop	400-600
	as a 2yr crop	250-300

The two-year crop assumes a thinning is undertaken during the dormant period after the initial undercutting.

MINIMISING THE VARIABLES

Seed testing. You must know what you have to work with. The tests that are done must be objective to enable you to calculate the bed density. Samples regularly taken and pre-germinated will give an indication of how the seed is developing and it is from this information that the calculations can be made.

Soil sterilisation (pasteurization). Partial sterilisation of the seedbed area with chemicals will eliminate many of the harmful pathogens that reduce bed densities. This operation should be carried out in the autumn when the soil is warm and in a moist condition. Covering the soil is essential to ensure thorough penetration of the fumigant released from the chemical and this also allows time for ventilation of the beds before normal sowing takes place at the turn of the year. Details of the rates of chemical to be used can be obtained from manufacturers, but on our soil type we find that 400 kg per hectare of Basamid (dazomet) incorporated to a depth of 15 cm has proven to be satisfactory.

Field factor. This is the term used to describe all those unfortunate conditions that reduce seed germination. It may be, for example, the ravages of vermin or birds. It is important to remember that the objective density, if not achieved, will change the shape and dimension of the seedling produced. Every effort should, therefore, be made to protect the crop against the ravages of such vermin. Where autumn sowing is practiced it could be the effect of rootrots during the winter. Raising beds to aid natural drainage will minimise this field factor.

Sowing. Attention to detail is vital. Care must be taken to ensure that the sowing is even, that there is no variation across the bed. Sowing in windy conditions can often lead to an uneven density. There must be irrigation backup. Remember, we are sowing an active seed that is still undergoing treatment and is in a moist condition. Drying out, particularly at sowing time, can be lethal Irrigation backup and immediate covering to minimise the field factor are part of the diligence that is necessary at the sowing operation.

SECURING THE CROP

It is reasonable to say that if all the foregoing has been carried out carefully, the growing of the crop is a comparatively routine operation. But we must ensure the best performance of our seedlings to maximise the crop.

Irrigation. Support will be necessary at all times and water should be given in frequent small doses, particularly at seed germination time where heavy doses could cause damage to the bed and encourage disease.

Feeding will be necessary to maintain the correct nutrient ratio and perhaps adjust the growth of the crop throughout the season. Normally fairly high levels of nitrogen in the early part of the year are necessary followed by increasing potash applications to mature the plants for autumn, the phosphate levels having been incorporated in a base dressing.

Pest and disease control. Regular observations will be necessary in addition to the routine prophylactic spray programme. Remember, a minor attack can soon become an epidemic where high densities of a monoculture are undertaken, and soft, young, seedlings are particularly vulnerable.

Undercutting. Root pruning to balance the growth and produce a firm, stocky seedling may be necessary during the growing season; this should be timed to coincide with cool, showery weather or, if this is not possible, be supported by a regular irrigation backup.

Thinning. This may be necessary where growth is vigorous. (This was the case in the very warm summer of 1989 with some of our seedlings). Germination always looks sparse at first and it is important to time the thinning operation so that no energy is lost from the crop. Early action will ensure that the objective size of plant is achieved. If a too dense crop is allowed to grow on, then only poor and inferior seedlings will result.

Shading. Some woodland plants that are known to grow naturally under a canopy may require shading during the middle part of the growing season.

Trimming. Some shrubby plants can be trimmed to condition them and this helps bud development on the upper parts of the stem and,

if used in conjunction with undercutting, can improve the transplantability of the crop.

Stressing. It is often necessary to stress or wrench the crop in order to help it harden-off and this is normally done toward the end of the summer. The important thing is to ensure that the crop is in good condition for lifting as early as possible. Seedlings are juvenile and tend to carry-on growing late into the season and this may cause die-back if plants are lifted before they are ripened-up, particularly where storage is used, and storage rots often occur in material that is not correctly hardened-off. Too early lifting will manifest itself in the die-back that occurs when the crop is transplanted.

CONCLUSIONS

Securing a high percentage of the objective grade with a minimal of off-grade and wastage will maximise the use of good seed and its potential and ensure that the correct size of plants for any specific operation are grown to the correct size and conditioned to give the maximum transplantability leading to a successful establishment of the final crop. This is largely a matter of achieving the correct bed density.

LITERATURE CITED

1 McMillan Browse P D A 1979 *Hardy Woody Plants from Seed* Grower Books

2 Nursery Practice Rev 1989 Forestry Comm Bull 43 J Aldous & W Mason

SEED COLLECTION; WHY, WHERE, WHEN AND HOW

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WHY

There are some advantages as well as some disadvantages in collecting one's own seeds. Among the advantages are:

Origin. With care, truly native sources of seed, better adapted to local conditions can be obtained.

Freshness. Seed can be collected at time of maximum quality giving better yields than can be obtained from bought-in seed.

Earliness. Early collections can sometimes shorten the period required for seed treatment and so save on time required to produce plants from seed.

Low Cost. On occasions—where distance is small, seed set is good, and conditions are perfect, collecting one's own seed can be very economical.

The major disadvantages are:

High cost. Unless properly organised, collecting one's own seed can be quite significantly more expensive than bought-in seed. This is particularly true where large distances are involved and where expensive collecting equipment is needed.

Conflict of interest. Because of other pressures in the nursery, seed may not always be collected at the proper moment.

Inadequate storage and extraction equipment. Poor storage facilities and poor equipment can result in dead and damaged seed, poor yields, and relatively expensive seed. Home seed collections should therefore not be undertaken without careful planning, or estimation of the costs involved, and a clear appraisal made of the advantages to be gained.

WHERE

Where to collect seed is determined by many factors:

Legal. Seed collection of some species is covered by government regulations that restrict the use to which the plants may be put.

It is important not to trespass or to collect without the owner's permission. Often owners expect some financial reward for granting permission. Where enforced it is usually between 10 and 15% of the retail value of the seed.

Origin. Is the source truly native or is it recently planted and therefore likely to be from non-native sources? Both types of seed may be of interest but should be kept separate.

Plant population. Is the source isolated and therefore likely to show inbreeding and reduced seed viability? Are there adequate

individuals present to ensure good mixing of the existing gene pool? This is particularly important when collecting from trees under stress, which often produce above-average flowering and fruiting. Collection from such trees should be avoided, however tempting it may be!

Plant form. Where a seed crop is plentiful it is sensible to collect seed from plants of good form. However collections should not be restricted to such trees, unless intended for forestry use. (Seed for use for forestry may normally only be collected from specially Registered Stands of superior physical form). In a population of trees, tree form and growth can be shown to be affected by many factors including seed origin (by up to at least 25%), by planting density, by predation, by fertilisation, by thinning, by location. Restricting seed collections only to stands of superior form may therefore unnecessarily restrict the amount of seed available.

In a good crop year collections should be concentrated on Registered Seed Sources of forestry species or from other stands of good quality but probably the best chance of obtaining seed of truly improved genetic character is to look for superior individuals in native or semi-natural woodland and to collect seed from them.

Projected yield. Flowering is the first hint of a potential seed crop; there is no seed without flowers. However, although flowering may occur widely in a crop it does not necessarily mean that there will be a good yield of seed. Many factors influence the set of seed and the potential harvest. The weather at pollination, after pollination, during ripening and at time of harvest significantly influence the yield of seed. Frost, rain and wind influence the seed set; newly-formed fruits may be killed by frost.

The persistence of the crop is affected by wind during mid-summer and, finally, the rate of loss of the seed from the tree is also determined by frost, wind, and rain. Before planning a collection it is advisable, therefore, to make an estimate of the potential yield. Failure to carry out estimates of the yield can result in much waste of time and effort.

Homogeneity of crop. Some species have been shown to hybridise, so the proximity of two closely-related species may render collections unwise. *Tilia platyphyllos* and *Tilia cordata* hybridise freely. Another group of species that cause difficulty is *Sorbus* spp. which hybridise freely as anyone trying to grow pure *Sorbus aria* knows only too well. Perhaps the most notorious species for hybridisation problems are *Quercus* spp. *Quercus robur* and *Quercus petraea* hybridise freely and have been planted so widely that it is questionable whether any truly pure stands now exist.

WHEN

Proper planning of collections is important if seed is to be collected at the optimal stage for whatever purpose. Sometimes collections are made very early in order to bypass the natural dormancy of the seeds. *Acer campestre* is a good example of what can be achieved by early collections although the smaller size of seedlings that are obtained from early collections may not always be acceptable.

Provided satisfactory handling facilities are available it is possible to collect some species while they are slightly immature, e.g. *Acers* and many conifers, in order that the period of collection may be extended. This is done when few collectors are available or when very large quantities of seed or cones are required and time may be limiting.

The facilities required involve areas where the seeds can be subjected to good drying conditions, possibly involving moving air over or through the seeds or cones and turning them frequently to prevent spontaneous heating or the development of mould.

Collections are normally made when seed is fully mature. For some species the period of maturity lasts a long time, e.g. *Pinus* spp.; for other species the period can be very short because of the influence of weather (wind *Acer* spp.; rain *Quercus* spp;, frost, some species of *Quercus*), or animals. Squirrels eat seed of hazel and many conifers, birds are a pest on berried fruits such as *Berberis darwinii* and *Sorbus* spp.

There is a group of species where the timing of collections is more in the hands of the plant than those of the humans making the collections. These are the nutty fruits that are shed by trees and shrubs as they ripen, e.g., acorns, chestnut, beechnuts, and walnuts. Some weather conditions, such as wind or frost, aid the nut-drop but are not an absolute requirement for nuts to drop. Empty seeds of beech are regularly shed before the full seed and the heaviest drop of acorns usually follows a very severe frost and wind.

Where collections are to be made some distance from base it is invaluable to have someone nearby who can be relied upon to advise on the ripening of the crop. They can save much wasted time and effort.

HOW

There are many ways to collect seed and fruits. The methods obviously depend upon the type of seed or fruit produced.

Collection of seeds on the ground. For these, site preparation is a key factor. Clearing away the undergrowth around heavy fruiting trees helps in the speed of collection and is usually justified. It is desirable to try to do it on a regular yearly basis even in non-crop years as this lessens the task in subsequent years. For beech, removal

of cupules from previous year's crops, or stones or chalk of similar size, can help to reduce the bulk of material to be processed and certainly helps in the final cleaning of the seed.

Traditionally tarpaulins are recommended for laying on the ground under heavy fruiting trees. However, tarpaulins are very costly, do not allow rain to run off and can aggravate the sprouting of acorns is wet years. A cheaper and more effective tool is heavy-duty netting as used in nurseries for frost protection. They are widely used on the European continent for beech nuts but should only be used after due consideration of the risk of vandalism. The nets allow only seed and newly fallen leaves to be collected and make seed cleaning much easier.

Collection from shrubs at ground level. This is the most comfortable method of collecting seed and fruit. The object is to maximise the amount collected by making both hands available. The collection receptacle should be strapped on by a harness. To catch seeds that fall outside the receptacle, hessian or netting should be spread under the bushes.

Collection from ladders. Step ladders or orchard ladders can be used but at the top they are not very stable. Some point of anchorage aids stability and allows two hands to be used. Extendable ladders can also be used but they are heavier, more cumbersome and are not good for collecting from the lower branches due to the angle they make with the trunk. Hard hats are also advisable.

Collection by climbing. This is still one of the commonly used methods in many countries. In the long-run, properly-trained climbers are arguably as economical to use as trying to use one's own labour. All health and safety procedures and employees liability insurance must be strictly complied with.

Collection from felled trees. Theoretically, this is the most economical way to collect seeds of many species, particularly conifers except the true firs. However, if timber removal is proceeding at the same time as seed collection, operations must be properly coordinated. Heavy forest machinery can bury the fruit-bearing parts of trees and make seed collection very difficult.

TREE AND SHRUB SEED: WARNING!—HANDLE WITH CARE

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INTRODUCTION

As Government policy in Britain shifts towards encouraging the planting of more broadleaved trees many nurserymen are increasing production with an emphasis on native species. For those nurseries which have produced such stock over a number of years this task is relatively straightforward, but those expanding into production of seedling stock for the first time are not as successful as they could be because of a lack of knowledge of the seed that they handle.

As one of the British companies supplying the home market it is of concern that seed improperly handled will generate poor results, cause significant lost production, waste valuable seed, and reduce future trading prospects. This paper therefore addresses the problems contributing to loss of seed viability from the parent tree to the new seedbed or container unit. Special reference is made to the storage of *Quercus robur* acorns.

WHERE IS SEED VIABILITY LOST?

A seedlot collected from a stand of trees can be handled many times before it is finally sown on the seedbed or in the container. Reducing the time interval between collection and sowing is the easiest way of minimising viability losses. For certain deeply dormant seeds this may also encourage germination 12 months earlier. A classic example is *Viburnum opulus*, where if the seed is cleaned from the fruit (collected just as it turns red in August) and sown in the seedbed it will germinate the following spring. Seed which is collected later, cleaned, dried, stored and dormancy broken artificially will take a further 12 months to germination, and viability will have decreased.

The main factors causing loss of viability are cited in Table 1. Temperature, moisture, and oxygen are the three prime factors to consider. Perhaps the best general guide is to remember what is happening to the seed dispersed naturally. If these conditions are suitably mimicked, viability can be maintained at or near the percentage at collection.

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[1] Managing Director

Table 1. Loss of seed viability can occur at or during:

	Factors causing losses
Collection	Freezing/excessively high temperatures Excess moisture/drying Lack of oxygen/excess fermentation of fruit Physiological immature seed
Processing & cleaning	As above plus—physical damage
Storage-orthodox species	Too high a moisture content— Temperatures exceeding 5 °C
Recalcitrant species	Too low a moisture content Temperatures exceeding 5 °C Inadequate oxygen supply Premature chitting of seed
Treatment to break dormancy	Exposure to high temperatures Excess moisture/drying Lack of oxygen Premature chitting of seed Physical damage, e g. during acid scarification
Despatch & transport	Poor packaging allowing exposure to temperature extremes, lack of oxygen and physical damage
Pre-sowing storage	Exposed to temperature extremes and drying
Sowing	Radicles on chitted seed damaged Incorrect depth of sowing Uneven seedbed coverings Poor condition of soil in seedbed Poor condition of compost in container
In the seedbed	Inadequate irrigation Absence of shading Predation of seed Fungal and pest attack
In container production	Inadequate irrigation High temperatures Fungal & pest attack Predation of seed

WHAT KNOWLEDGE IS REQUIRED TO PREVENT VIABILITY LOSSES?

Intimate knowledge of the seed biology of each species sown by the nurseryman is the surest way of preventing viability losses. Table 2 summarises the basic data for four common British broadleaved trees. If the nurseryman buys from a seed house he may only have to acquaint himself with columns VI and VII in detail. If he makes collections of his own he must document the history of each seedlot to assist in building up his knowledge.

An example of the type of information which must be recorded is given in Appendix 4B of the *Forestry Commission Bulletin No. 59*. There are many other sources of information. (See Reference List).

Table 2. Basic seed biology of four common British broadleaved trees

	English oak *Quercus robur*	Wild cherry *Prunus avium*	Field maple *Acer campestre*	Common alder *Alnus glutinosa*
I Date of seed collection	Sept-Nov	July	Oct-Jan	Sept-Dec/Jan
II Dormancy type	None	Exogenous(Am) Endogenous (PIM strong)	Endogenous (PIM strong)	Endogenous (PIM weak)
III Seed type	Nut	Stone/drupe	Winged	Nutlet
IV Average no Viable Seeds/KG	220	4,000	8,900	250,000
V Processing/ Cleaning	Air-dry surface moisture only, riddle	Macerate & remove pulp, air-dry seed	Air-dry, hand-clean & riddle	Air-dry cones, extract seed, re-wet cones, air-dry & extract
VI Storage requirements	Recalcitrant Do not dry to less than 40%	Orthodox Dry to 12%	Orthodox. Dry to < 15% minimum	Orthodox Dry to < 10%
VII Treatment requirements	None. Storage in peat maintains viability	2-4 weeks WMP, 15-20 weeks CMP	4-8 weeks WMP, 12-24 weeks CMP	"naked" 4 weeks CMP

Am—Mechanical dormancy
PIM—Physiological inhibiting mechanism
WMP—Warm-moist pre-treatment
CMP—Cold-moist pre-treatment

WHAT HAPPENS IF A SEEDLOT IS HANDLED INCORRECTLY?

Let us take the example of English oak (*Quercus robur*) seedling production in Britain. The genus is not regarded as difficult to propagate, yet even with the English oak there are difficulties in obtaining a high seedling yield because basic seed biology is forgotten.

Table 3 indicates the potential loss of seedling production of two seedlots from the 1988 acorn harvest sold in April 1989. The decrease in viability of the British provenance seedlot was 6.5% during five months of storage under correct conditions. The Dutch provenance seedlot showed a loss of 33.3% of the original viability over the same period—primarily due to incorrect storage conditions. The latter resulted in a potential lost seedling production of over 73,000 seedlings per tonne of seed.

Table 3. Potential seedling production losses due to storage conditions for two seedlots of English oak (*Quercus robur*).

	British	Dutch
Origin	Unknown	Unknown
Provenance	Suffolk, Thurlow Estate 88 (40)	Netherlands Region 3
Seed test data at cleaning	23/12/89, 91% viability*	10/11/89, 69% viability
Storage method	Air-dried, riddled, then mixed with an equal volume of moist peat and bagged into hessian, stored in cold store at +2 to -4 °C	Air-dried, cleaned, then bagged into fine mesh sacks, stored at ambient temperature in an unheated warehouse
Seed test data at despatch for spring sowing	20/4/89, 85% viability	21/4/89, 46% viability
Decrease in viability as a % of original viability	6.5%	33.3%
Potential loss of seedling Production**	14,300 seedling/tonne	73,260 seedling/tonne

* Viability is defined as normal + abnormal germination + fresh seeds
** Assumes a field factor of 80% for open ground production
Based upon an average viability of 220 viable seeds/kg

Why should such losses occur? The storage requirement of acorns of *Quercus robur* have been known since the 1950s (Table 4) and have recently been demonstrated again (Table 5), including the usefulness of soaking seed that has dried to between 30-40% moisture content (fresh weight basis) before storing it.

Table 4. Storage requirements to maintain satisfactory viability of oak (*Quercus robur*) over three years (Holmes and Buszewicz, 1955)

Temperature	+2 °C
Moisture Content	40-45% (fresh wt. basis)
Storage medium	Dry peat or sand
Storage method	Closed but not sealed containers
Other factors	High initial quality (viability) Free from disease/damage

Table 5. Conditions to maintain high viability for spring-sown oak (*Quercus robur*) (Gosling, 1988)

Temperature	+2 °C
Moisture content	Greater than 40% (fresh wt. basis)
Storage medium	Naked storage
Storage method	Acorns in hessian sack, surrounded by perlite in open-necked polythene bag
Other factors	Seed of 30-40% moisture content, should be soaked for 48 hours in water at +2 °C

The effects of poor storage of the 1988 acorn harvest on lost seedling production in Britain is calculated in Table 6. For the purposes of these calculations it was assumed that 75% of the seed was autumn-sown (i.e. before 30 December 1988) and that the remainder was sown in the spring (March-April 1989). Small viability losses were defined as 5% or less of the original viability, medium losses as 15%, and large losses as 30%. The viability loss classes were apportioned to the total tonnage of British and Dutch seed. While the figures are open to debate, and some nurserymen are losing less than 5 percent of the original viability at collection, substantial lost seedling production is indicated. An equivalent of 1.4 million plants were "lost", representing 6.4 tonnes of seed which was wasted!

Table 6. Estimated loss of oak (*Quercus robur*) seedling production in Britain due to losses incurred during storage of the 1988 seed crop

Provenance	Estimated seed useage (tonnes)	VIABILITY LOSS CLASSES Small	Medium	Large	Total seedlings lost	Weight of seed crop lost (%)
Autumn/winter-sown stock (assumes 75% of seed sown)						
British	3.75	41,250	—	—	41,250	5
Dutch	60 0	660,000	—	—	660,000	5
Spring-sown stock (assumes 25% of seed sown)						
British *	1 25	3,440	28,875	4,125	36,440	13
Dutch **	20 0	55,000	396,000	198,000	649,000	15
				Total	1,386,690	

* Assume 25% crop has Small viability loss
70% crop has Medium viability loss
5% crop has Large viability loss
** Assume 25% crop has Small viability loss
60% crop has Medium viability loss
15% crop has Large viability loss

Reiterating an earlier point, it is often observed that autumn-sown seed can minimise loss of viability (assuming adequate protection and optimum conditions in the seedbed/container). The total weight of the acorn crop lost from autumn sowings was 5% compared to 13-15% for spring-sown seed. Also a significant factor, supported by evidence from British seed houses, is that it is easier to maintain the viability of seed collected from British forest stands since moisture content can be accurately controlled from the point of collection—a crucial factor for the recalcitrant acorn.

That *Quercus robur* represents a species whose seed biology is straightforward (it does not require protracted cleaning, difficult storage conditions or lengthy stratification procedures) would indicate that lost seedling production of other native broadleaves through inappropriate handling may also be significant.

The recent increases in demand for the supply of broadleaved tree and shrub seed are welcomed. Handling seed with care will not only increase seedling production, but will ensure careful use of a valuable asset, especially the hard-won harvests from British provenances.

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HOW TO OVERCOME SEED DORMANCY

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What is Dormancy? When seed is given satisfactory environmental conditions, germination will normally take place. If, however, despite these favourable conditions, germination does not occur and is incapable of doing so until the seed is subjected to different treatment or treatments, the seed is said to be dormant.

Dormancy is a condition of nature which has evolved to ensure the seed's survival, that is to say it will only germinate when the correct environmental conditions occur.

Treatment to remove or prevent dormancy is easier if you consider where the species grows naturally and what type of climatic conditions it is subjected to. This gives you an indication of the possible treatment and handling of the seed to achieve satisfactory germination:

(a) Hot dry conditions tend to produce seeds with very dry and hard seed coats, e.g. *Gleditsia triacanthos.*
(b) Seed from areas that are subjected to long periods of low temperatures tend to need long-term chilling, e.g. *Sorbus aucuparia.*
(c) In seed produced in wet or damp conditions, germination can be impaired by subsequent drying, e.g. *Salix* spp.

Seed may often have more than one type of dormancy and it is important to understand them in order to provide the correct treatment or treatments at the right time and in the correct sequence.

The types of treatments chosen are also influenced by other factors:

Condition of the seed. Has the seed adequate food reserves to enable it to survive through a long type of treatment? Old seed with poor food reserves will often die before treatment is completed and therefore a shorter, perhaps a more complex, treatment would have to be adopted.

Arrival of seed—lack of time. In some cases seed may arrive too late to choose the easiest but longer method of treatment. A different method has to be adopted to reduce the period of treatment if the subsequent seedling is to have an adequate growth period to produce a usable sized plant capable of over wintering. For example, where seed could have been given a warm-moist treatment for 8 weeks or more, acid would have to be considered as an alternative to reduce the treatment time.

Imported seed. Generally late collection and/or over-drying, especially in hotter climates mean dormancies become well and truely formed, making subsequent treatment more difficult and time consuming.

Home collection. Home collection of seed has many advantages, it enables the propagator to choose the optimum time for collection and to provide the right systems of handling to prevent or reduce dormancy.

Time—knowledge. *Many plants will respond successfully to more* than one type of treatment but will vary considerably in the time needed.

For example, *Acer palmatum* seed can be treated with heat and cold to achieve germination the following spring. Alternatively, one can allow nature to provide the treatment which will take a further 12 months.

In many instances it may be more convenient to adopt the longer treatment as it is often easier once continuity is established. There are times, due to crop failure, that the continuity is broken but that can be overcome by adopting the shorter treatment.

The method of seed treatment chosen will depend on the facilities available, the better the facilities the more flexibility one will have *in being able to choose the right method of treatment to obtain the* best results at any given time.

SEED COAT DORMANCY

This can be one of two types, but seed of some species exhibits a combination of both types:

(1) *Hard seed coat.* Seed is able to take up water and oxygen but because of the restrictions of the testa the expansion of the embryo is inhibited and germination will not occur.

(2) *Impermeable seed coat.* Seed is incapable of water uptake and gaseous exchange because of water repellant materials in the coat.

The best techniques will vary from species to species and from year to year. They are governed by the seed size, the relative hardness of the seed coat, and the maturity of each batch of seed. To obtain rapid and more even germination the seed must be subjected to some form of physical or chemical treatment.

Treatments to overcome seed coat dormancy:

Mechanical scarification. This is achieved by agitation of the seed with some form of abrasive material, e.g. grit or coarse sand in a cement mixer or passing it through rollers covered with abrasive material such as sand or emery paper. This is best used for seed with impervious seed coats.

Chipping. As the word implies, this involves the removal of a small part of the seed coat to allow water uptake. It is only practical on

large seeds but can be a useful method with small batches of valuable seed.

Cracking. Hard seed coats can often be cracked without damaging the seed inside, e.g. *Corylus* species lend themselves to this. It can be done with specially developed rollers, or with hammers on a small scale for small batches of valuable seed.

Sulfuric acid treatment. Reduction of the seed coat by the use of acid is an effective method to reduce the time needed to achieve germination but attention has to be paid to ensure that the seed coat is sufficiently broken down without causing damage to the embryo. The length of time to achieve this will vary with each seed batch and from year to year within the same species.

This method is only suitable on dried seed as any trace of moisture will allow the acid to penetrate the testa and destroy the embryo.

Hot water. This can be a very useful technique, which is used on seed where the embryo is dry, e.g., *Robinia, Gleditsia*. If the embryo is not dry it will be killed or damaged during treatment.

The treatment consists of placing the seed in heatproof containers and pouring over them three times their own volume of boiling water. This will break down any organic substances which may be present on the outside of the seed preventing normal water uptake.

The high temperature also causes any air inside the testa to expand and in order to escape it ruptures the micropile which in turn allows water to be imbibed. The high temperature created by the hot water quickly falls preventing damage occuring to the imbibing seed.

Seed is left in the water for a period of 24 to 48 hours. If left for the longer period the water should be topped up with fresh cold water. After this period the water is removed and any seed that has failed to swell up can be carefully sieved out and treated again. The treated seed should be sown immediately or placed in moist peat allowing any further imbibition to take place. At no stage should treated seed be allowed to dry out as germination will be greatly reduced. Within 3 to 4 days of treatment the seed quickly develops, especially under high temperatures. For example, with *Robinia* and *Gleditsia* the radical would have started to emerge and the seed must be sown.

As this is a simple and quick technique it is worth treating samples of seed beforehand with cold and hot water to find out which gives the best results. After 24 hours this will be very apparent.

In some years, when batches contain many soft seeds, cold water will prove more successful, in other batches, hot water may prove the best. On the other hand, if both produced poor results, acid treatment would then be adviseable.

This technique sometimes works well on other species that have dry embryos and cannot imbibe water, such as *Tilia* and *Koelreuteria*.

Heat or warm period. This consists of subjecting the seed to a period of heat in a moist, aerated medium which can be achieved by mixing one part of seed with two parts by volume of moist peat and placing it in a frame, container, or plastic bag. The mixture should be shaken or turned on a regular basis, say once a week, to maintain good aerobic conditions, adding further water to the medium if necessary.

With the use of a glasshouse or a cold frame the energy of the sun can be captured to provide the heat required for treatment; heating cables can be used to top up the heat during cooler periods.

An alternative is to insulate a room and provide a heat source. Fitting a fan maintains an even air heat distribution, which is very important if racks are to be used. A thermostat or probes should maintain the air and media temperatures at the desired levels, normally around 80 °F. The length of heat period required for each species will vary from batch to batch and year to year.

Acid + heat. It may not always be possible to reduce the seed coat to the desired level with the use of acid, in these cases the seed is given a shorter period of moist-heat conditions to complete the treatment.

EPICOTYL DORMANCY

With this type of dormancy, once the seed has received a moist-warm period the radicle will emerge but the plumule cannot emerge until the seed has received a period of cold to enable the epicotyl to develop.

The most practical way to deal with this type of dormancy is to sow the seed before it has received any warm period, into prepared beds outside to allow the root to develop straight. If necessary, provide protection in early spring as germination can occur very early. An example of this is *Viburnum opulus.*

COLD PERIOD DORMANCY

Many plants exhibit a dormancy that can only be overcome by a period of exposure to cold temperatures, usually between 1 and 5 °C. The seed must be fully imbibed otherwise the seed is only being stored; it must be in an aerated condition to allow respiration.

The length of time required will be governed by the depth of dormancy. Some plants exhibit a very shallow dormancy, e.g., *Betula* spp. (2 to 3 weeks). Others may be much deeper, e.g. *Sorbus aucuparia* (12 weeks plus).

When treating any batch of seed some will require less cold than others and therefore will start to grow in advance of the rest. This problem can be reduced with home collection of seed and by keeping each batch separate rather than mixing them together or collecting when the seed is evenly developed.

To find out the optimum duration of cold required, samples of the seed will have to be treated well in advance of the main batch. This is why, when importing seed, it is important to receive the more dormant species early so you can test the seed in advance.

Cold can be provided in two ways:

Naturally. Seed can be stored outside in a growing medium where it is subjected to natural cold and then spring-sowing before germination occurs. Alternatively sow direct in the autumn or early winter and allow it to receive its cold *in situ* over a long period.

Artificially. Seed is placed in an imbibed condition into a domestic refrigerator or cold store. It must be shaken up at least once to keep the medium separated; water should be added if the medium or seed shows signs of drying out.

Cold period dormancy can be reduced with home collection of seed by not drying the seed out after extraction but placing it in moist peat and preventing any further drying and hardening of the seed coat. This technique reduces the subsequent duration of cold required to obtain germination.

IMMATURE EMBRYO

Some plants will produce seed with an immature embryo and in order that germination can take place a period of moist-warm conditions are required to enable this embryo to develop to mature size. Only then can the cold period dormancy be broken—examples of this type of dormancy are found in *Hamamelis* and *Fothergilla*.

OTHER FACTORS

Early collection. As dormancies are formed in the final stages of ripening, provided the embryo is mature, it is possible to collect the seed before these developments occur thus eliminating the problem, e.g. *Daphne mezereum, Carpinus betulus*, and *Viburnum lantana*.

Removal of fruit. Seed should never be treated with its fruit in place as these often contain inhibitors which may take a long time to break down and greatly increase the period of treatment.

Collection and handling. Many problems we have with seed are self-inflicted. With home collection, good timing and subsequent good handling we can reduce many of the problems with which we are faced. Keeping detailed crop records each year over a period of time will provide valuable information enabling one to choose the correct treatment for different species in different conditions.

ACID TREATMENT TO OVERCOME SEED DORMANCY

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Many growers experience problems germinating seed of tree and shrub species with hard or impermeable seed coats. For hard seedcoated species the usual method of overcoming these problems is by a long period of warm stratification to allow natural breakdown of the seedcoat. Species with an impermeable seedcoat can be scarified mechanically by abrasion of the testa to allow water absorption. A quicker, more reliable method that has been advocated for many years is the immersion of seed batches into concentrated sulphuric acid (H_2SO_4) to break down the seedcoat. Sulphuric acid has different effects, depending upon whether the seedcoats are impermeable or hard.

Impermeable Seedcoats. The effect on impermeable seedcoats, such as can be found in legumes, was illustrated by Liu *et al* (6) by using a scanning electron microscope on seeds following acid treatment. The surface of these seeds consists of an impermeable, waxy cuticle layer on the exterior, beneath which is found a palisade layer of cells. Acid treatment dissolves the waxy cuticle and the ends of the cells beneath so allowing imbibition of water. Conventional scarification by abrasion tended to cause some injury to the seeds being treated resulting in decreased vigour and viability. They also found that immersion of the seeds in boiling water ruptured and separated the macrosclerid layer thus permitting the entry of boiling water to the embryo, thereby reducing viability.

Acid treatments of up to 2 hours resulted in an increase in germination over the control. For *Gleditsia triacanthos* germination was 98% compared with 32%, for untreated seed. For *Gymnocladus dioicus* germination was 95% compared with 4% for the control.

The immersion time for some legume species can be quite lengthy. Garner (4) found that even after 90 min. acid treatment germination of *Koelreuteria paniculata* remained low compared with mechanical scarification. Frett & Dirr (3) needed an 8 hour treatment to improve germination of *Gymnocladus dioicus* seed.

Hard Seedcoats. The effect of acid treatment on hard seed-coated subjects was shown by Roberts (7). He found that by reducing the width of the seedcoat using concentrated sulphuric acid, the time required for warm stratification of subjects, such as Rosaceae, could be substantially reduced.

By reducing the width of the seedcoat by a third, the percentage germination of *Rosa dumetorum* 'Laxa,' after 30 days at 24°C

followed by 12 weeks at 4 to 5 °C was 80% compared with only 50% without acid treatment.

Hilton, *et al* (5) compared the effects of acid scarification (H_2SO_4), mechanical scarification, and immersion in sodium hydroxide (NaOH), on the rosaceous subjects, *Amelanchier* and *Sorbus*. *Amelanchier laevis* seeds were immersed for 15 minutes in sulphuric acid, whereas seeds of *Sorbus aucuparia* and *Sorbus decora* were treated for 10 min. Mechanical scarification was done by abrading the seed coats of both species with sandpaper until the cotyledon was exposed at one place. The last treatment involved soaking the seeds of all species in a saturated solution of NaOH for 20 min. Seeds of both species were then subjected to stratification periods ranging from 30 to 120 days.

Maximum germination of all species occurred after 120 days stratification period at 2 °C following acid treatment. The negative effect of mechanical scarification compared with the control was attributed to the inward leaching of growth inhibitors to the embryo thus prolonging dormancy, although mechanical damage may also have been a factor.

Flemion (1) worked on several *Crataegus* species. She found that with acid treatments of up to 3 hours, followed by various temperature regimes, one can reduce the period of warm treatment. By using sulphuric acid, the warm period requirement to obtain 80% germination was reduced from 12 weeks to 3 weeks prior to cold stratification.

Flemion was probably one of the first authors to emphasise the importance of safe technique when using sulphuric acid. The following procedure is one that I have used for a number of mainly Rosaceous species.

TECHNIQUE FOR ACID TREATMENT

Operator equipment. The most important aspect of acid treatment is operator safety. The following items are essential:

1. Respirator—Fitted with cartridges for gas filtration.
2. Perspex face shield—To provide protection from splashing. This should be kept lowered, with head held down while operations are taking place.
3. Rubber gloves/gauntlets.
4. Full protective suit with heavy duty plastic apron.
5. Rubber wellington boots.

Other equipment/materials. It is important to avoid items made from metals. All utensils should be constructed from rubber, plastic, or glass.

1. Concentrated sulphuric acid (H_2SO_4).
2. Washing soda—For acid neutralisation.
3. Plastic sieve—For holding seed batches during immersion.

4. Glass thermometer—For temperature monitoring during treatment.
5. Plastic spoon.
6. Plastic containers—One for acid immersion, the other for neutralisation.
7. A large plastic tub—For final rinsing of the seed after treatment.

Site selection. The area should be concrete and must slope into a soakaway into which waste products can drain. The site should not be situated where there is a high water table, and it must be well separated from water courses. There should also be a plentiful supply of water, and it is advisable to have a hose pipe available which should be kept running continuously during treatment.

Preparation. Damp or wet materials should not come into contact with the concentrated sulphuric acid at any stage or a dangerous reaction may occur. It is, therefore, essential that only dry seed should be used. Any trace of dampness in the seed may also result in damage to the embryo resulting from acid penetration.

Before treatment, seed lots should be subdivided into smaller batches that can be placed into the plastic sieve for immersion. With large batches of seed there is a danger of overheating of the acid during treatment. The volume of sulphuric acid used should be three to four times the volume of seed, to ensure adequate coverage of the seed and to prevent overheating.

Acid treatment: immersion. The appropriate quantity of acid should be placed into the first plastic container. The seed batch should then be carefully lowered into the acid, and remain there for the specified immersion time. A thermometer should be used to monitor the temperature at regular intervals and, if there are any sudden temperature rises, the process should be stopped immediately. A plastic spoon should be used to gently stir the seed occasionally during treatment to prevent clumping of the seed and the formation of any hot spots.

Neutralisation. After immersion of the seed for the appropriate time period, the sieve with the seed should be transferred to the second container which should contain a saturated solution of washing soda to neutralise the acid. This solution should be changed regularly to ensure effectiveness of neutralisation.

Rinsing. The seed should then be transferred to a large tub, into which there should be a steady flow of water, to give the final rinsing. The seed can then be drained and mixed with peat and sand, ready for stratification or other treatment.

Assessment of optimum immersion time. Before treating whole lots of seed it is advisable to undertake tests to find out the optimum treatment time. If samples of seed are cut open after various immersion periods, the optimum can be assumed to be when a

percentage of the seedcoat has been removed, but not so much that the embryo is nearly exposed.

SUMMARY

Acid treatment, using concentrated sulphuric acid, has been shown to be useful for reducing the warm period requirements for those tree and shrub species with hard seed coats. For species with impermeable seed coats, acid scarification may give better germination than by using mechanical scarification. It should be remembered however that a safe and responsible work procedure is essential when carrying out this potentially hazardous technique.

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PRODUCTION OF *DAVIDIA INVOLUCRATA* FROM SEED

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Davidia involucrata, the pocket handkerchief tree or dove tree, was considered by Ernest Wilson to be "the most interesting and beautiful of all trees of the north temperate flora." He likened the white bracts to "huge butterflies hovering among the trees."

In the 85 or so years since its first introduction from China to Britain, the dove tree has become one of the best known of all hardy exotic trees. Despite this, plants are still surprisingly difficult to obtain in the trade, perhaps due to the inability of propagators to find a reliable method of rooting cuttings. Seed production still remains the only simple means by which this tree can be produced in quantity.

In this paper, I hope to be able to briefly outline, how I have been successful with seed germination over the past few years.

Seed source is the first consideration for successful germination. *Davidia* seed is available commercially from various seed houses but by far the best source is one's own collection.

The walnut-sized fruits are often freely produced in Britain. There are two forms regularly encountered in cultivation, *D. involucrata* and its variety, *vilmoriniana*, the latter being the more common and preferable for propagation as the fruits of the variety are more likely to contain viable seed.

When a tree bearing fruits has been located, it is worth cutting a few open to inspect for seed viability. One seed may contain up to six live embryos with one or two only being quite common.

The fruit is ripe from October through to December when it begins to fall from the tree, although many fruits will remain on the tree well into the following year. They can be dislodged from the tree by shaking the branches, and can then be gathered from the ground and placed in black plastic sacks, ready for fermentation.

The fleshy part of the fruit has to be removed before stratification or seed pre-treatment can take place. To do this the fruit must remain in the sacks in a warm, dry place usually until the following February. By this time the fruits will be soft and smell rather rank. Cleaning is now easily achieved, macerating the fruits in a sieve and washing away the debris with water.

Davidia seeds need a prolonged period of warm pre-treatment followed by a cold spell before germination can take place. In my experience the warm treatment is best left to nature, leaving the seed in the stratification medium out of doors from February, when they are cleaned, until November, in a warm but not baking hot situation. An open cold frame or against a north wall would be ideal.

Large plant pots can be used to contain the seeds but I find the "Dutch crate" ideal for this purpose. The stratification medium needs to be very open; I would suggest a mixture of equal parts of moss peat and sharp grit or perlite.

The box is lined with newspaper to prevent the compost from falling through the bottom and sides. Eventually the newspaper will rot away but the compost should stay in place when moist.

A 1-in. layer of the medium is placed into the bottom of the crate followed by a layer of individually spaced seed. Continue with alternate layers of seed and compost until the box is 2 in. from full. A 2 in. layer of gravel is used to cover and complete the box. This cover prevents the compost from drying out and also helps obstruct rodent damage and weed seeds from germinating.

The crate must now be left in its summer resting place and thoroughly watered. The seeds must not be allowed to dry out during the long period.

In November the seeds and medium are removed from the boxes and the compost washed away through sieves. When the seed is once again clean, it will be noticed that the embryos have expanded, forcing the seed casing apart. Even at this stage they are not ready for full germination; they still require cold stratification. The prepared seeds are mixed with moist peat and placed in polythene bags with the neck of the bag loosely tied and labelled. The bags of seed are then placed in a cold room or refrigerator set to a temperature of between 2° and 4°C and inspected on a weekly basis.

of radicle emergence and are then ready to sow. They *can* be sown individually, but as there is quite often more than one embryo per seed, they are best sown in deep seed trays and placed on bottom heat, set to approximately 20°C. By mid-April the seeds should all have germinated and at the cotyledon stage, can be knocked out of the trays and potted individually into small pots.

The seedlings are very vulnerable at this stage and care should be taken to protect them from direct sunlight with shading, and from frost at night. The crop is a valuable one, so it would be prudent to pot them into a frost-protected glasshouse.

By the middle of July, the seedlings will be at least 12 in. high. They quite often need staking as growth in the first year is usually soft. At this time, they can be potted into intermediate one-litre pots and held in this container until the following spring, after which they can be moved into their final pot.

Well-grown containerised plants will have a retail market value of between £10 and £25, depending upon their size. Although the process may seem lengthy, the end product is well worth the wait.

SOIL STERILISATION FOR OUTDOOR SEEDLING PRODUCTION

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Soil sterilisation is needed primarily to control annual weeds in the seedbed. The average nursery propagates many cultivars and although weed-control using pre-emergence herbicides is suitable for a few cultivars it is risky or damaging to many seedlings. Mechanical weed-control is not very effective in a typical damp season.

Soil sterilisation gives further benefits because it can control soil-borne diseases and stimulates crop growth.

In a survey of 15 British seedling nurseries the typical sterilisation operation involves the following:

Timed in September, Basamid (dazomet) Granular is applied at standard rate (380kg per ha) to a moist soil using a Sisis Lo-spread applicator. Incorporation to a depth of 15cm (6 in.) is made using a rotavator. To seal the soil surface 80% of nurseries lay polythene, the remainder roll and irrigate.

Using standard rate Basamid and polythene covering, materials cost is some £ 1300 per ha at 1989 prices. Including the labour cost of application, incorporation and covering, a figure of £ 1450 is probable.

A contractor will charge £ 1800 per ha, which is competitive if allowance is made for capital expense and maintenance of machinery.

To put this expense into perspective, the value of a seedling crop after one year's growth can be £ 40,000 per ha.

In Holland, metham-sodium liquid injected into the soil is used widely. This material decays to form the same active sterilant gas as does Basamid. The chemical is soil injected by a contractor and the soil is sealed by rolling.

In France and the USA, methyl bromide gas is more widely used. Both countries manufacture the injection machinery.

MAKING THE MOST OF STERILISATION

Ensure adequate soil moisture content at the time of sterilisation. Fifty percent of field capacity is ideal.

Cultivate soil well. Clods of soil resist sterilisation.

Do not sterilise a greater depth of soil than you need. David Antill of Stockbridge House EHS, has shown that lettuce drilled into soil, sterilised with half-rate Basamid incorporated to half depth (8 cm.; 3 in.), results in good weed control in the crop.

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[1] Production Director

If you have a soil that seals with rolling, without need for polythene cover, consider a step better. Rather than the usual heavy roller towed passively, substitute a lightweight powered roller that will improve the surface seal by smearing rather than compaction.

UK contractors using metham sodium and methyl bromide are getting better equipped. Both chemicals are probably every bit as effective if properly used, according to Dutch and American contractors. U.K. contractors charges are currently £ 2500 per ha for methyl bromide at the standard 750kg per ha, and £ 1540 per ha for metham sodium at 800 litres per ha (51% formulation). This rate of metham sodium is as used in Holland and is some three times more than normally used in Britain for nematode control; despite this the cost appears very attractive.

THE USE OF VERMICULITE AS A SEED COVERING

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Growing a crop from seed relies on the basic principles of providing the right conditions for the seed to germinate and grow on.

At The Nurseries we have found that using vermiculite as a covering has helped us to provide the right conditions for growing alpines from seed, but the technique would be equally suitable for nursery stock.

We sow our seeds in seed trays using a compost of 50:50 peat and sand. Once sown, the seeds are covered with a thin layer of vermiculite and placed on a heated bed to germinate.

The advantages of using vermiculite are:

Prevents capping. This allows air and water to reach the seed. It also makes it easier to remove the seedlings at pricking out.

Retains moisture. It is critical that the seed does not dry out; the vermiculite provides a film of water to protect it.

Permeable to light. Where needed, enough light reaches the seed to prevent germination being inhibited.

Reflects heat. Useful where high temperatures inhibit germination.

However, there are disadvantages, too. Vermiculite is so good at holding moisture that this can cause problems. If you have slow-growing seed the vermiculite gets caked in liverworts which makes germination difficult. So for slower germinating seed that takes months rather than weeks to come up we stick to the traditional covering of fine grit.

IMPROVING SLOW-RELEASE HERBICIDE TABLETS FOR CONTAINER NURSERY STOCK

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INTRODUCTION

The use of slow-release herbicide tablets have several advantages in the production of container-grown nursery stock. Included are the greater accuracy of herbicide application, greater safety to humans and plants, and reduction of possible environmental pollution. To be commercially acceptable, however, the tablets must also provide long lasting wide spectrum weed control without phytotoxicity to the plants.

Tablets have been formulated with water-soluble herbicides such as alachlor and metolachlor and, although they are effective, they do not control a broad range of weed species. Most pre-emergence herbicides currently in nursery use have a low water solubility and have not been successfully utilized in a slow-release technology.

In recent work by Horowitz *et al.* (1), the area of weed control surrounding a slow-release herbicide tablet was markedly increased by adding a surfactant to the tablet. As a follow-up to this work we conducted studies to; screen a number of surfactants; screen various herbicides and herbicide combinations; field-test the final product for weed control; and assess phytotoxicity in container-grown nursery stock.

MATERIALS AND METHODS

Slow-release herbicide tablets were produced by dry compression of dicalcium phosphate as a filler, magnesium stearate as binder, and the commercial formulation of herbicides and surfactants. The tablet-making process involved the use of a Stokes single punch tablet machine. Finished tablets measured 12 mm in diameter and weighed on the average 1.25 g/tablet.

Experiments were conducted in 1 gal. containers (18 cm. top diameter) filled with a commercial medium of Metro Mix 350. Containers were seeded with 'Seaside' bentgrass (*Agrostis stolonifera* 'Seaside'). A tablet was placed on the soil surface in the center of the pot or equidistant apart if more than one tablet was applied on the day of seeding.

A series of four experiments was conducted in order to evaluate surfactants and herbicides in greenhouse trials prior to the final tablet formulation which was evaluated outdoors on 10 species and cultivars of landscape plants.

Study No. 1—Preliminary Surfactant Evaluation. Nine surfactants were evaluated as ingredients in the tablets to ascertain their effect on the release of Goal 1.6E (oxyfluorfen). Surfactants included Buffer X, Dash, Regulaid, Triton AG 98, Triton B 1956, Triton X-100, Tween 20, Tween 80, and X-77, along with Goal only and control (no surfactant and no herbicide). Each surfactant was incorporated at a rate of 1.0% and 2.5% of product formulation. Goal was incorporated into all but the control tablets at 0.5 lb a.i.a., of product formulation. All trials were conducted in the greenhouse in 1 gal. containers seeded with 1 tablet/container. Containers were seeded and treated February 17 and evaluated March 6, 1989.

Study No. 2—Final Surfactant Evaluation. The most effective results in Study No. 1 were achieved with Goal plus Triton X-100, Tween 80, and X-77 and these were again compared at 1.0 and 2.5 percent, along with Goal only at 0.5 a.i.a. and with control tablets. Trials were conducted with 1 gal. seeded containers with either 1, 2 or 3 tablets per container in the greenhouse. Containers were seeded and treated March 11 and evaluated March 27, 1989.

Study No. 3—Preliminary Herbicide Evaluation. Five pre-emergence herbicides and four herbicide combinations were compared to control tablets. The rates for each product were company recommendations and half rates a.i.a. in the combination treatments. Triton X-100 was incorporated into all but the control tablets at 1.0 percent. Herbicide treatments included Dual (metolachlor), Gallery (isoxaben), Goal (oxyfluorfen), Ronstar (oxadiazon) and Surflan (oryzalin). The combination treatments were Dual plus Gallery, Dual plus Goal, Dual plus Ronstar, and Dual plus Surflan. All containers were seeded with bentgrass. Containers were seeded and treated April 3 and evaluated April 17, 1989.

Study No. 4—Final Herbicide Evaluation. The least effective herbicide in study No. 3 was Gallery alone and in combinations with Dual so was dropped from further evaluation. Otherwise all herbicides used in study No. 3 were repeated, with some adjustment in rates. Each herbicide treatment was further evaluated with either 1, 2 or 3 tablets per container spaced equally apart. The surfactant added was again Triton X-100. Containers were seeded and treated April 24, and evaluated May 10, 1989.

Study No. 5—Nursery Evaluation. Tablets were prepared with Triton X-100 at 1.0% and the combination of Goal at 0.5 lb. a.i.a. and Dual at 2.0 lb. a.i.a. The plant species and cultivars evaluated for phytotoxicity and weed control included:

Chamaecyparis pisifera 'Boulevard'
Cotoneaster dammeri 'Royal Beauty'
Euonymus fortunei 'Emerald Cushion'
Euonymus fortunei 'Emerald 'n Gold'
Forsythia × *intermedia* 'Spring Glory'
Pachysandra terminalis
Rhododendron 'PJM'
Rhododendron 'Hino-pink'
Spiraea × *bumalda* 'Gold Flame'
Spiraea nipponica var. *tosaensis* 'Snowmound'

Plants were potted in 2 gal. containers, placed outdoors and treated on June 14 and evaluated June 29, July 13, July 27, and August 10, 1989. Each container was treated with either 2, 3 or 4 tablets.

RESULTS AND DISCUSSION

Study No. 1—Preliminary Surfactant Evaluation. The objective of this study was to screen a number of surfactants using Goal 1.6E at 1.0 lb. a.i.a. as the test herbicide. Goal was selected as the test herbicide due to its low solubility of 0.1 ppm and its wide spectrum of weed control. The most effective weed control was achieved with the surfactants Triton X-100, Tween 80, and X-77 and these were selected for further evaluation. The 2.5% formulation of Triton X-100 and X-77 were superior rates to 1.0%.

Study No. 2—Final Surfactant Evaluation. Triton X-100, Tween 80, and X-77 were further evaluated at 1.0 and 2.5% with Goal 1.6E at 0.5 lb. a.i.a. as the herbicide. The most effective surfactant treatments were Triton X-100 at the 3 tablet rate at both 1.0 and 2.5% surfactant levels. Since the area of weed control was similar, Triton X-100 at 1.0% was selected for further evaluation. With all treatments there were significant increases in weed control, as expected when the number of tablets were increased. However, the best treatments were still only yielding approximately 50% weed control in one-gal. containers which is not good enough from a commercial standpoint.

Study No. 3—Preliminary Herbicide Evaluation. Among the most effective herbicides for container-grown landscape crops are Goal, Ronstar, Surflan, and a relatively new material, Gallery. All are relatively insoluble materials, for example: Goal = 0.1 ppm, Ronstar = 0.7 ppm, Surflan = 2.4 ppm, and Gallery = .0001 ppm. Dual, however, is very water soluble at 530 ppm. The idea was to evaluate each herbicide separately with Triton X-100 and in combination with Dual and Triton X-100.

The preliminary results were not strikingly different in 1 gal. containers although Gallery and Gallery plus Dual were the least

effective. Thus, these two treatments were dropped from further evaluation.

Study No. 4--Final Herbicide Evaluation. With the exception of Gallery, the herbicide treatments in study 4 were a repeat of study No. 3. However, 1, 2 and 3 tablets per 1 gal. container were evaluated. As with study No. 2, as the number of tablets increased the weed control increased.

The results indicate that 80% weed control was achieved with 3 tablets of Goal at 0.5 lb. a.i.a. and 90% with Goal at 1.0 lb. a.i.a. Furthermore, Dual at 3 tablets yielded 100% weed control of 'Seaside' Bentgrass. The combination of Goal (0.5 lb. a.i.a.) and Dual (2.0 lb. a.i.a) resulted in 98% weed control. Recognizing that Dual as an herbicide is most effective against grasses and Goal most effective against broadleaf weeds, it was decided to continue research with the combination product of Triton X-100 at 1.0%, Goal at 0.5 lbs. a.i.a. and Dual at 2.0 lb. a.i.a.

Study No. 5—Nursery Evaluation. Ten species of woody nursery stock were planted into 2 gal. containers and treated with either 2, 3 or 4 tablets per container. There was no evidence of phytotoxicity 6 weeks from treatment on any plant. However, at 8 weeks some retardation of growth was observed with *Spiraea* × *bumalda* 'Gold Flame' and *S. nipponica* var. *tosaensis* 'Snowmound'.

Acceptable weed control for 2 tablets was 8 weeks, 3 and 4 tablets, 8+ weeks. These containers were not sown to 'Seaside' Bentgrass. The native weeds were evaluated and the following weed species were controlled: lesser bittercress, spotted spurge, and oxalis—all weeds that cause significant labor problems in container nurseries. Dual alone will not control these weed species.

SUMMARY

A series of 4 studies was conducted to determine the most effective surfactant and herbicide to incorporate into slow-release tablets for the most effective control of weeds without plant phytotoxicity. The most effective surfactant was Triton X-100 and the most effective herbicide was a combination of Dual and Goal which results in broad spectrum weed control. These tablets were then field tested on 10 species and cultivars of woody landscape plants. There was no observable phytotoxicity for 8 weeks on 8 of 10 plant selections and acceptable weed control was achieved with 2 tablets for 8 weeks, and 3 and 4 tablets for 8+ weeks.

Continued research is needed to evaluate more crops, varying rates, and economic analysis.

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FIELD PROPAGATION OF SELECTED ORNAMENTALS IN NEW ZEALAND

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Duncan & Davies Nurseries are situated at Waitara, a few kilometres north of New Plymouth, on the west coast of the North Island. We have a temperate climate with an average temperature range of 10 °C in mid-winter to 18 °C in mid-summer. In mid-winter we would normally experience several ground frosts, of about -3 °C, and in summer the highest temperature would reach 28 °C. We have a total of 2,150 sunshine hours annually and a 60 in. annual rainfall, which is spread throughout the year. Soil type is a very fertile free-draining volcanic loam. We have a prevailing westerly wind which places importance on effective shelter in the nursery. The combination of favourable climate and soil type enables field production of hardy trees and shrubs to be a major part of our total nursery production. One of our specialised lines is the field propagation of budded trees and shrubs, of which we bud up to 250,000 plants annually, using approximately 200 cultivars over a range of 20 genera.

The plant species that I wish to discuss here are: *Acer palmatum, Cornus florida, Hamamelis mollis,* and *H.* × *intermedia.*

ROOTSTOCKS

The rootstocks used are *Acer palmatum, Cornus florida,* and *Hamamelis* × *intermedia*. All the rootstocks are seedling produced as this is still a relatively cheap method of producing large volumes. With *Cornus* and *Hamamelis* we plant out a one-year-old seedling of 20/30 cm grade. With *Acer palmatum* there is a large variation in seedling quality so we use a selected seed source which produces strong, one-year seedlings of 70/90 cm grade.

Ideally we like to plant out the one-year-old seedlings in late autumn to early winter. In our climate we get a substantial amount of root growth in this period which leads to stronger top growth in spring and summer. The rootstocks are planted out in single rows through black polythene mulch at 30 to 40 cm spacing. The polythene mulch has the following advantages:

It depresses weed growth around the plant.

The water-shedding effect keeps the soil around the root zone drier and warmer which encourages earlier bud break in spring.

It reduces soil splash on the stem of the rootstock where the bud is to be placed.

Any lateral growths on the rootstock, in the region where the bud is to be placed are removed one or two days prior to budding.

BUDDING OPERATIONS

The timing of budding with these species is very important for successful results. The importance is on budwood maturity when selecting current season's growth with the buds fully developed. A good indication of mature budwood is when the leaf petiole ''snaps off'' easily without damaging the bud or stem.

Acer palmatum cultivars are budded in the late summer period, from early January to late March, with *Acer palmatum* dissected-leaf cultivars budded mid-February to late March. The budding period for *Cornus* and *Hamamelis* is late January to early February. The growing season is usually long enough to allow two budding rounds if necessary. The sap flow of *Hamamelis* species slows down very quickly in early autumn so a second round must be completed by the end of February.

The budwood is collected from either the nursery row or from stock plants. It is collected in early morning prior to the day's budding. The leaves are removed and the budwood is stored in plastic bags of 35 micron thickness and kept in a cool shady situation.

All these species are chip-budded at 5 to 8 cm. above the base of the rootstock. With chip-budding it is important to try and match the bud size with the cut on the stem of the rootstock. A plastic strip is used to tie the bud in place. In our moist climate the plastic strip has proved to be the most effective compared to rubber types. For best results, weather conditions should be warm and dry at budding time. A skilled budder will chip-bud 800 to 1,000 *Acer* per 8-hr. day and 1,000 to 1,200 *Cornus* and *Hamamelis* seedlings.

After 4 to 6 weeks the plastic ties are removed. With *Acer* the percentage bud take depends upon the cultivar and can vary from 50 to 85 percent. The bark on some cultivars is very thin which makes budding difficult. With *Cornus* and *Hamamelis* we normally expect a 90 percent bud take.

TRAINING BUD GROWTH

The rootstocks are root-conditioned at the end of the first growing season, prior to heading back. The rootstocks are headed back to the live bud in late winter (late July through early August) and the cut is painted with an acrylic paint containing a fungicide.

Most *Acer* cultivars require a 120 cm. stake to train the bud growth with a straight stem. The majority of the red-leaf cultivars produce a strong single stem (up to 200 cm.) in the first growing season of the cultivar, which is then headed at 100 cm. to produce a branched plant in the second season. The majority of the variegated and green-leaf cultivars will produce a well-branched plant in the first growing season.

The *Cornus* cultivars require a 120 cm. stake to train a straight stem and they will produce a well-branched plant of 70 to 120 cm. depending on the cultivar.

With *Hamamelis* we like to produce a well-branched shrub from the bud union of 40 to 70 cm. depending on the cultivar. Staking is not necessary.

With all species, during the first growing season adventitious shoots (suckers) will appear from the rootstocks. These must be removed at an early stage or they will compete with growth of the budded cultivar.

At the end of the growing season the stakes are removed and the plants are machine wrenched with a reciprocating U-shaped blade which also lifts the plant slightly so they are easily pulled out for grading and bundling.

PESTS AND DISEASES

All crops are sprayed on a three-week cycle during the growing season with a general fungicide/insecticide mixture. *Cornus* and *Hamamelis* are prone to red spider mite so miticides are used from November onwards.

WEED CONTROL

Weed control between the rows is achieved with pre-emeregence herbicides in early spring for grasses and broadleaf weeds, and another pre-emergence herbicide in early summer for summer grasses. Any additional weed control is by selective spot spraying.

THE STORY OF BALLERINA APPLES

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Many major leaps forward in plant development have resulted from natural sports. Ballerina apple trees are no exception and it was an observant Polish-Canadian fruit grower called Wijick who, in the early 1960's, spotted a sport growing on a 'Macintosh' apple tree. The particular sport was instantly recognisable. Instead of the normal well branched shoot, it had short internodes and lateral buds developing in short spurs, rather than extension shoots. Fortunately, part of the shoot he passed to the local experiment station multiplied and ultimately pollen was sent to East Malling Research Station in England where a breeding programme was started in the early 1970s by Kenneth Tobutt. In 1976 Ken Tobutt raised about 10,000 seedlings and, to date, about ¼ million seedlings have been raised. In 1977 they were screened for field resistance to scab and mildew and for the columnar habit. About 500 of the best were selected. Between 1980 and 1984 these were grown on and assessed for quality, ease of propagation, and ornamental quality. During 1984, 20 of the best were accepted for replicated trials and it is from these that today's four cultivars were chosen. A unique feature of the original sport is the dominance of the upright habit—approximately 50 percent of the resulting seedlings continued to show the columnar habit.

In 1986 Plant Breeders Rights were granted to the National Seed Development Organization (NSDO), the government-owned company responsible for marketing all plants raised on government establishments. In 1987 as part of the government's privatisation programme, NSDO was sold to Unilever and now trades as PBI, Cambridge, Ltd.

At this stage, many British nurserymen feared that these exciting new cultivars were going to follow the route of so many British innovations and be exploited by other countries. Thankfully a consortium of four growers won a contract to market the trees throughout Europe and these four companies, including Anglia Nurseries, Blakedown Nurseries, Farplants, Ltd., and Notcutts Nurseries, Ltd. formed a joint company with PBI, each owning equal shares.

Market Research. The first decision the consortium made was to carry out an in-depth programme of market research to ascertain reaction of the public to its trees. Over 1,500 people were interviewed in two separate studies. The trees created a huge amount of interest.

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[1] Managing Director

Before seeing them many gardeners cited lack of space as the main reason for not having an apple tree. A large number were also put off by the worries about pruning and the shade traditional trees cast.

Before seeing Ballerina apple trees 80 percent of those interviewed did not intend to buy an apple tree; after seeing them, 62 percent were interested in buying the tree. They, therefore, have the potential to treble the existing amateur fruit apple market.

The trees are unique because of their very tight columnar habit, growing like a natural cordon without branches. The apples grow on spurs on the stem. Potential use of the trees is immense with the main attraction for the private garden being that they occupy little space and will need little or no pruning.

Naming. Good products need good names and the consortium felt it was essential to produce a generic name which could be protected and produce cultivar names that were easily remembered and could have a common link. Ballerina was chosen as the group name and is being registered as a trade mark throughout Europe and the world. Dance names were chosen as the cultivar names of the apples, and 'Maypole' as the name of the ornamental crabapple.

For various reasons the consortium decided to exploit the UK market first followed by France and Western Germany; 120,000 trees were produced in the UK in the first year, quite a significant decision as the retail value of this number was over £2m.

The trees take some three years to produce so numbers for the second and third years had to be decided before the first tree was despatched. Sales figures of 170,000 in the second year and over 200,000 the third year were projected so a production commitment was made to £8.5m worth of trees at retail value before the first tree was despatched.

The Launch. Chelsea Flower Show 1989 in England was fixed as the launch pad to the retail public, when Mark Rumary, Notcutts landscape designer was employed to design a stand to exploit the benefits and uses of the trees.

The main benefits are:

- space saving—no garden is too small;
- little or no pruning—easy to spray;
- heavy cropping—very high yield for space taken;
- attractive—they look good, stay neat and create minimal shade.

The main uses are: in lawns and borders as specimen plants; as a hedge between ornamental and vegetable gardens; in groups to form a mini orchard, and in pots or troughs on patios or balconies.

The Chelsea exhibit was awarded a gold medal and orders for 4,000 were sold at the show. Over 90,000 trees were ordered by garden centres through the U.K. within two months of the launch.

Cultivars—

'Bolero': Shining green apples with a golden pink blush. Pick and eat early to mid-September. Crisp and juicy. Attractive white blossom flushed with pink from early to mid-May.

'Polka': Bright red/green apples of excellent flavour. Pick and eat from late September. Deep pink and white blossom in early to mid-May.

'Waltz': Sweet, red/green apples. Pick and store from early October. Apples keep for several months in cool conditions. Purplish pink and white blossom early to mid-May.

'Maypole': Masses of beautiful carmine flowers from early May for two weeks, with attractive bronze-coloured leaves followed by large purple-red crab apples through the summer, maturing in mid-September.

Propagation and production. These trees propagate as easily as any other apple tree, with good bud takes on MM106 rootstock. The main problem is obtaining sufficient budwood because of the extremenly short internodes. The wood is very thick so they need to be budded on good-sized stocks planted at a minimum of 8 mm girth in the spring.

The problem of the low yield of budwood is being solved by growing mother trees in the glasshouse, which is extending the internodes and, of course, the growing season. The average yield of buds from a mother tree has been approximately 20 to date, but in the glasshouse this can easily be doubled.

Because of their upright nature, it is critical that they are budded onto stocks that are upright; bud guides are also used to ensure that there is an upright union. They must be potted right in the centre of a pot and must be handled with care. Because of the unique feature of buds being formed on the trunk, it is critical that the trees are handled below the bud union at the potting stage, and after potting we encourage the staff to handle by the pots only.

The future. Ballerina trees has recently signed an agreement with East Malling Research Station for the rights of future columnar trees produced at East Malling Research Station and currently it is bulking up a new cooking cultivar and is considering the introduction of a 'Cox' seedling. Ballerinas will be offered for sale in France during the 1989-90 season and will be available in Sweden and Holland during 1991-92. Contracts for marketing the trees in Belgium, Denmark, and West Germany are currently being negotiated. The rights for marketing the trees outside Europe are held by PBI, Maris Lane, Trumpington, Cambridge. CB2 2LQ.

INFLUENCE OF DAYLENGTH AND IRRADIANCE LEVEL ON GROWTH OF THE STOCK PLANTS AND ROOTING OF *BETULA UTILIS, CORYLUS MAXIMA* 'PURPUREA', AND *PINUS MUGO* CUTTINGS.

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REVIEW OF LITERATURE

Betula, Corylus, and *Pinus* are genera to which belong many valuable species of ornamental plants. They are usually propagated by grafting in the greenhouse, but *Corylus* cultivars also by layering (1). They are not generally recommended for propagation by cuttings (8). Ondruska and Schmidt (16) propagated cultivars of *Betula pendula* by cuttings, Pellett and Alpert (17) propagated those of *Betula papyrifera* and they obtained about 80% rooting but over half the cuttings died after potting. It is known that rooting can be influenced by etiolation (9, 13) and daylength; the level of irradiance of the stock plants can also influence rooting (15, 20), but the results depend mostly on the species. Levels of irradiance provided to the cuttings can also influence rooting (4, 20).

MATERIALS AND METHODS

Two-year-old stock plants of *Betula utilis, Corylus maxima* 'Purpurea' and *Pinus mugo* in containers were placed in greenhouse compartments or in growth chambers. They were etiolated or treated with three different daylengths (8h, 16h, 24h). For 8 hours all plants had natural light. Later all compartments were darkened completely. Plants in the long days (16h and 24h) were lighted with high-pressure sodium lamps (SON-T) for additional 8 or 16 hours with irradiance 12.5 Wm-2. In each daylength, three different levels of irradiance were used (100%, 33% and 10%). After etiolation the plants were grown in the 8h or 16h day.

For comparison one set of *Betula* and *Pinus* plants was also left in the greenhouses in natural day conditions. *Corylus* cuttings from natural days were obtained from mother plants that grew outside in the open. All treatments were made in 4 replications with 20 plants of *Betula*, 15 plants of *Corylus* and 30 plants of *Pinus* per replication.

Cuttings received from each stock plant treatment were divided into three groups and rooted under: 100%, 33% or 10% irradiance. Rooted cuttings were potted and overwintered.

RESULTS

Mostly the reduction of daylength and irradiance slowed down the maturation, postponed the date of taking cuttings, and reduced the number and length of shoots. The stock plants from the lowest irradiance were the weakest and most sensitive to *Botrytis.*

Betula utilis and *Corylus maxima* 'Purpurea' were propagated effectively by cuttings when the stock plants were forced in a greenhouse in early spring. Cuttings of *Betula* and *Corylus* most often rooted best when treated with 1% IBA, but in short days 2% IBA was beneficial. In most treatments cuttings rooted best under 33% irradiance. Too much or too little light to the stock plants and/or cuttings usually inhibited rooting and regrowth.

The *Betula* cuttings root and regrew the best after giving the stock plants 16h days with a full light. But it can be seen that the total amount of light on the motherplants and cuttings determined rooting of cuttings (Table 1A). Betula cuttings from stock plants grown in constant and full light (24h/100%) rooted poorly under high ırradiance level. Lowering of the irradiance improved rooting. If stock plants grew in an 8h day, lowering of irradiance level, especially to 10%, caused a trend to lowered rooting.

In the case of *Corylus* plants a supraoptimal level of irradiance was not noticed. Reduction of light access to the stock plants by shortening the daylength, or/and by decreasing the irradiance level caused lowered rooting (Table 1B). *Corylus* cuttings rooted and regrew best after giving the stock plants 24h days with full light. A 24h day with 33% light, or a 16h day with 33% light, and etiolation followed by a long day, were also favorable.

At the end of the growing season, the potted rooted cuttings of *Betula*, on an average for the best treatments, reached a height of 63 cm. For *Corylus* this was 34 cm. The plants overwintered successfully and started new spring growth. For the best treatments *Betula* was over 90%,–*Corylus* was over 80% (in relation to the number of cuttings before rooting). *Pinus* cuttings rooted 50% in the best treatments. After potting they started new spring growth (data not shown). An 8h day for the stock plants, or etiolation with a short day after etiolation and the reduction of high irradiance to 33% during rooting, showed a trend for better rooting.

DISCUSSION

All data presented here agrees with the suggestion of Moe (14) that optimal cutting irradiance for rooting is strongly influenced by the previous history of the stock plant's irradiance, but our results can be explained differently. One possibility is the inhibition of rooting caused by supraoptimal or a too low a level of carbohydrates (5, 6,7). In our experiments the carbohydrate content was not determined,

but presumably there was more carbohydrate in the cuttings from high irradiance stock plants than in those from low irradiance (7).

Another explanation could be that a supraoptimal or too low level of light causes decreasing auxin or/and synergestic co-factors levels (15, 18) or an increase of root inhibitor levels (15). In part, this agrees with the results of our experiment on the influence of IBA treatments. The trend for better rooting was noticed when the concentration of IBA was higher, together with lowering of the daylength for the stock plants. It was more clearly seen in the case of *Corylus* cuttings, which were more difficult to root, but it could be recognized also with *Betula*.

Similar results but with changed light intensity for *Malus* stock plants were found by Christensen *et al* (2), while opposite results were found with *Pinus* cuttings by Stromquist and Hansen (20). Other results suggest that increase of length and/or intensity of irradiance influenced the rise of the level of endogenous auxin and, according to species requirements, at different irradiance levels could reach an optimal level for rooting. Addition of a certain amount of exogenous auxin could improve rooting. For *Corylus* cuttings some quantity of exogenous auxin was even necessary for reasonable rooting (without IBA rooting was at the most 20%). It is also possible that an increase of light causes a better supply of rooting co-factors, which, as suggested by Hess (10), in a complex with auxin, are necessary for good rooting. Cuttings taken from *Betula* plants grown in good light conditions rooted reasonably well even without exogenous auxin, but an excess of optimal auxin level inhibited rooting. Supraoptimal content of auxin could also be a cause of reduction in rooting and overwintering of *Betula* cuttings from treatments with high irradiance for stock plants and cuttings (Table 1-A).

Light treatment of stock plants influenced rooting much more strongly than did light treatments of cuttings during rooting, but for both *Betula* and *Corylus* there was a general trend for best rooting under 33% irradiance level. This agrees with the rule presented by Moe (14) that the optimal irradiance level for cuttings is lower than for the stock plants. This is also true for the results of others (4, 20). Grange and Loach (5) supposed that inhibition of rooting in high light intensities could be associated also with a decrease in osmotic potential, probably as a result of the soluble sugar accumulation in cuttings. When the cuttings were grown under low irradiance, rooting was restricted because of the limited availability of photosynthetic assimilates (3).

In our experiments etiolated cuttings rooted well only, if after etiolation, the stock plants were grown in long days (16h). After etiolation the stock plants grew very poorly in short days (8h). With *Betula* the shoots even often died. Therefore there were not enough

Table 1. Influence of light on percent rooting of cuttings of *Betula utilis* and *Corylus maxima* 'Purpurea' in relation to the number of cuttings started. Data taken on April 20

Stock plant treatments					
Daylength	Irradiance level	Irradiance level for cuttings 100%	33%	10%	Mean
		A. *Betula utilis*			
8h	100%	82 9 f-j[1]	78 0 f-j	71 4 e-i	77 6 bc[2]
8h	33	51 3 a-e	66.6 c-h	41.2 a-c	53 1 a
8h	10	50.4 a-e	68 0 d-h	33 9 ab	50 8 a
16h	100%	76 3 e-j	90 9 i-k	86 2 g-j	84 9 bc
16h	33	70 0 d-i	79 8 f-j	87 5 h-k	79 6 bc
16h	10	88 6 h-k	86 9 g-k	31 0 a	71 3 b
24h	100%	32 3 a	44 6 a-d	70.0 d-i	52.1 a
24th	33	71 5 e-i	75.4 e-j	81.3 f-j	76 2 bc
24th	10	90 5 i-k	93 6 jk	52 0 a-e	81 5 bc
Et/8h		x	x	x	x
Et/16h		72 7 e-i	98 7 k	85 2 g-j	88.1 c
Natural		59.2 b-f	64 1 c-g	81 4 f-j	68.7 ab
Mean		69 0 a	79 1 b	68 7 a	
		B *Corylus maxima* 'Purpurea'			
8h	100%	16.6 b-g[1]	37.3 f-l	30.8 e-k	27 8 b[2]
8h	33	—	—	—	—
8h	10	8 5 b-e	9 1 b-3	6 3 a-d	7.9 a
16h	100%	42 0 g-l	77 2 no	58 5 k-o	59 7 cd
16h	33	37 5 f-l	45 7 h-m	52 9 l-o	48.7 c
16h	10	9 8 b-e	24 6 c-i	12 3 b-f	15 0 ab
24h	100%	674 0 l-o	83 4 o	78.8 no	75 8 d
24h	33	52 6 i-n	74 7 m-o	61.9 l-o	63 3 cd
24h	10	3 8 ab	18 6 b-h	4.9 a-c	8 1 a
Et/8h		0 0 a	13.1 b-f	26 4 d-j	8 9 a
Et/16h		55 3 j-n	83 2 o	71.6 m-o	70 7 d
Natural		0.0 a	0.0 a	0.0 a	0 0 a
Mean		24 4 a	46 0 b	39 1 b	

Results were calculated with the use of two-way analysis of variance after Bliss transformation

[1] All values of the different treatments followed by the same letter are not significantly different at the 0.05 level by Duncan's multiple range test.

[2] Mean values within the column, or the row, followed by the same letter are not significantly different at the 0.05 level, by Duncan's multiple range test

In the table, treatments from which cuttings were lost by accident are marked by "—" and treatments omitted since there were not enough cuttings are marked by "x".

cuttings available which caused the omission of this treatment. The etiolated *Corylus* cuttings from the short-day treatment rooted very poorly, just as did cuttings from the short-day and the lowest light intensity. It indicated that after etiolation the stock plants require good conditions for active growth—long days and presumably high light intensity. After the cut-off of the possibilities for assimilation, and after the stress caused by darkness (etiolation), further reduction in normal growth conditions negatively influenced rooting and growth of rooted cuttings. This is probably caused by the necessity to increase the carbohydrate content.

Cuttings taken from stock plants of *Acer palmatum, Cornus florida, Magnolia, Hamamelis* grown in the greenhouse often root better than those from outside plants (8, 12). Such a difference was also shown with *Corylus* in this experiment. Stoutemyer (18) suggested that this better rooting could be promoted by increasing air humidity and temperature, or by stopping access of ultraviolet rays.

Pinus mugo cuttings in our current experiment rooted worse than in preliminary experiments, where cuttings obtained from stock plants overwintered in the greenhouse rooted in the spring in over 70%. Data of our current experiments are not in agreement with results of Hansen *et al.* (7) and Stromquist and Hansen (20) where lower light intensity for *Pinus sylvestris* stock plants promoted rooting. On the other hand some lowering of irradiance for cuttings was beneficial in our experiment, similar to the findings of Loach and Whalley (11) for many kinds of plants.

The results presented here show that stock plant manipulation can provide successful rooting of cuttings of plants known to be difficult to root. It can also accelerate nursery production and reduce necessity for auxin treatments.

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PRODUCTION OF QUALITY ONE AND TWO YEAR UNDERCUT STOCKS

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Tilhill is a private forestry management company with it's activities split into the following divisions: Forestry management, nurseries, and landscaping.

The Company began operations in 1948 with it's principal work being advising landowners on the best methods for replanting the areas of woodland felled during the Second World War. It was soon realised that plant supply was an important aspect of reafforestation so the Nursery was developed and the choice of a heathland site was very fortunate.

The Nursery is situated at Tilford near Farnham, Surrey, on 100 hectares of sandy heathland soil with a natural pH of 3.5 which is raised to between 4.5 and 6.0 by the application of ground magnesium limestone.

Advantages of the site:

100 ha on one site of relatively flat ground approximately 60 metre above sea level.

A very light sandy soil, free draining and workable all year round and which warms up rapidly promoting growth.

Geographically situated in southern England having a very long growing season.

Ample water available for irrigation and two 5-million gallon reservoirs.

Disadvantages of the site:

High risk of early and late frosts.

Local populations of rabbit and roe deer must be fenced out.

A short dormant period means a high pressure of work during the lifting period.

Land preparation. One of the keys to successful production is the management of the soil. A typical cycle in the nursery following a crop is:

1) A stone picking machine removes stones and residues from previous crops—to a depth of 15 cm.
2) The land is ploughed to 22 cm to keep a good depth of cultivation.
3) Following soil testing, ground magnesium limestone is applied to correct pH deficiencies. A high potash basal fertiliser with phosphate and magnesium is added. Organic matter in the form of hop waste and well-rotted chicken manure is applied at 40 to 60 tonnes per hectare. The fertiliser and organic matter are lightly harrowed in.

4) The land is subsoiled to 0.5 metre depth at 1 metre centres, sometimes in both directions and is then ready for seedbed preparation or sterilising.

Soil Sterilisation. For the production of one-year stocks the sterilisation of the soil using Basamid enhances growth and quality of the product. The sterilising operation, carried out in September, involves the accurate application to the soil of Basamid granules using a Sisis Lospread.

This is then rotovated in to a depth of 15 to 20 cms and the 1 metre wide seedbeds are then formed using a tractor-mounted bed-maker which incorporates a light roller. Because of the very light nature of the soil, polythene sheeting is then laid over the beds to seal the surface using an MJF polylayer. Some nurseries with heavier soil can seal the surface by watering and rolling but on the very light soils at Tilhill polythene is necessary to seal the surface to enable the gas to work. Using five tractors 1.8 hectares can be sterilised and covered in polythene in a normal working day. A total of 12 hectares will be sterilised at Tilhill this year for seedling production. The polythene is removed in January and weed which has grown in the alleyways is sprayed with Paraquat. The beds are then lightly raked to remove any remaining gas. The soil is tested by sowing cress seed on to samples of soil contained in sealed jars. The land is now ready for seed sowing.

Seed. Seed will have been obtained during the previous year and pre-treated if required.

Germination data is obtained and tests are carried out to enable the correct sowing densities to be worked out. For most hardwoods, end-of-season bed densities of between 60 and 120 plants per m^2 is ideal, while for conifers 150 to 200 plants per m^2 gives a high proportion of usable plants.

Sowing. Seed sowing begins in February and is normally completed during April. The seed being sown for the production of the two-year undercuts is sown on unsterilised seed beds. The two-year growing period gives adequate height growth without the need or cost of sterilising. Undercuts aged one or two years can be produced from either broadcast or drill sowing.

Four methods of seed sowing are used by Tilhill:

- Sisis Lospread for broadcasting seeds of most conifer species and of beech.
- Sisis Lospread with a drill sowing attachment is used for the larger seeded broadleaves, e.g. oak, sweet chestnut, and hazel.
- Matco-Fahse vacuum precision drill for conifers.
- By hand for small lots of conifer and hardwood seeds and for difficult-shaped seeds, e.g., birch, sycamore, ash, Lawson cypress and western red cedar.

For seeds to be sown on the bed surface, using either the Sisis Lospread or by hand, a fine tilth is created using a tractor-mounted machine which levels, rolls, and brushes in one operation.

The seeds are then sown at the predetermined density, rolled into the surface and covered by a thin layer of lime-free grit, applied with a tractor-mounted grit spreader. The bed surface preparation is also required for conifer seeds that are sown with the Matco-Fahse precision drill, as these seeds are also placed on the bed surface, rolled in, and covered by grit.

Deeper drilling of seeds of broadleaved species is done using the Sisis Lospread with the drill sowing attachment. Seeds of round-seeded species, such as oak, sweet chestnut, and hazel, can be drilled, covered and the surface rolled in a one-pass operation. Seeds of the winged species, *Acer* and *Fraxinus* are sown by hand into the open drills, drawn out using the Sisis attachment, and then covered with soil and rolled by a second pass of the machine.

Protection. Once the seeds are sown most species require protection from attack by birds and are covered with plastic netting held off the bed surface by wire hoops. Some 100 km of netting is put down annually over the seedbeds.

Undercutting, wrenching, and lateral pruning. Once the seeds have germinated and the protective netting removed, the undercutting of the roots can commence. The roots are cut at depths of 10 to 15 cm depending on species and size of plant. Using the Summit Reciprocating Undercutting machine developed in New Zealand, it is now possible to undercut plants at a smaller size than previously possible.

Undercutting of hardwood species commences in June with strong-rooted species, such as cherry, sycamore, oak, and ash and is completed in August with lighter rooting species, such as birch and alder. Conifers are normally undercut in August.

A wider blade is used on the Summit Reciprocating Undercutter for wrenching the plants in the beds during late August, September, and October to stimulate the production of more fibrous roots and to encourage the growing shoot to harden off. Other machines with fixed blades can be successfully used for this operation.

In the production of two-year undercuts, particularly conifers, a Summit Lateral Pruner, which consists of a set of steel discs on a frame, cuts the laterally growing roots between the rows. All these root modifying operations lead to the production of well balanced plants with compact fibrous root systems ideal for planting and growing in the forest.

Irrigation and frost protection. Irrigation is normally required from sowing, depending on the season's weather, to keep the moisture content of the seed correct for germination, for the root

cutting operations, and to incorporate granular fertiliser application.

Many of the species being grown, both conifers and hardwoods, are susceptible to shoot damage from early and late spring frosts. To avoid this the Portagrid irrigation system is set out to apply 1/8 in. of water per hour once the air temperature falls to 0 °C. Ice forms on the tops of plants but the latent heat produced when the ice is forming keeps it above the temperature which can cause damage to plant cells.

Some 25 hectares of the most susceptible species can be protected in this way at Tilhill and up to one million gallons of water may be used during an 8 hr. frost night.

Fertiliser applications. Following seed germination, top dressing of Gold'N', a slow-release nitrogen fertiliser, is applied at 150 Kg. per ha. This type of fertiliser can be applied when the plants are very small because no foliage scorching occurs. Two top dressings of K Nitro (25:0:16) are applied during June and July at rates of 185 to 250 Kg per ha. The rate varies depending on the density of plants on the bed and the amount of rainfall or irrigation applied. K Nitro is used because the nursery soils are generally low in potassium.

Then, during late August or September, a high potassium (14:0:28) fertiliser is applied at 185 Kg. per ha., to encourage hardening-off and to keep the plants in a healthy condition during the dormant period.

Lifting and grading. The plants are loosened in the bed using a tractor-mounted Magnifique bed lifter. By careful adjustment the plants can be loosened but still left with a covering of soil on the roots. This prevents the roots from drying out and from any damage which could occur from an overnight frost. Grading and counting can then take place as the plants are being lifted, or the plants can be taken directly into cold storage for the grading operation to be carried out later.

EVALUATING THE QUALITY OF SITKA SPRUCE PLANTING STOCK BEFORE AND AFTER COLD STORAGE

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Abstract. Replanting second rotation conifer forests in Great Britain will require better quality planting stock because of more difficult site conditions compared with the first rotation Case histories revealed that poor cold storage practice was a major cause of planting failure Data from three studies with Sitka spruce are presented to explore the relationship among storage, plant type, physiological quality and forest performance. Plants lifted to cold store from early December to March and outplanted in April showed generally high survival with no difference between undercuts and transplants The onset of this lifting window coincided with a rise in prestorage root growth potential (RGP) and around 300 accumulated chilling hours below 5 °C. However, undercut plants could be lifted up to two weeks earlier than December 1 without apparent loss in quality Alternative tests of physiological status such as mitotic index and membrane leakage gave as good indication of planting stock quality as RGP and were quicker to use

INTRODUCTION

Successful establishment of forest plantations is achieved by using good quality planting stock, together with appropriate site preparation, plant handling, planting, and post-planting maintenance. In Great Britain, there is increasing awareness that replanting of clear-felled conifer forests will require planting stock of higher quality than was used to establish the first rotation. This is because the presence of stumps and harvesting residues makes cultivation more difficult and there are greater pressures on newly planted trees from insects, browsing animals, and weeds (13). As a result the morphological grades applied to conifer planting stock have become more stringent, and now include the requirements for a larger root-collar diameter for a given height (2). Stricter morphological standards have both short- and long-term benefits for the forest performance of conifers (7, 12), but there is only an imperfect relationship between morphology and physiological status. The latter is generally considered a better guide to the forest performance of a batch of planting stock (8, 14).

Recognition of the importance of seedling physiology in influencing plantation success (4, 8) has resulted in the development of a range of tests for monitoring the physiological status of seedlings. These include techniques for assessing nutrient and carbohydrate status, bud dormancy, frost hardiness, shoot water potential, stomatal resistance and root regenerative ability and other parameters. One or more of these tests could be used to complement or even replace the morphological criteria of seedling quality used at present.

Case histories of post-planting failure can offer a guide to problem areas and indicate which tests may be useful. Table 1 gives figures for the number of cases of immediate post-planting failure investigated by Forestry Commission Northern Research Station (NRS) staff from 1985-1989 and the likely causes. The number of plants involved in a single case can be considerable. For instance, one investigation in 1989 covered nearly one million dying trees planted in some 10 forest areas. It is clear that lifting practice, particularly time of lifting and subsequent storage regime, is implicated in most reported cases of planting failure. Therefore, our recent work has considered the ability of conifer planting stock of varying quality to withstand the stresses imposed by lifting and/or cold storage. We have also attempted to relate post planting performance to various measurements of physiological status. The research programme is still continuing, but this paper presents results from 3 cold storage studies with Sitka spruce (*Picea sitchensis*). This is the major conifer species in British forestry and featured in each year of Table 1. These studies illustrate some of the complex problems which will need to be considered before monitoring the physiological status of seedlings can become a reliable operational measure.

Table 1. Cases of conifer post-planting failure in seasons 1985-1989 and attributed causal factors

		Attributed causal factors			
Season	Number [3] of cases	Lifting and/or storage practice	Causes[1] Handling/ Insecticide	Planting, site factors	Species[2]
1985	6	2	4	1	DF, SS
1986	9	7	3	2	SS, NF, SP
1987	8	5	2	2	HL, SS
1988	13	9	4	5	JL, NF, DF SP, CP, SS
1989	11	10	3	1	JL, DF, SS, NF, LP
Total	47	33	16	11	

Notes
[1] Total of causes is more than number of cases since in some cases a single causal factor could not be identified
[2] Species codes are DF—Douglas fir, SS—Sitka spruce, NF*-noble fir, SP—Scots pine, HL—hybrid larch, JL—Japanese larch, CP—Corsican pine, LP—lodgepole pine
[3] Case histories are from both private and state forests

MATERIALS AND METHODS

Experiment 1. Two-year-old planting stock of Sitka spruce of Queen Charlotte Islands (QCI) origin was raised at Wykeham nursery,

North Yorkshire, during 1984-85 as either 1+1 transplants or 1u1 undercut plants. Nursery regimes followed those described by Aldhous (1) for 1+1 and by Sharpe (11) for 1u1 plants. At fortnightly intervals from October 15, 1985 to December 15, 1985 and on January 15 and March 15, 1986, 100 randomly chosen plants of each treatment were lifted, put into a sealed black-and-white coextruded polythene bag and placed in a direct-cooled cold store (1 °C). On April 2, 1986, a further 100 plants were lifted and kept in temporary cool storage to provide a direct lifted contrast. On April 11, 1986, all treatments were removed from cold or temporary store, and 10 plants per treatment were placed in a root observation box (see 13, Plate 1) in an unheated greenhouse under natural day length. After 21 days the number of new white root tips more than 1 cm long was counted to give an estimate of Root Growth Potential (RGP) (10). A further 50 plants per treatment were planted in Wykeham forest on cultivated ground; a randomised block design was used with 5 replicates of each treatment and 10 plant plots. Plant survival was assessed at the end of 1986. Air temperature on the nursery was recorded daily from September 1, 1985, using max-min thermometers.

Experiment 2. Two-year-old transplants or undercuts of QCI origin Sitka spruce were raised at Wykeham nursery during 1985-86 (see Experiment 1). Plants were lifted to cold store at fortnightly intervals from October 1, 1986 to January 15, 1987 and again on April 1, 1987 (direct lifted). Trees were removed from storage for planting and RGP testing on April 6, 1987. RGP tests and experimental design and assessments in the forests followed the procedures used in Experiment 1. In addition, mitotic index of shoots calculated as the number of actively dividing cells as a percentage of the total of mitotic cells viewed (3) was assessed on 10 samples per lifting date during October-December 1986 to indicate when plants entered dormancy. Air temperature on the nursery was monitored as in Experiment 1 and chilling hours below 5 °C were accumulated hourly from September 1986 (Biophenometer TA5I, Omnidata Systems Inc, Utah, USA). Chilling hours below 5 °C may be an reliable indicator of a plant's dormancy status (8).

Experiment 3. Two-year-old transplants or undercut planting stock of Sitka spruce (QCI origin) were again raised at Wykeham nursery during 1987-88 (see Experiment 1). At fortnightly intervals from October 1, 1988 to January 1, 1989 and on February 1 and March 1, 80 randomly chosen plants of each treatment were lifted and cold stored as in Experiment 1. On each of the 9 lifting dates, a further 40 plants of each treatment were lifted for measurement of RGP (14 day test in a growth room at 20 °C with 16 h photoperiod) and other parameters. The terminal bud from 20 plants in each treatment was fixed immediately for later determination of mitotic index.

Chronic cold tolerance of fine roots was also assessed (McKay and Mason, in prep.). The degree of damage was assessed by electrolyte leakage using a temperature compensated conductivity meter (8), with values in the text expressed as the post-storage figure divided by the pre-storage ones. On April 1, 1989, all plants were removed from cold store and planted in Wykeham forest using a similar design to Experiment 1, except 20 plant plots were used and survival was assessed at the end of June. In addition, a further 30 plants were checked for RGP after storage. At time of writing, data analysis has not been completed so only preliminary results are reported here.

RESULTS

Experiment 1. For the first 4 dates of lifting only, there were highly significant differences in survival between the 2 plant types (Table 2) with undercuts showing better survival than transplants. RGP at time of planting was significantly lower in transplants than in undercuts for all dates of lifting.

Table 2. Experiment 1. Sitka spruce plant type and cold storage Relationship between forest survival, RGP, and monthly mean temperature for 1+1 and 1u1 stock lifted to cold store on different dates during 1985/86

	Date of lifting								
Plant type and assessment	15 Oct	1 Nov	15 Nov	1 Dec	15 Dec	15 Jan	15 Mar	1 Apr	5% LSD
1+1 Survival[1]	0	0.6	4.4	7 8	10 0	9 4	10.0	10.0	) 1 03
1u1 Survival	9.0	9 2	10 0	10.0	9 8	10 0	10 0	10.0	
1+1 [2] RGP	0	0	3.4	4.2	4.6	20 0	15.8	20.8	) 12.6
1u1 [3] RGP	17.9	28 5	29.6	30.9	57 0	33.0	57.4	47.4	
	Oct	Nov	Dec	Jan	Feb	Mar			
Temperature, °C	10 5	3.0	4.7	2.1	-0 8	3.8			

[1] Survival is average number of plants per pot (maximum=10).
[2] 1+1=transplants, [3] 1u1=undercuts.

Experiment 2. For the first 3 dates of lifting, there were significant differences in survival between the Sitka spruce plant types, with the undercuts being superior to the transplants (Table 3). From the November 15 lift onwards survival was high throughout with no significant differences occurring. RGP values were consistently higher in the undercuts than the transplants when averaged across all lifting dates ($P<0.001$). RGP values were noticeably higher in the undercuts at the beginning of the experiment. Apart from a mild

spell in early October, chilling hours accumulated progressively throughout the winter months. Mitotic index values were high in October and declined progressively until January when no bud activity was apparent. Values for undercuts tended to be lower than for transplants (standard errors are typically 10% of the means).

Table 3. Experiment 2. Sitka spruce plant type and cold storage Relationship between forest survival, RGP, mitotic index (MI), mean monthly temperature and chilling hours of 1+1 and 1u1 stock lifted to cold store on different dates during 1986/87

	Date of lifting									
Plant type and assessment	1 Oct	15 Oct	1 Nov	15 Nov	1 Dec	15 Dec	1 Jan	15 Jan	1 Apr	5% LSD
1+1 Survival[1]	0	0 6	8 6	9.4	9 6	10 0	10 0	9 8	10 0	) 0.9
1u1 Survival	8 2	9 2	9.6	10 0	10.0	9 8	9 8	10 0	10.0	
1+1 [2] RGP	0	0	21.8	31 9	51 7	30.8	38 5	50 6	47.9	
1u1 [3] RGP	17 7	7.5	38 5	42.1	61 1	35.7	48.0	62 6	58.6	
1+1 MI	12.4	10 0	11.7	10.2	6 5	1 2	0 0	—	—	
1u1 MI	9 7	6.3	8.4	8 7	4 3	1.9	0 0	—	—	
Chilling hours 5 °C	33	33	1-4	170	324	500	809	1133	—	—
	Oct	Nov	Dec	Jan	Feb	Mar				
Temperature, ° C	9.3	6 2	4.2	1.4	3.0	2.5				

[1] Survival data are average number of plants per plot (maximum = 10)
[2] 1+1 = transplants,
[3] 1u1 = undercut seedings

Experiment 3. Survival at the end of June showed significant differences among plant types for the first 3 dates of lifting with undercuts outperforming transplants (Table 4). RGP values before storage (i.e. fresh lifted) show few significant differences among treatments except in January and March when the undercut plants had higher values. However, RGP after storage revealed differences among plant types with undercuts being consistently higher than transplants. Post-storage RGP values were generally lower than pre-storage ones. Plants stored on or before November 15 had much greater root membrane leakage after storage than was found for plants stored later in the season. Assessment of mitotic index showed that activity in shoot tips declined from October to December, remained negligible until after March 1 and then increased rapidly in the spring. Frost hardiness testing (data not presented) revealed shoots of both plant types to be hardy to -10 °C by late October and to -25 °C by late November.

Table 4. Experiment 3. Numbers surviving at end of June, 1989, monthly mean temperature, RGP before and after cold storage, mitotic index and membrane leakage for 1+1 and 1u1 plants of Sitka spruce lifted to cold store on different dates during 1988/89

		Date of lifting										
Plant type and assessment		1 Oct	15 Oct	1 Nov	15 Nov	1 Dec	15 Dec	1 Jan	1 Feb	1 Mar	1 Apr	5% LSD
Survival	1+1	3 0	1 4	9 0	19 4	19 0	16 2	19 6	17 2	20 0	17 8	3 7
Numbers[1]	1u1	12 8	9 8	19 4	19 8	19 8	19 6	19 6	20 0	20 0	19 6	
RGP	1+1	13 8	5 9	5 5	9 1	19 9	9 9	18 3	44 4	19 8	5 6	8 5
before	1u1	15 9	7 5	6 1	10 4	15 4	11 2	31 8	40 0	49 9	12 6	
RGP	1+1	0	0	0 1	4 3	3 3	4 9	5 0	7 2	3 8	—	4 7
after	1u1	2 4	2 1	3 2	9 2	8 9	10 5	8 4	13 6	20 6	—	
Membrane	1+1	D	D	10 2	2 6	1 2	1 4	1 9	1 2	1 3	—	N/A
leakage	1u1	1 8	4 9	1 9	N/A	1 3	0 9	1 4	1 1	1 3	—	
Mitotic	1+1	2 2	2 5	1 8	1 3	0 3	0 1	0	0	0	2 7	N/A
index %	1u1	3 0	1 9	1 5	1 1	0 1	0 1	0	0	0	2 8	

Temperature,	Oct	Nov	Dec	Jan	Feb	Mar
°C	9 1	5 1	6 5	5 1	4 6	5 8

[1] D = dead, N/A = no data available

1+1 = transplants, 1u1 = undercut seedlings

Survival is average number of plants per plot (maximum = 20)

DISCUSSION

The results from these experiments indicate that undercut Sitka spruce of QCI origin can be safely lifted to cold store from mid-November onwards, and transplants from early December, without reducing post-planting survival. The results with transplants agree with recent general lifting recommendations for this species in Britain (13). The variation we found among plant types shows that these lifting seasons could be lengthened if physiological status could be monitored easily. The difference among plant types is consistent, even though temperature records show appreciable differences among seasons (Tables 2 and 4).

In Experiment 3, fresh lift RGP was highest between December and March, supporting the view that there is a positive relationship between high RGP and storability (10). From the chilling hours data of Table 3 and other unpublished data we suggest that the earliest recommended storage dates coincide with the accumulation of around 300 hours below 5 °C. From the mitotic index (MI) values, we believe plants can be lifted safely to store before activity in the shoot

tip has ceased (e.g. December data of Tables 3, 4). The difference in MI among seasons probably results from the use of different observers.

A knowledge of RGP cycles and/or accumulated chilling hours and their relationship with plant dormancy status can help to devise safer lifting and cold storage schedules for a particular nursery. These schedules could be used to predict or manipulate planting stock quality (9).

However, there are problems with this approach since the relationship between chilling hours and RGP is not consistent among plant types within species. Thus, 1u1 Sitka spruce can be safely lifted earlier than 1+1 transplants and this difference is evident in the post storage RGP values but not in the values recorded before storage.

Jenkinson (5) reported that the length of lifting seasons for different seed sources of Douglas fir could vary from between two to four months over the period November to March. There would clearly be major logistical problems in attempting to establish definitive storage schedules linking chilling hours, RGP, and survival for all 10 to 15 conifer species commonly grown in large British forest nurseries if seed source and aspects of growing regimes (e.g. undercutting, nitrogen top-dressing) are to be taken into account. The RGP test is also likely to take too long (14 days) for a commercial nursery. Test results are variable and a poor prediction of forest performance (6).

If physiological tests are to be of operational use in defining cold storage schedules, they must firstly indicate that plants are adequately cold-hardened to withstand cold storage and, secondly, reveal any serious damage when plants are removed from the store for dispatch. In both situations, speed of determination and repeatability of measurement are of considerable managerial and financial importance.

It is unlikely that there is any single test available which can be used for both purposes. Shoot MI appears to be useful for identifying the start of the lifting season in early winter since low mitotic activity is linked with the onset of true dormancy and peak storability (Table 4).

After one week's training, at least 40 samples can be processed per day to give an indication of the level of activity in the terminal bud. However, this method is possibly a conservative indicator of storability since plants can be lifted before MI has approached zero, and therefore it may be necessary to define safe threshold levels. Work is also needed to determine how useful the technique could be in determining the end of the lifting season in spring as plants begin growth.

Testing for membrane leakage of shoots after storage when compared against prestorage standards also seems to be a fast,

repeatable measurement that could be used to check batches of doubtful plants. Results could be obtained within a maximum of 24 to 48 hours.

Further work is required testing both techniques on a wider range of species before their potential can be properly assessed, but both have the theoretical advantages of being cheaper and faster to apply than RGP while monitoring plant status directly, unlike accumulated chilling or other temperature records.

CONCLUSIONS

It is essential that storage practice be founded upon a sound physiological basis, using appropriate tests to determine when plants should go into store, to monitor their health while in store, and to check their quality after store. Such tests could become equivalent to the "sell-by" date labelling used in supermarkets. Ensuring that plants are in the best physiological state when they leave the cold store will not eliminate planting failure, but it may help to make plantation performance more predictable and assist in more cost-effective establishment operations.

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ORNAMENTAL NATIVE PLANTS OF BRITISH COLUMBIA: THEIR SELECTION, PROPAGATION, AND INTRODUCTION

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British Columbia has a resource of native plants whose potential is not always appreciated. The range of plants is extremely variable and very dependent upon the Province's diverse climate—from the alpine areas of the coast and Rocky Mountains to the dry, arid areas of the south east. Also there is the high rainfall area of the Queen Charlotte Islands, containing many unique species, to the drier Vancouver Island and numerous adjacent islands.

This paper is to discuss some of the species that the University of British Columbia considers as a basis for further selection and introduction into nursery production for sale as ornamental plants for the urban landscape.

Besides the many economically important forestry species such as *Abies grandis, Pseudotsuga menziesii, Thuja plicata,* and *Tsuga heterophylla*, perhaps the best known native tree is the Pacific or western flowering dogwood, *Cornus nuttallii.*

Cornus nuttallii. This is distributed naturally throughout southern British Columbia and on into Southern California. Spectacular in flower, with its white showy bracts, it is normally seen growing in and among other native flora, as too much sun will split its bark. Also in recent years, the dogwood leaf blotch fungus, *Gloesporium* sp. has severely weakened trees through dieback of young shoots and premature defoliation. Flower size and habit is variable in the wild so that considerable scope is offered for selection in flower size, habit, hardiness, and resistance to dogwood leaf blotch.

The fruits and seeds of *Cornus nuttallii* mature in September and October. Following fruit collection, seed is extracted. Prior to sowing under glass in the spring, two methods are effective for overcoming dormancy—cold stratification at 3 °C for 14 weeks, or acid digestion for 20 min., using concentrated sulfuric acid followed by cold stratification at 3 °C. The latter is particularly useful for seed collected in hotter climates or older seed but care must be taken as to the length of acid digestion, as embryo damage may occur. For clonal forms such as *C. nuttallii* 'Ascona' and *C. nuttallii* 'Corigo Giant', cutting propagation is rather unpredictable but bench grafting in January or February, or chip or T-budding in August is effective in British Columbia. *Cornus florida* should be used as the rootstock

[1] Director

because of its easy availability, but of more importance, is that it also gives considerably better establishment following transplanting.

One of British Columbia's pioneer nurserymen was Henry M. Eddie. During the 1930s and 1940s, he began hybridizing *C. nuttallii* with *C. florida* to bring together the qualities of both plants. Besides hardiness, habit, and fall colour, his initial aim was to breed a pink-flowered hybrid with flowers similar to the parent *C. nuttallii*. A number of hybrids arose including a compact weeping form, but all these were lost in the very heavy flooding of the Fraser River in 1947. Fortunately for us today, he planted one selection adjacent to what is now the Vancouver International Airport. This tree was subsequently named *Cornus* 'Eddie's White Wonder' and patented and introduced into the United States by Wayside Gardens. This unique hybrid has since been internationally acclaimed and grows successfully in various regions of the world. Although it is hardy in Ohio and Tennessee, it first did not grow well. Initially this was thought to be due to climate, but later it was found that trees bought from the West coast were worked on *C. nuttallii* and not *C. florida*.

A foundation has now been initiated at the University of British Columbia Botanical Garden and named the Henry M. Eddie Plant Development Foundation. This Foundation will be used mainly to support plant breeding, plant collecting programs, and clonal selection. Repeating some of the crosses initially made by Henry Eddie are planned for the future.

Arbutus menziesii. This is another tree but with a narrower natural distribution. It has attractive cinnamon-coloured bark and orange dull-red fruit. In the wild it grows from 10 to 25 m in height and normally is found on rocky, coastal outcrops of Western British Columbia and off-shore islands. When first seen growing in nature, I realized why we were having problems growing it on nurseries in the U.K. It thrives in dry locations and excessive water quickly makes it susceptible to *Phytophthora* root rot. Provenance does affect hardiness following seed collection. Seed is best stratified for 12 weeks at 3 °C prior to sowing under glass. The seedlings must be protected from late spring frosts during the early years following germination.

Amelanchier alnifolia. Another species under evaluation is a different form of *Amelanchier alnifolia*, which has intense white flowers and fall colour. In Canada, the work at Beaverlodge Experimental Station, Alberta, is well known for research in selecting fruiting forms for culinary purposes, e.g., *A. alnifolia* 'Smoky'. Seed propagation in spring is reliable following a 8 to 12 week stratification period at 3 °C. (Timing is vital when collecting the berries as trees are quickly stripped by birds). *A. alnifolia* seed is particularly prone to fungal infection during stratification, so precautions are advised.

Although softwood cutting propagation is often unpredictable, satisfactory results have been produced when preparing cuttings just as the basal tissues of the new shoots become lignified. Following shallow wounding, 0.8% to 1.0% IBA in talc is applied and the cuttings are stuck into a well-drained medium of 1:1 peat moss and perlite (or peat moss and bark) and then placed under mist or fog. Premature leaf fall takes place if cuttings are stressed.

Overwintering of rooted cuttings can be a problem. As with other *Amelanchier* species it is best not to remove cuttings from the flats for potting until after the first flush of growth the following spring. Root cuttings are reliable if prepared in 5 to 10 cm lengths during January or February and dusted with a fungicide prior to sticking. To provide greater reliability in vegetative propagation, micropropagation is developing as a standard technique for the clonal forms.

Paxistima myrsinites. An evergreen widespread native shrub found in drier locations is *Paxistima myrsinites* (Oregon box or myrtle boxwood) with its very small red flowers and leaves similar to *Buxus sempervirens* and *Ilex crenata.* Despite being popular as cut foliage for florists, it is becoming increasingly in demand by landscape architects. There is considerable variation of habit and leaf form in the wild so that seed-raised nursery crops show a considerable variation in product. Clonal selection of different forms collected by Al Rose, curator of the University of B.C. Native Garden, has resulted in a very attractive weeping form, *P. myrsinites* 'Emerald Cascade', which roots readily under contact polyethylene film during September through January, following a 0.8% IBA application in talc. Its consistent performance makes it an ideal candidate for direct sticking. Its drawback in nursery production is its susceptibility to the soil-borne pathogen, *Pythium irregulare.*

Trials are underway at participating nurseries for further study. In the long term we are sure this native plant will be widely used within dry locations in the urban landscape.

Vaccinium ovatum. This is another genetically variable native plant. *Vaccinium ovatum* (evergreen huckleberry) is abundant in many coastal locations. An outstanding form with excellent reddish-brown new growth with masses of pink flowers in the spring followed by black berries in late summer has been named and registered as *V. ovatum* 'Thunderbird'. Obtaining enough cutting material may be a problem as branches containing flowering shoots are shy to break. Hard pruning of stock plants will encourage vigorous non-flowering shoots. Also rooting cuttings containing flowers are very irregular in breaking the following spring.

Successful rooting within 8 to 10 weeks under contact polyethylene from September through January is accomplished using 0.8% IBA in talc.

Ribes sanguineum. This is a well-known deciduous shrub relatively widespread in the coastal regions from British Columbia into northern California. Many cultivars are standard features in many European gardens. In the wild, flower colour is variable with colours ranging from mid-pink to bright pink into red. Other variations include inflorescence size and habit. Recently a long racemed white form from our Botanical Garden was named, registered, and introduced as *Ribes sanguineum* 'White Icicle'. A very attractive soft shell-pink clone is currently under evaluation for potential introduction. An unusually hardy form has been collected with the hope it will subsequently mean that this plant has a wider sales distribution within Canada. Propagation by the standard procedure of softwood cuttings in June and July and deciduous hardwood cuttings in November and January, as used for other cultivars is recommended.

Philadelphus lewisii. This is another deciduous shrub showing genetical variation, particularly in flower size. We are currently testing a particularly large-flowered form. However, mainly because of hardiness, we are hybridizing the more compact forms with other ornamental species. One of these is the Asian species, *P. delavayi* var. *melanocalyx*, which has an outstanding purple colour on its pedicel and calyx.

Potentilla fruticosa. This is widespread in British Columbia and noted for its extreme hardiness. The British Columbia nursery industry has found some of the current pink and red clones from Europe not sufficiently hardy in containers during extreme cold weather. Also a number of the current yellow clones do require considerable shearing during their production cycle. A plant given to the Garden in 1976 by the late Ed Putnam of Kirkland, Washington was named by the evaluation panel of the Plant Introduction Scheme of the Univ. of British Columbia (PISBG) program for introduction. It is very compact, thus requiring minimal pruning, produces a mass of yellow flowers with an attractive wavy petal over a long period, but also is extremely hardy in containers. The 1988/89 winter of extreme temperatures severely damaged a number of the current commercial yellow cultivars. This cultivar has been registered and named as *Potentilla fruticosa* 'Yellow Gem'. It is readily propagated by softwood cuttings in May through July, or deciduous hardwood cuttings in November through January. Stock plants should be heavily pruned in winter because a profusion of flowers reduces vegetative growth available for cuttings.

Arctostaphylos uva-ursi. Native plants of British Columbia provide a number of important ground covers, e.g., *Cornus canadensis* and *Gaultheria procumbens*, but *Arctostaphylos uva-ursi* is, by far, the major ground cover favoured by landscape architects. Again it is very widespread and variable in the wild and, until recently, nursery

growers mainly propagated from shoots collected in the wild which, in turn, gave a variable product. Also, percentage rooting varied considerably with a range from 40% to 70%. By far, one of the most important introductions through the P.I.S.B.G. has been *A. uva-ursi* 'Vancouver Jade'. Rooting up to 90% is obtained and it is vigorous with an excellent uniform habit, producing in the spring numerous darker pink flowers than the type species. It has bright green foliage, that is more tolerant to some of the common pathogens and turns an attractive purple-red colour in cold climates. It is best rooted under mist, plastic or fog, using 0.8% IBA in talc as nodal or heel cuttings in October through January. There are two important criteria for success, firstly ensuring the cuttings are not stressed prior to sticking (being an evergreen this is often overlooked, particularly if late summer and early fall cuttings are stressed—so irrigation of stock plants in dry summers is important). Secondly, the rooting medium must be well drained; we use 1:1:1 peat moss, perlite, and pumice. Two to three cuttings per pot are recommended for direct sticking.

Rosa woodsii. Two very hardy species which are being increasingly used for reclamation and erosion control are *Rosa woodsii* (Woods' rose) and *Shepherdia canadensis*. *Rosa woodsii* is widely dispersed and typically it is relatively low-growing, bearing fragrant pink flowers and small leaves. Recently we have been collecting variants in the wild and have a promising low-growing selection for container work bearing a profusion of bright pink flowers and fruits which will subsequently require vegetative propagation from softwood cuttings. Typically *Rosa woodsii* is propagated by seed. As with many rose species, seed germination from year to year can be unpredictable. However a guideline confirmed through work at Reid, Collins Nurseries, Aldergrove, B.C. is to proceed with a pre-sowing treatment of warm stratification 60 days at 20 °C, followed by 90 days at 3 °C, which should give around 45% germination.

Shepherdia canadensis. This belongs to the Elaeagnaceae family and thrives in dry open areas. It is a dioecious nitrogen-fixing species that varies from low to medium in height, has a silvery underside to the leaf, and bears coloured berries ranging from yellow to red.

Propagation by cuttings is difficult thus seed propagation is the recommended method. Best results have been achieved at Reid, Collins Nurseries through a pre-sowing treatment of 5 to 7 minutes of acid digestion, using concentrated sulfuric acid, followed by a 30-day cold-moist stratification at 3 °C. This treatment should result in a 55% to 60% germination.

The Ericaceae family contains a number of gems for ornamental use—many of which are listed in specialist catalogues in Europe and North America. These include *Andromeda polifolia, Arctostaphylos columbiana, Cassiope mertensiana, Cladothamnus pyroliflorus,*

Gaultheria ovatifolia, Kalmia poliifolia, Menziesia ferruginea, Rhododendron macrophyllum, Phyllodoce empetriformis.

Although many of these root successfully from cuttings, seed propagation is very satisfactory. For native species and other ericaceous plants the procedure we use at the University of British Columbia nursery is to sow seeds in containers or flats in the early spring. The seed-sowing medium is: sieved sphagnum peat moss; perlite (can substitute coarse sand or Turface(r)); sterilized loam 1:1:1.

To each cubic metre (cubic yard) of the mix is added: 1160 g (31.2oz) superphosphate; 580 g (15.6 oz) dolomitic limestone; and 110 g (2.9 oz) Ethazol (Truban).

A thin layer of milled sphagnum moss is laid over the medium on to which the seeds are carefully sown and left uncovered. Next they are lightly misted and placed on the glasshouse bench with an optimum air temperature of 16 °C. The containers or flats are best covered with shade cloth or a sheet of glass and brown paper. It is essential they are checked once or twice a day for watering needs and signs of damping off. When of sufficient size to handle, the seedlings can be transplanted into flats or small pots.

We feel that some native herbaceous perennial species offer considerable potential for introduction. With this in mind we applied to the B.C. Nursery Trades Association for a provincial-federal grant under the economic and regional development agreement in Canada for new agricultural and horticultural programs. A grant for $99,616 was received and currently a systematic collection is being carried out by Dr. Wilf Nicholls and Dr. Gerald B. Straley in many different locations in British Columbia.

Beforehand considerable consultation was carried out with industry to develop criteria and target species. Emphasis will be for retail sales and for export into the United States. Criteria include a wide range of hardiness across North America, compactness in a 10.0 cm pot, and floriferous during April and May, after which time garden centre sales can drop dramatically. Target plants include *Anemone multifida, Douglasia, Dryas, Lupinus, Penstemon, Plemonium,* and *Phlox*. Already a number of interesting finds have occurred, which include an excellent *Penstemon* and a dwarf perennial *Lupinus* on Vancouver Island, growing no more than around 15 cm.

Another important aspect with this program is also the support and advice being received from the Provincial Department of Highways which is particularly interested in species which can be mass planted or sown adjacent to new road development.

In conclusion, British Columbia, with its some 3,000 different species, offers considerable potential for recollecting and evaluation for modern nursery production and subsequent wholesale and retail sales. This challenge opens up a new phase in our plant introduction

scheme to stimulate the selection and use of improved forms and relatively unknown species for the British Columbia nursery industry. In turn, it is a challenge the University of British Columbia Botanical Garden eagerly accepts.

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INDUCTION OF JUVENILITY AND ROOTING OF SOME WOODY ORNAMENTALS

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Abstract. In experiments between 1978 and 1989, ornamental members of the Cupressaceae family and *Tilia tomentosa* displayed more or less clearly distinguishable histological and morphological marks in their juvenile and adult (sometimes also in transitional) stages of development, the juvenile always being the better rooters Adult specimens of the above mentioned plants could be reverted to the very juvenile stage by vegetative propagation, shading, etiolation, changing the position of shoot, or other treatments The first new leaves, however, retained their adult shape and only the further, entirely newly initiated ones began to display transitional or juvenile characters.

INTRODUCTION

Juvenility is a key factor during the propagation by cuttings of hard-to-root woody plants. Much research has been done to overcome the problem by using originally juvenile material (young seedlings), (7), or by rejuvenating old mother plants using different cultural methods (1, 2, 3), often called ''preconditioning'' or ''pre-treatment'' (4). The aim of the present paper is to contribute to the complex question of preconditioning, juvenility, and rooting by reporting on some experimental results.

MATERIALS AND METHODS

The experiments were carried out between 1978 and 89, with 12 cultivars and species, using different methods of preconditioning. All the cuttings were rooted in an unheated plastic house in sharp sand, under polythene sheeting. Before insertion, they were treated with a 0.1 or 0.2% alcoholic solution of IBA (5 sec. dip).

RESULTS AND DISCUSSION

Rejuvenation through vegetative propagation and experiments with members of the Cupressaceae family:

Between 1987 and 89, the rooting of 10 cultivars, either as cuttings taken from field-grown, 5 to 11 year old plants, or cuttings taken from young plants propagated in the previous year and pot-grown for one growing season under 50% shade, was compared.

As seen in Table 1, the higher rooting ability of young plants was always accompanied by presence of juvenile foliage.

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Table 1. Effect of the age of vegetatively propagated stock on the juvenile character and subsequent rooting. (1987-89, averaged from three experiments)

Species or Cultivar	Age, (years)	Percent of cuttings with some juvenile foliage before rooting	Percent of cuttings with some juvenile foliage after rooting	Rooting, percent
Chamaecyparis lawsoniana 'Globus'	6-8	0%	37%	13%
	1	65	85	42
Juniperus chinensis 'Pfitzerana Aurea'	6-8	20	65	39
	1	100	100	60
J horizontalis 'Plumosa'	6-8	44	86	62
	1	100	100	80
J sabina 'Mas'	6-8	23	89	73
	1	100	100	80
J virginiana 'Grey Owl'	4-6	15	78	40
	1	87	100	58
J virginiana 'Skyrocket'	9-11	5	72	49
	1	78	87	60
Thuja occidentalis 'Hoveyi'	6-8	40	81	78
	1	64	78	74
T occidentalis 'Wagneri'	6-8	5	76	69
	1	53	78	73
Platycladus orientalis 'Compactus'	4-6	0	15	3
	1	36	44	26
× *Cupressocyparis leylandii*	9-11	0	5	0
	1	100	100	69

The biggest contrast in performance between the two cutting sources was obtained with × *Cupressocyparis leylandii* 'Stapehill'. In Western Europe, it is mainly propagated by cuttings, but in Hungary it is extremely hard and slow to root. The mother plants for this experiment were imported from southern England in July, 1978, as unrooted cuttings taken from an unpruned hedge. In the first year they rooted quickly and with full success (94%). But after three years of growing in the nursery, these plants produced non-rooting cuttings, which would stay for 1 to 2 years in the propagation bed and callus heavily, before the first roots appeared.

When shoots appeared, they looked more like a young *Cupressus* seedling than a Leyland cypress; they had soft awl-shaped leaves with long internodes and these produced cuttings that rooted well again. When potted up and grown in a lathhouse, these plants continued to produce juvenile shoots for 3 to 4 months but they returned to the "normal" leaf form.

Rejuvenation by full or partial etiolation (shading):

In experiments with *Tilia tomentosa* between 1978 and 1982, etiolation of stock plants, either by earthing-up the shoot bases or by "forcing" the stock plants under black polythene tunnels, stems showed juvenile histological structure (higher percentage of

increased markedly the subsequent rooting of cuttings. Etiolated stems showed juvenile histological (cell and tissue) structure (higher percentage of parenchymatic and meristematic tissues and a lower degree of sclerification) which was retained for 4 to 6 weeks afterwards. When earthing up, formation of juvenile stolons was also observed (5, 6).

Later experiments showed that etiolation can be partially substituted by a heavy shading, which is considered as a partial etiolation.

Table 2 illustrates the effect of shading on some *Juniperus* cultivars. The results are most prominent with *J. virginiana* 'Tripartita', an old bush growing under a tree for 6 years and having entirely juvenile branches on the shady side and adult ones on the sunny side.

Table 2. Effect of shading of the stock plants on juvenile characters and subsequent rooting (1987-1989; average of three experiments)

	Percent of shoots with some juvenile foliage		Rooting, percent	
Cultivar	Full sun	Shade*	Full sun	Shade*
Juniperus communis 'Hornibrookii'	0%	34%	64%	87%
J communis var *saxatilis*	0	22	52	75
J horizontalis 'Glauca'	16	48	74	88
J. virgiana 'Tripartita'	24	100	68	98

* Note. *J. virginiana* 'Tripartita' had been growing for 6 years under a tree, the others were provided 50% shading (dark plastic net) for 1 to 3 years.

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PRODUCTION OF SCIONWOOD AND ITS USE IN SPECIALIZED BUDDING AND GRAFTING

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The production of scionwood for all purposes of budding and grafting on our specialist tree nursery has made specific stock tree management necessary to service not only our own nursery but to provide sales of scionwood to others. We are at present producing 250,000 trees per year and a similar number of buds for sale. Graftwood production, although not in such large numbers, also supports a wide range of grafting techniques.

The main reasons for taking on this large production approach to budwood and graftwood came about for the following reasons:

EMLA virus-free programme in fruit trees. The first introductions of virus-free fruit material were made in 1969 by East Malling and Long Ashton Research Stations. This required the establishment of isolated scion blocks under the scrutiny of the Ministry of Agriculture and the Plant Health Propagation Scheme.

Increase in demand. It was soon recognized that managed stock trees were very productive and increased the availability of quality material and gave more efficient collection at peak propagation periods.

Application to ornamental trees. The principles of high health and efficient production have been applied across the range of all fruit and ornamental trees produced by budding and grafting.

STOCK TREE SYSTEMS

Stock tree systems have developed from wide spacings with standard pruning to more intensive plantings with variable training and pruning techniques to suit individual cultivars.

Planning. Assessing numbers that will be needed in the future is a difficult exercise. If you estimate present production and demand for scionwood and double this quantity this would be a good starting point. It is also necessary to estimate the variable numbers of propagating wood from different species and particularly cultivars within a species that can vary so much in the productive wood they produce. Trees produced mainly from grafting, requiring greater numbers, should be calculated accordingly.

Density. This is linked directly to likely age of replacement and to make good use of production area. Single row and bed systems have both been used to meet this criteria. Single row plantings have come down to 4 metre by 1.3 metre spacing for intensive

management and variation in bed systems with overall herbicides and grass strip alley-ways as an alternative.

Rootstocks. All fruit mother trees are produced on vigorous rootstocks for maximum growth and anchorage. Clonal rootstocks are ideal for uniformity, but seedling rootstocks can be used where these fail to produce the necessary growth. This also applies to ornamentals where clonal rootstocks are not available. It has to be remembered that seedling rootstocks are generally virus-free, which does not threaten the virus-free status of many cultivars. *Pyrus communis* for pear, is a good example where fruiting and ornamental stock trees have superior vigour and hardiness compared with normal quince rootstocks.

Early establishment. There is often an inevitable time lapse between the instant need for propagating wood and the actual delay caused by establishment time and build up of stock, and this is particularly so in the case of new cultivars. There are two ways in which stock trees can be established quickly:

Establishing *in situ* rootstocks, planted at final spacings on an on-going basis, allows for quick response to demand because it avoids the growth check caused by planting-out of stock trees. Multiple budding or spring grafting are both used in this instance. Extra close plantings with later thinning can also help to increase production in the early years.

Alternatively, on the basis that one has twice as much stock available than is needed at any one time, there should be a number of stock trees available for topwork grafting. Simple rind or stub grafting can produce quick results with little work. There is a danger of allowing suckers to grow undetected in the tree canopy.

Pruning and tree training. Hard pruning is necessary on all stock trees to produce the vigour for good quality scionwood. This can vary, but removal of most of the previous season's growth is generally needed. In instances where vigour is too strong, tying down of some branches can help to spread this excess growth creating a larger productive surface area. Discouraging apical dominance is important in over-vigorous stock trees to produce uniform growth. Early season tipping of very feathering cultivars can help to create useable shoots when none would otherwise be possible. The height at which the cropping area is created should have some bearing on the ease of collection and pruning.

Trueness-to-type. The establishment of stock trees from which propagation material is taken year after year is a secure way of ensuring the proliferation of the right cultivars, provided correct labelling and care is taken when collecting wood. There are, however, circumstances in fruit production that require the monitoring of fruit colour to ensure trueness-to-type. Off-types can occur in unstable cultivars so fruiting branches are encouraged to allow

inspection of fruit. Reversion in some ornamentals, particularly variegated types, needs to be watched carefully.

Disease. Annual heavy pruning can cause some species to be susceptible to bacterial diseases, such as silver leaf, bacterial canker, and coral spot. This is particularly so of *Prunus, Acer, Robinia,* and *Betula*. Once a tree is infected with any of these diseases it should be removed. Some types of stock trees can only last five or six years and need to be replaced on a regular basis.

There are certain circumstances where it would be advisable to take scionwood from young production trees.

Stock trees under protection. There are many circumstances where forced or protected growth improves propagation material for budding and grafting. This has always been so of most softwood cuttings but is perhaps not so recognised with hardwood material. There are several advantages in this approach:

The first is improved vigour. Various slow growing species, such as *Acer pseudoplatanus* 'Brilliantissimum', that are naturally dwarf can be forced and elongated to provide better propagation wood.

The second is freedom from disease. Peaches are a good example of a subject that grows well under glass to providing early and ripe budwood free from leaf curl disease.

Thirdly, timing is easier. Many of the more difficult species, such as *Acer* and *Betula,* require precise budding timing to match ripe budwood with exact growth stages of rootstocks. By producing early ripening of wood under cover one is then in a position to bud at the precise time.

Coldstorage. Cold storage of budwood allows flexibility when budding. De-leafing should be immediate but storage of prepared wood at approximately 5 °C is possible up to 10 days.

Cold storage of graftwood is vital to enable late spring use. Although 0 °C is ideal it is possible to freeze graftwood provided moisture levels are maintained by either wrapping in polythene or using a jacket coldstore.

SPECIALIZED BUDDING AND GRAFTING

It is not planned to go into exact details of budding and grafting techniques as these are well catalogued. We will only deal with various ideas and possibilities in light of the previously described management of stock trees, cold storage, and recent trials in relation to timing of budding and grafting.

Budding. Although chip budding is used for nearly all subjects it is worth noting certain observations. Chip budding allows and encourages the use of larger diameter wood to enable a good cambium match. Thin budwood and large diameter rootstocks often means reverting to T-budding with some species, e.g. *Malus, Pyrus,*

Prunus. Inverted T-budding can still be advantageous for some subjects such as *Aesculus* and should be tried where chip budding is not fully satisfactory. Removal of wood from the back of the bud eye can help where the bud is too large for the rootstock. Where buds are particularly proud and delicate and liable to damage then the stick budding technique is often the best method.

Multiple budding. This can be extremely useful in many circumstances. *In situ* virus-free mother trees are double-budded to produce twin maidens for maximum early canopy development.

Interstems. These are mostly raised by double-budding or grafting over one or two years. Originally, interstems were used to alleviate incompatibility between scion and rootstock. For fruit growers interstems are now used for other reasons:

- Using a strong base root system with a dwarf interstem piece for a free standing dwarf tree.
- To induce better cropping in main crop cultivars by using a prolific cropping cultivar, such as 'Golden Delicious.'
- To induce hardiness or resistance to disease.

Spring chip budding. Although resulting growth is inferior to previous year's budding, spring chipping can be useful in certain circumstances where there is a shortage of propagation material. This can be done on established rootstocks in the field, in pots, or even on bareroot rootstocks for raising under glass. Timing is critical to coincide with early sap rise.

With all forms of budding, polythene tape tied over or around the eye, depending on proudness, is used to allow precise tie removal.

Field grafting. Field grafting (whip and tongue) as a back-up to poor bud take is used throughout the nursery provided a high percentage of first grade trees can be produced. Complete immersion in wax of the scion can improve take and eventual growth.

Bench grafting. Bench grafting is only used on difficult subjects and where other propagation methods of the same time scale are inferior. These are produced as container whips to complement the field-grown tree. The plentiful resources of rootstocks and graftwood in coldstore up until the beginning of April gives excellent opportunities to respond to demand for the following autumn. The use of large diameter rootstocks and scions is important to promote maximum growth. The ability to produce a saleable tree inside six months can be very advantageous.

Hot pipe callusing. We have only used this technique for three years but it is well described in previous IPPS articles on subjects such as filberts and walnuts. Although this is an expensive operation the main advantages are to make difficult subjects easier to graft and to produce a superior tree by extending the growing season. Pre-callusing of the graft union during the winter months sets up the tree for the difficult spring period and from a management approach it

is possible to spread the heavy spring workload over a wider period. The subjects we have concentrated on are *Acer, Betula,* and *Fagus.* The main principles are as follows:

1) A period of three weeks at approximately 30 °C appears to be the optimum treatment.

2) The heat should only be applied to the graft union.

3) Any graft method can be hot-callused.

4) Potted or bareroot rootstocks can be used depending on the difficulty of the subject.

5) Cables or hot water can be used, although hot water is preferred as it is a more even temperature.

6) It is vital to seal the heat in around the union to provide an even and economic temperature.

7) It is important to graft species that run sap easily, e.g. *Acer* and *Betula* at peak of dormancy, and make sure that the rootstocks have been dried off well.

8) Other subjects can be callused up until early spring provided graft and rootstock are kept dormant outside the heated union. Some form of cold storage to control air temperature would be helpful for late hot pipe callusing.

Materials. It is well established that overall waxing of the graft is essential for good results in any form of bench grafting. Dipping paraffin wax is used mostly, but it is brittle (although it is the cheapest and easiest of waxes to use). Like many other nurseries we have developed our own wax which is low-melting, soft, and flexible, so that subsequent handling does not cause cracking and flaking. A thermostatically-controlled wax heater has been produced to provide instant liquid wax throughout the grafting season.

Tapes of numerous types can be used and a soft wax allows for the use of more flexible tying materials that will not cut into the graft union. Rubber is still the best material and the degradable budding rubber ties, used single thickness, are very suitable.

PRODUCTION OF SPECIMEN ILEX SPECIES IN VIRGINIA, U.S.A.

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The holly cultivars we produce at Mobjack Nurseries have been selected for:

1) Popularity in the U.S. mid-Atlantic states.
2) Cold hardiness in our market area.
3) Cultural requirements that our production system can fulfil.

Though we are constantly searching for hollies to meet these criteria, the following are currently in production:

1) *Ilex.* 'Nellie R. Stevens', a putative hybrid between *I. aquifolium* and *I. cornuta*, is a large evergreen shrub or small pyramidal tree. It is hardy in Zones 6 to 9 (U.S. Dept. of Agriculture hardiness map). This plant was released by G. A. Van Lennep, Jr. of St. Michael, Maryland, USA, in 1954. (1)
2) *Ilex attenuata* 'Foster No. 2' is one of a group of five interspecific hybrids of *I. cassine* and *I. opaca*. It has a compact, narrow growth habit to 30 ft. at maturity and is heavily fruited with small red berries. Also hardy in Zones 6 to 9, this plant was selected by. E. E. Foster of Bessemer, Alabama, USA. (2)
3) *Ilex* × *attenuata* 'Foster Brilliant', a selected seedling of 'Foster No. 2' grows more compactly and yet more rapidly than its parent. The leaves have an olive-green cast and the bright red fruit is larger. It was selected by Charles Shreckhise of Weyers Cave, Virginia, USA.
4) *Ilex* 'Dr. Kassab', a beautiful dark green evergreen with a broad pyramidal form grows to 20 ft. high. This hybrid between *I. cornuta* and *I. pernyi* is hardy in Zone 5 to 9 and was introduced by Dr. Kassab, a gardener from Philadelphia, Pennsylvania, USA.
5) *Ilex* × *koehneana* is an interspecific hybrid between *I. aquifolia* and *I. latifolia*. A vigorous growing evergreen tree 20 to 30 ft. tall, *I.* × *koehneana* has superior hardiness to both species. Named and introduced in 1919, this outstanding holly has somehow been overlooked.

PROPAGATION

The *Ilex* cultivars we grow can be propagated from cuttings during most of the summer, fall, and winter months so we take cuttings when we have time and space available. The bottom leaves are

stripped and the cuttings are bound together with rubber bands in the field. After being immersed in a Benlate solution, they receive a basal dip of 10,000 ppm (1%) aqueous solution of the potassium salt of IBA. The cuttings are stuck into flats of 3 in. peat pots containing a medium of pine bark and perlite, 3:1. These flats are pre-set under a mist system in warm weather or over bottom heat and mist in cool weather. Either way, by spring the cuttings will have enough roots to be planted out into one-gal. plastic pots.

Our growing medium is milled pine bark and washed concrete sand; 6:1, with 2 lbs. dolomitic limestone and 1 lb. urea (43:0:0) added per cu. yd. The pots are filled and set into our growing areas during late fall and early winter. The cuttings will usually flush so receive one trimming before planting out after danger of a late frost (mid to late April). The cuttings are dibbled by hand into pots at this time.

CULTURE

Liners for field planting are grown in 1 gal. pots for one year. They are sheared flat to produce a dense, branched base. After the land is prepared and limed with two tons of dolomitic limestone per acre, the hollies are planted out into 7 or 8 ft. rows on 5 ft. centers. Irrigation is provided by 16mm tubing with in-line emitters on 2 ft. centers. A preventative spray program using Orthene, either Benlate or Bravo, and a miticide is applied every two to three weeks as needed with a mist blower type sprayer.

Cultivation between the rows is by disk or spring-tine cultivators. Herbicides are applied through low volume nozzles using a small narrow gauge farm tractor. Pre-emergence and post-emergence herbicides are applied in this way. Those weeds and grasses which escape control are treated with backpack applications of Roundup. Fertilizer is applied by hand three times per year. The first application is of 10:10:10 in early spring, the second is of 43:0:0 after the spring flush, and the last application is applied after frost.

Our hollies are shaped by one of two methods. During the winter or early spring those not listed for spring sales are heavily sheared to a narrow pryamidal form. After the spring flush the plants not scheduled for summer sales are sheared again to a fairly tight pyramidal form. During the rest of the summer our hollies are given a light clipping to maintain shape, to keep tops narrow and tight and to encourage continued growth.

HARVESTING

Virtually all of our field-grown plants are harvested with a hydraulic tree spade. The plant is brought in the spade to the head of the row and put into a wire basket-burlap sack on a low farm

wagon. The sack is secured around the stem, the top of the basket is laced and drawn tight around the stem with poly twine and any loose wires are twisted with a hook to tighten them. The size of the ball can be adjusted to the size of the plant by lowering or raising the tree spade with adjustable legs. An operator and three men can produce 75 to 100 trees per day on wagons ready for loading into semi-trailers.

LOADING

Our semi-trailers are equipped with steel racks along the sides which support 2 in. by 12 in. pine shelving. Field-grown plants are loaded horizontally on the floor and container plants are then loaded on to the shelves. Our farm wagons are backed up to the semi- and a ramp is made using the shelving boards. The plants are pulled up the ramp into the trailer. We feel this method is far safer than the use of loading equipment by unskilled workers.

CONCLUSIONS

We endeavour at the nursery to keep the plant's environment weed-free and to protect them from insect pests. Sandy loam soil to grow in, sufficient moisture, and an adequate supply of nutrients are only basic. The single factor which is the strongest contributor to plant quality is timing. The timing of both shearing and feeding enables us to put the maximum amount of growth where it is most needed during the development of the plant.

We have learned that root elongation and nutrient up-take is highest when shoot elongation is least during the growing season. We try to ensure that nutrient availability is highest just before our plants begin to grow. In late spring we attempt to stop growth with heavy shearing and again feed heavily. We shear slightly before our hollies would normally finish their growth cycle and, therefore, speed up the process. During this second growth in mid-summer we trim very slightly to maintain shape and to encourage multiple breaks on new shoots where needed.

These procedures have enabled us to produce specimen hollies of very high quality which command the best price in our marketplace as well as being a lot of fun to grow!

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THE NATIONAL COUNCIL FOR THE CONSERVATION OF PLANTS AND GARDENS IN RELATION TO THE IPPS

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In horticulture, awareness of plant conservation has been evident for many years by many individuals and organizations. The National Council for the Conservation of Plants and Gardens (NCCPG) has been in the vanguard of this movement and is the only organization that embraces the professional and amateur sectors with equal confidence. Increased collaboration between it and nurserymen could be mutually beneficial.

A conference, convened by the Royal Horticultural Society in October, 1978, proposed the formation of a National Gardens and Plants Council and put forward the idea of national reference collections (now known as National Collections), (1). Interested parties identified at that time included botanic gardens, arboreta and other similar gardens, National Trust gardens, parks and other gardens of local authorities, nurseries, specialist societies, state research and other establishments, educational establishments, private gardens and small groups within horticultural societies.

The role of the IPPS as an interested professional body was mentioned where it was recognized that "the expertise to propagate many rare and threatened plants was available in the IPPS."

At the inaugural Conference it was felt that rare and threatened plants in cultivation could be divided into two groups, those threatened with extinction in the wild, and those threatened with extinction within gardens (1). Within this context five catagories were considered to be important, viz: (1) historically important hybrids; (2) genetically important hybrids; (3) unusual cultivars of fruit, ornamentals, and vegetables; (4) species or variants now in cultivation but where stocks in the wild no longer exist, (5) species and variants known to be rare in the wild.

The NCCPG was, in effect, born at this meeting. It was registered as an independent charity and based at the RHS Garden, Wisley, Surrey.

The strength of the organization lies in its membership, based on 39 autonomous, county-based groups, currently totalling 8,500 members.

The National Collections of genera form the key to active conservation. These are comprehensive reference collections maintained by private members or corporate bodies (5).

Initially a number of rather arbitrary guidelines had to be drawn. For example, when was a plant considered to be endangered? Here nursery catalogues were found to be of considerable value. Where plants were listed by three or fewer nurseries then the plant was considered at risk of being lost to cultivation (2, 3).

Which endangered plants should be conserved? Obviously, it is impractical to attempt to conserve everything because of a lack of space, time, and funds.

The importance of maintaining genera with medicinal qualities such as *Salix* (which yields aspirin), *Digitalis* (the source of a heart stimulant, digitalin), *Catharanthus* (used in the fight against cancer) and, more recently, *Linum* (currently being investigated by the University of Nottingham for its anti-cancer properties) are examples.

In order to assess priorities Lowe (3) proposed four main guidelines in assessing a plant's merits with regard to conservation. These were: its use to man; its historical importance; its scientific uses, and aesthetic value.

Many of the plants at risk have now been incorporated within National Collections. Here conserved stocks are maintained by various groups, including nurserymen.

As the collections grow and mature so their value for reference puposes and as a source of known stock material increases. Accurate naming has been found to be one of the greatest problems. For this reason herbarium and slide collections are being built up at the headquarters at Wisley, as are computer-based databases.

By 1989 there were 503 National Collections, with 50 more being approved each year and this pace is quickening rather than slowing.

Since 1981 membership has risen from a few enthusiasts in one county (Dorset) to the current strength of 8,500—an enormous jump by any standards.

The provision of accurately known reference material for medical research is particularly important. Similarly the reference collections (both living and as herbarium specimens) form a base for the taxonomic and botanical research of cultivated plants.

However, conservation is active, not passive, and it is the involvement of the producer or the grower (whether for pleasure or profit) that will, in the long term, reflect the degree of success of the venture.

THE VALUE OF THE NCCPG TO THE IPPS

Not surprisingly the relations between the NCCPG and nurserymen have been extremely good; 14% of the National Collections are held by nurserymen while several of the colleges hold collections which are of value as teaching aids (examples being Somerset College, Cannington, with *Abutilon, Ceanothus*, and *Wisteria;* Merrist Wood,

Surrey, with *Cotoneaster, Euonymus fortunei,* and *E. japonicus* cvs.; Hadlow in Kent, with *Enkianthus* and *Pernettya*; and Writtle in Essex with *Pyracantha*).

Examples within the nursery industry are Notcutts Nurseries, which hold 24 taxa of *Hibiscus syriacus*; Webbs Nurseries with 30 taxa of *Forsythia* and *Potentilla*; Glendoick Gardens with *Kalmia* and *Enkianthus*, Secretts Garden Centre with *Cornus florida* and a *Kalmia latifolia* collection; Goldbrook Plants with *Elaeagnus*; The Knoll Gardens, Stapehill, with *Mahonia*; and Tavistock Woodlands with *Nothofagus.*

Within the public sector, Leeds Parks holds a number of collections; Brighton Parks hold an internationally registered *Syringa* collection; Torbay Parks, *Abelia, Carya,* and *Jasminum;* Plymouth, *Camellia*; Derby City Council, *Hydrangea;* and The Hillier Arboretum, *Carpinus, Cornus, Corylus, Cotoneaster, Ligustrum,* and *Quercus.*

The collections are a ready source of material available to the nurseryman. It is hoped that where nurseries are in difficulty with particular plants, they might well be able to purchase limited propagation material from such sources. Such arrangements would seem appropriate as individuals hold and maintain these collections on a voluntary basis.

Besides providing a network of accurately named stock sources the NCCPG may also look to the IPPS membership for expertise at various times. Pattison (4) in assessing the reasons why garden plants survive or fail listed four major contributors to loss: Propagation difficulties; disease; genetic instability (many new cultivars may not be as stable as their parents and where plants have been propagated vegetatively for centuries stocks may be weakening); and fashion.

A number of factors contribute towards the importance to the nursery trade of the NCCPG. Amongst these are: the current upsurge in interest in conservation at national and international levels; the interest from the gardening public and hence the garden centres in 'new' or 'novel' plants; and the withdrawal of interest (and funding) of government-sponsored research at this level in the U.K.

Thus the opportunity exists for nurseryment to take advantage of the rich collections of genetically known material that are being collected. Purchase of known stock of older, rare or existing (but difficult) plants may at times be commercially advantageous.

Obviously an even more positive step would be for the nursery concerned to take an even greater interest in the particular plants in question and to develop, where appropriate, a National Collection.

Thus there is a unique opportunity for the IPPS, particularly within the U.K. and Europe, to work with the NCCPG in retaining a broad base of genetic material. Such a role could be financially stimulating and mutually interesting. The opportunity for such a cooperative venture should not be missed.

Note: A list of plants and their locations can be obtained from the NCCPG, R.H.S. Gardens, Wisely, Surrey, U.K.

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WORK SAVING METHODS IN PLANT PROPAGATION

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Since the early 1970s our nurseries at Boskoop specialized in the production of rooted cuttings, partly for the local market, but mainly for export.

Our propagation methods are similar to those in most Boskoop nurseries, using polythene and bottom heat from hot water pipes lying about 6 in. deep below the surface.

About five years ago we were in a position to expand our greenhouses by about 2.5 acres on a plot situated about 10 miles from Boskoop. We started propagation there in the way we were accustomed to, but found that three or four weeks after sticking the cuttings, the compost (peat and sand) had turned extremely wet.

Then we realized that our new department was situated in a deep polder 16 ft. below sea level. The heated pipes together with the excessive natural capillary action not only sent heat but also humidity upwards.

That experience made us change the complete propagation system. A complete new drainage system meant covering the soil with 2 in. polystyrene sheets to stop capillary action from below. Tubes filled with water were inserted into the sheets with interspaces of 6 in. and the whole was covered with aluminium foil and polythene to keep it as dry as possible. On top came a culture mat, kept wet by rigid tubes with tiny holes at 10 in. spaces.

In order to prevent contact with the culture mat each tray is placed on two tubes. The heating system is in use for 10 months a year so humidity comes upwards and enters the tray from its bottom. There it continues going up and watering the cuttings. Control of the right humidity and watering on top is seldom necessary. A problem turned out to be an advantage!

A second possibility to reduce inspection is furnished by our hygiene program. Being convinced that cuttings should be as clean as possible and free from waste material such as bracts, dead leaves, and twigs, we accent hygiene. We collect finished cuttings in a plastic basin. When it is full we lift the cuttings out and put them into a big tray. Turning the whole basin upside down would cause waste material to lay on top of the cuttings, causing damage later on. So, from the moment we collect cuttings—always in a tray, never in a plastic bag—until they are stuck, we lift them six to eight times.

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[1] Nurseryman

When sticking the cuttings we keep them, as well as the compost, dry by putting a rigid plastic sheet on the compost.

The watering system under the trays, together with the hygiene program, save us a lot of work. During the six to eight weeks rooting period of *Cotinus coggygria* 'Royal Purple' cuttings are inspected only once. After inspection a new polythene sheet is essential.

PROPAGATION AND REGULATION OF PHASE CHANGE IN SOME NEW ZEALAND HETEROBLASTIC SPECIES

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Abstract. Various heteroblastic species endemic to New Zealand were investigated. Seeds of most species germinated in four to five months when they had been overwintered outside, although some required scarification and others failed to germinate even after two periods of overwintering. The best rooting of cuttings was obtained from material collected in summer and placed under intermittent mist. Juvenile cuttings rooted much better than cuttings from adult plants.

When gibberellic acid (0.4 mg per plant) was applied to rooted cuttings of adult plants it produced a transient elongation of stems of all species investigated and induced a juvenile-like habit and leaf form in *Carpodetus serratus* and *Pennantia corymbosa*, a juvenile growth form with transitional leaf-form in *Parsonsia heterophylla*, but no such changes in *Elaeocarpus hookerianus*, whereas treated adult rooted cuttings of *Pseudopanax crassifolius* died Attempts to manipulate the internal gibberellin levels of juvenile rooted cuttings by the application of gibberellic acid (GA_3) and paclobutrazol (PP333) failed to induce any adult characteristics

INTRODUCTION

The occurrence of distinct juvenile and adult stages in the life cycle of many woody plants is one of the most distinctive features of the New Zealand flora. The phenomenon has been recognised for many years and has been referred to as ''heteroblasty'', ''phase change'', or ''maturation''. Phase change in New Zealand species is frequently observed as a change in both form and leaf shape (11). The ''classic'' example of heteroblasty is the common ivy, *Hedera helix*, while the phenomenon in the New Zealand species is exemplified by *Pseudopanax crassifolius* (10).

Research on phase change has a practical application as plant propagators frequently are interested in prolonging the juvenile phase or rejuvenating mature tissue in order to obtain a supply of material that is easy to root or micropropagate, whereas plant breeders may wish to hasten the onset of the adult phase to obtain early flowering and seed set.

Although little is known of the nature of the physiological and biochemical factors associated with maturation and phase change, the gibberellins promote rejuvenation in ivy and may be involved in the maintenance of the juvenile condition (12). However, attempts to promote maturation by reducing the effective endogenous gibberellin levels by use of gibberellin antagonists or inhibitors have failed to promote the mature form of ivy (2, 5).

This paper reports on germination and rooting procedures needed to produce seedlings and rooted cuttings of juvenile and mature forms, the effect of gibberellic acid (GA_3) on rejuvenation, and of paclobutrazol (PP333), a potent inhibitor of gibberellin biosynthesis (3) on maturation of several heteroblastic species endemic to New Zealand. Ivy was used as a model system and the details of experiments with ivy are reported elsewhere (4, 5).

MATERIALS AND METHODS

Asexual propagation. Cuttings for propagation were collected in the early morning and kept cool and moist. Approximately ⅓ to ½ of the foliage was removed from each cutting and in large-leaved plants the remaining leaves were reduced in size to minimize transpiration losses. The base of each cutting was dipped into a commercial rooting powder (Seredix No. 2) containing 0.3% B-indolebutyric acid. The cuttings were planted directly into either coarse river sand with a layer of peat at the bottom of the propagating box (when placed under an intermittent mist system (with or without heat), or in a peat:sand mix (1:3 v/v) (when placed under a cold frame or on a hot bed). Once rooted, cuttings were transferred into a 1:1:1 mixture of soil, peat, and sand, with added fertiliser, then potted into 500cm³ planta bags, and repotted into 2 litre planta bags prior to experimentation.

Sexual propagation. Both seeds and cuttings were collected from the same adult trees of *Carpodetus serratus* J.R. & G. Forst., *Elaeocarpus hookerianus* Raoul, *Pseudopanax ferox* Kirk, and *Pennantia corymbosa* J.R. & G. Forst., whereas seeds only were collected from other plants of *Pseudopanax crassifolius* (A. Cunn.) C. Koch, *P. simplex* (Forst. f.) Philipson and *Parsonsia heterophylla* A. Cunn.. All plants were located close to Dunedin, South Island. Seeds were sown either fresh or stratified. Seeds with very hard or impervious seed coats were chipped with a knife. The fleshy outer coat was removed from a portion of the *Pseudopanax* species' seeds.

Seeds were sown onto a modified John Innes seedling mix (4). The seed boxes were covered initially with wet newspaper, then glass, and left in a heated glasshouse (25 °C) for six weeks. Seed boxes containing ungerminated seeds were then placed outside for winter stratification (June to mid-August 1985), and then back into a glasshouse (25 °C) with a 16-hr photoperiod.

Germinated seedlings were ''pricked out'' into trays containing equal parts of soil, peat, and sand and maintained in the same glasshouse. Seedlings were potted out after six to eight weeks, initially into size ¾ planta bags and then six weeks prior to experimentation into size 3 planta bags using the same soil mixture used for pricking out. During repotting matted roots were loosened.

Boxes which still had ungerminated seeds were placed outside for a second winter.

Experimental plants were maintained in a glasshouse under a 16-hr photoperiod at 25 °C and investigated between July and December, 1986.

Application of plant growth regulators. Procedures are described by Horrell (4) and Horrell *et al.* (5, 6, 7). Briefly, rooted cuttings or seedlings were supplied with gibberellic acid (GA_3) *via* a wick threaded through the first internode above soil level (8). Each end of the wick was immersed in an Eppendorf tube supplying an aqueous solution of GA_3, which was applied weekly for four weeks as 1 ml aliquots containing 0.1 mg GA_3 per plant. Paclobutrazol (PP333) was applied directly on to the soil near the base of the plant as 5 ml of an aqueous suspension of "Cultar" (9), containing 1.25 mg PP333, daily for 20 days. In some instances GA_3 and PP333 were supplied simultaneously.

RESULTS

Germination. Seeds of most species germinated after four or five months and required a chilling period. However, seeds of *Elaeocarpus hookerianus* required scarification and two overwintering periods before any seeds germinated, whereas germination occurred within four weeks when the fleshy outer layer was removed from seeds of *Pseudopanax crassifolius*. In contrast, no germination occurred even after two overwintering periods when the flesh was removed from seeds of *P. ferox* and *P. simplex*. However, some germination occurred when seeds of *P. crassifolius* and *P. ferox* were sown with the flesh attached, but only after overwintering, whereas no *P. simplex* seeds germinated even after two overwintering periods. High germination occurred in seeds of *Carpodetus serratus* and *Pennantia corymbosa*, although seeds of *Pennantia* required scarification, whereas seeds of *Elaeocarpus hookerianus* and *Parsonsia heterophylla* showed only low germination.

Rooting of cuttings. Attempts were made to root cuttings of 12 heteroblastic species. Juvenile cuttings rooted much more readily than adult ones (Table 1). No juvenile or adult cuttings rooted in the cold frame, although this may be due to their collection in autumn. The best rooting occurred in cuttings collected in summer (January or February) and placed under intermittent mist (with or without heat). However, mature cuttings proved extremely difficult to root so that only five species were available for experimentation.

Table 1. Percentage of rooted cuttings of juvenile and adult forms of various heteroblastic New Zealand species (The propagation structure and month of propagation are given and the figures in the brackets indicate the total initial number of cuttings taken)[a]

	Growth phase	Percentage rooting		
		Hot bed	Intermittent Mist	
		(spring)	Heat (summer)	No heat (summer)
Carpodetus serratus	juvenile	—[b]	87 (100)[c]	90 (100)
	adult	—	0 (50)[c]	10 (70)
Pennantia corymbosa	juvenile	0 (50)	70 (50)	98 (200)
	adult	0 (50)	7 (70)	26 (100)
Parsonsia heterophylla	juvenile	70 (100)	—	98 (200)
	adult	8 (100)	—	32 (170)
Elaeocarpus hookerianus	adult	0 (70)	0 (100)	10 (100)
Pseudopanax crassifolius	adult	0 (100)	0 (100)	12 (100)
P ferox	adult	0 (100)	0 (100)	—
P simplex	adult	—	0 (200)	—
Weinmannia racemosa	adult	16 (50)	—	—
W silvicola	juvenile	—	—	—
	adult	0 (50)	—	—

[a] Additionally, cuttings from adult plants of *Plagianthus betulinus*, *Pseudopanax edgerleyi* and *Hoheria angustifolia*, as well as those listed in the table were taken in winter and placed in the cold frame No rooting occurred

[b] no cuttings propagated

[c] cuttings taken in spring.

Responses of adult plants to gibberellic acid. GA_3 promoted juvenile-like habits and leaf forms in *Carpodetus serratus* and *Pennantia corymbosa*. There was a statistically significant increase in internode angle in *Carpodetus serratus* which indicated reversion to the divaricate juvenile habit whilst plants of *Pennantia corymbosa* developed the reflexed laterals characteristic of the juvenile form. Plants of *Parsonsia heterophylla* produced a vine-like growth with a transitional type of foliage while *Elaeocarpus hookerianus* remained "adult" in appearance. *Pseudopanax crassifolius* exhibited a rapid but transient elongation, as did all the previously listed species, but then died. Further details are given in Horrell et al. (7).

Responses of juvenile plants to paclobutrazol and GA_3. PP333 caused almost complete inhibition of stem elongation in all five native species, although the application of GA_3 completely overrode this inhibition and often caused stimulation relative to the control (Table 2). For example, GA_3 alone or in combination with PP333, promoted elongation growth and caused hyponasty in *P. crassifolius*, whereas PP333 alone severely reduced elongation growth (6).

PP333 did not induce the formation of any mature characteristics in the New Zealand native species.

Table 2. Effects, relative to untreated controls, of PP333[a] and GA_3[b] on the extension of the main shoots of juvenile forms of various New Zealand heteroblastic species[c]

	Carpodetus serratus	*Elaeocarpus hookerianus*	*Parsonsia heterophylla*	*Pennantia corymbosa*	*Pseudopanax crassifolius*
PP333	depression	died	depression	depression	depression
GA_3	stimulation	stimulation	stimulation	stimulation	stimulation
GA_3 + PP333	no effect	died	stimulation	stimulation	stimulation

[a] PP333 Paclobutrazol was applied directly to the soil surface as 5 ml of an aqueous suspension of "Cultar" (9) containing 1 25 mg PP333, daily for 20 days

[b] GA_3 was applied weekly for four weeks as 1 ml aliquots containing 0 1 mg GA_3 per plant

[c] Except for *Parsonsia heterophylla*, where there were insufficient surviving plants for statistical analysis, all differences are significantly different from the controls ($P < 0\ 05$)

DISCUSSION

The application of GA_3 to adult native plants caused some reversion to juvenility, particularly in *Carpodetus serratus*, *Pennantia corymbosa*, and *Parsonsia heterophylla* (7). There are other unpublished reports of partial reversion following the application of GA_3 for *Elaeocarpus hookerianus* (13) and *Parsonsia heterophylla* (E Beuzenberg, personal communication). Our own studies of ivy have also reconfirmed that at least partial rejuvenation can be induced in adult ivy plants by the application of gibberellic acid (GA_3) (4).

However, no mature characteristics were induced by attempts to reduce levels of endogenous gibberellins. The fact that Cultar is a mixture of two enantiomers of PP333 (14), (ICI personal communication 1988), one of which is an inhibitor of sterol biosynthesis in plants (1), might account for the severe inhibition

that occurred in treated native plants, although GA_3 completely overcame the inhibitory effect of PP333 in *Pseudopanax crassifolius*, *Parsonsia heterophylla* and *Pennantia corymbosa*, suggesting that the predominant effect of PP333 had been to reduce the endogenous levels of gibberellin (6, 7) (Table 2).

In conclusion it seems likely that gibberellic acid could be supplied to mature tissues of at least some New Zealand native plants to promote juvenile-like growth for use in propagation. Promotion of novel forms such as the hyponastic response of the juvenile *P. crassifolius* following GA_3 application (6) may also have commercial relevance. However, any reduction in endogenous gibberellins caused by the inhibition of their biosynthesis by PP333 appeared unable to promote maturation, at least at the concentrations of PP333 used in our experiments.

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A POTPOURRI OF IDEAS

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The nursery industry has passed through many phases during the last thirty years. Firstly, we had the container revolution when many companies shifted from field-grown stock to container production. This led to numerous technological changes, especially in growing grounds, media, and nutrients. The next phase of development was the propagation revolution with the onset of mist-controlled systems, fogging units, and tissue culture. We are now experiencing a third revolution, the marketing revolution, which is taking the form of technological advancements such as bar coding, packaging and presentation, and higher quality standards. On top of this we have to overlay the fact that society is going ''green'' and whatever we do must be environmentally friendly.

You may ask how the marketing revolution affects the propagator, especially as we are told we have to be market-driven rather than production-driven if we are to survive as businesses until the next century, which happens to be only 3,739 days away. I believe as propagators we have, fortunately or unfortunately, everyone as a customer. We have internal customers within the nursery and customers through the traditional market avenues. If we are to be market-driven it has to start with the propagator.

What does this mean? Gone are the days when we could just produce plants and pass them on down the chain. We now need market research on what sells and what does not. We need strict quality standards, and we need to change our attitudes to what is right for the market place, and not necessarily what in our opinion is what we believe they should have.

What I will expand on in this paper is one small aspect of this revolution, and how it is changing our industry.

Traditionally we have grown up thinking pots are round containers, their only variation being in size, although occasionally companies have told us that square is better than round.

Round pots are great for growing plants, but is that what is asked of us in the marketing revolution? Already the round pot, as you and I know it, is being challenged in the market place.

The round pot is being challenged on two fronts: firstly, does it produce the desired product and secondly, does it enhance the product by ''adding value'' to the plants we have grown?

Desired Products. Carl Whitcombe's work in the U.S.A. has already challenged our thinking on the traditional pot. Quality of plants starts with a good root system and, for many subjects, the

worst thing you can do is put it in a round pot. The result will be roots curling around the pot, and, on woody subjects, this can do permanent damage and reduce the long term quality of the plant, even though it may leave the nursery looking A1.

To overcome this, we need to rethink our whole approach to pot design, and many manufacturers have already started challenging our traditional thinking.

In Europe it is now possible to purchase pots that have ridges going down the pot to encourage roots—when they hit the pot side—to move down and not around the pot.

Carl Whitcombe has produced his elaborately designed pots that are used successfully to produce trees in Australia, whilst Carter Holt Ltd. is selling the Rootrainer container in Australasia with the same objective of improving plant quality.

Adding Value. We may need to rethink our whole approach to production and marketing. Very few other industries market their product in the manufacturing container. If we are to ''add value'' to our plants we may need to consider repotting. The West German ''Meerslag'' container system was ideal as a ''manufacturing'' system, allowing various options for packaging at the marketing stage but, unfortunately, it never really caught on. I am sure somebody at this stage is thinking—what about the extra cost? Let us be honest. We need to get more money for our product if we are going to attract new people to our industry and invest in the future. Surely, the easiest option we have is to make our product look like it is worth more. This is the principle of ''adding value.''

The best example of ''adding value'' through pot design has been the introduction of 'Potfulls', which in six months has firmly established itself in the marketplace in the U.K. and U.S.A.

'Potfulls' have designed wedge-shaped containers that fit into an outer patio container. These containers are designed to allow the customer to mix and match plants as often as they wish, the result being plant material ''turnover'' in the garden centre more often and, if we follow that down the chain, it means the propagator has to propagate more plants on a regular timetable.

Probably the greatest marketing challenge is for us to start growing plants in environmentally friendly containers. U.S.A. research informs us that the customer will be prepared to spend more on a product that is packaged in an environmentally friendly way. The resultant pot may be a peat/paper-based pot, such as those recently launched in Australasia (and which are commonly used in the U.S.A. and Europe), or a plastic pot that is environmentally friendly. (The Dutch have such a product).

The Challenge of the 90's.

The challenge of the 90's must be for all of us to be market-driven. This means we will all need to think like customers. It should

affect everything you do, and it will challenge conventional thinking on quality standards, containers, and on what really sells! This challenge starts at propagation. If that fails, so does the company.

The 90's should be exciting with many new challenges. Let us ensure we all think like winners and put the customer first!.

PROPAGATING *HIBISCUS* BY CUTTINGS AND GRAFTING

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INTRODUCTION

Bayly's Nurseries Ltd have been engaged in the propagation of hibiscus (*Hibiscus rosa-sinensis*) for the past 25 years, since founding the nursery in Gisborne. All hibiscus in the early days were propagated by cuttings only, including the ''so called'' Fijian type, which was found growing well in the New Zealand East coast climate. Occasional frosts were experienced in winter, but the summers were usually hot and dry.

Cultivars popular at that time were: 'Agnes Gault', 'Suva Queen', 'Mrs Tonkins', 'Wrightii', 'Lambertii', 'Primrose', and 'Island Empress'. Eighteen years ago, we decided to grow more exotic types, mainly Hawaiian cultivars. Those on which we concentrated were: 'Golden Belle', 'Nathan Charles', 'Betty Patterson', 'Haywood', 'Ben James', 'Christine Phillips', 'Double Rainbow', 'Golden Oriel', 'Hawaiian Sunset', 'J. F. Kennedy', 'Molly Cummings', 'Powder Puff', 'Surfrider', and 'Tango'

These more exotic and tender cultivars need a strong, resistant rootstock to withstand our cooler and wetter conditions experienced in winter. Hence the decision was made to graft. Another reason to graft was that the amount of propagating wood available was limited

In our district, being geographically isolated, there were not many of the newer cultivars growing in gardens accessible to us. The fact that in grafting we only use one tip, and one bud, made the material go a lot further.

After studying the hibiscus that were grown in our district we decided that 'Agnes Gault', and 'Suva Queen' would be the most suitable for understock. They had stood the test of time, frost, drought, and wet conditions, and also there was plenty of suitable material available. We also found that home gardners were very happy for us to feed, spray, and subsequently prune their plants for the wood that we needed.

CUTTINGS

The cutting material was collected early in the day and kept moist. Cuttings were cut below a node to a length of 10 to 12 cm; ⅔ of the leaves were removed and the top leaves reduced by half. The cuttings were then wounded, dipped into a Captan bath, removed, and left to drain. When dry, the cuttings had a 3 sec. dip in 2000 ppm IBA in 50% alcohol, and were then placed in 6 cm square pots. The medium

consisted of pumice: peatmoss, 2:1 (vv). Cuttings were then placed under intermittent mist, with bottom heat at 23 to 25 °C.

There was a high percentage of complete rooting in 6 to 8 weeks, after which the plants were liquid-fed at weekly intervals. This gave them a good start before potting into 2 litre P.B. 3s.

GRAFTING

Firstly, the understock material was collected and kept moist. The wood was then cut into 8 to 10 cm lengths and all nodes removed with a sharp knife, placed into a Captan bath, and drained. The understock pieces were graded for approximate size and then wrapped in wet towelling to keep moist until the next stage. The scionwood was then prepared by cutting just above a bud, or using the tip, leaving just enough wood for the grafting. We used vigorous wood with wide internodes, which gave more room for the grafting machine.

The grafting machine used was a Ragget Field Grafter, designed and built in Gisborne, New Zealand. It consisted of two identical blades, forming a 'V' so that each cut was identical. Firstly, a cut was made in the scionwood, then a correct size understock was selected and cut from the opposite side. The two pieces were fitted together and then tied with floral tape. The grafted piece was then wounded and dipped for 3 sec. in 2,000 ppm IBA in 50% alcohol solution. The graft was then treated the same as cuttings, using mist, etc.

The graft took and the roots formed on the understock in 6 to 8 weeks. Once rooted it was essential to liquid-feed regularly to get buds started and also to produce growth before potting. We found that by feeding in the small pots we could get good growth and a better rooting system before potting in the usual manner in early spring.

TIMING PROCEDURE

The timing procedures for our nursery and climate are as follows:
Grafting is started in late fall and continued until mid-winter.
The grafted and cutting-grown hibiscus plants are potted in early spring into P.B. 3. standard potting mix, and then put into tunnel houses. They are kept as close and as warm as possible without the use of artificial heat. We expect, in a normal season, to have saleable plants ready for despatch by early summer. This timing programme means that we only need artificial heat during the propagation period. A regular spray programme during the growing period to control aphids, caterpillars, etc. is essential. Liquid feeding was done every two weeks.

CONCLUSIONS

These methods suit our particular climate in sunny Gisborne, and the use of the Ragget Field Grafter machine has sped up the whole operation, compared with the grafting knife method. The percentage of takes is 95% in most cultivars and the neatness of the graft union is evident. We graft in excess of 20,000 hibiscus each season. By using the methods described, we reduce the grafting time by two-thirds over other methods.

Five years ago, after attending the first world hibiscus convention in Brisbane, 1,000 cuttings of 100 cultivars, mostly new to New Zealand, were imported. They consisted of some older Hawaiian cultivars, plus many new Australian hybrids. We have trialled these cultivars and found that most of them can be grown in the warmer parts of this country.

A note of interest—two new models of grafting machines based on the same principle as the top grafter are being developed. One is a bench model, and the other is a foot-operated bench model, which will sell at a much lower price than the Omega-type machines, and give better results. Both these new machines will be built by Ragget Industries. To round off, if you are planning to grow hibiscus in quantity, check not only your climate, but also the market potential in your area.

POTENTIAL FOR THE PRODUCTION OF HIGH-PRICED EDIBLE SYMBIOTIC FUNGI IN NEW ZEALAND

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Abstract. The very highly-prized Périgord black truffle and Piedmont white truffle only occur naturally in Europe in close association with the roots of particular host plants. The Périgord black truffle has been introduced into New Zealand and techniques have been developed for raising oak and hazelnut trees infected with it. The life cycle of this fungus, its climatic and soil requirements, and the potential for growing it commercially in New Zealand are outlined

INTRODUCTION

Edible fungi can be divided into four groups depending on their source of nutrients. These are the saprophytes (e.g. button mushroom), ecologically-dependent saprophytes (e.g. morel), pathogenic (e.g. honey fungus), and mycorrhizal (or symbiotic, e.g. cep, chanterelle, and the truffles). The saprophytes live on almost fresh to composted plant or animal materials with the ecologically-dependent saprophytes requiring extremely specific conditions. Pathogenic fungi live on other living plants but cause disease, whilst the mycorrhizal fungi form a very close association with the roots of a host plant and generally benefit its growth.

Because of ease of culture, 99% of all fungi consumed worldwide (approximately one million tonnes) are saprophytes. However, some of the mycorrhizal mushrooms are highly sought after and can command very high prices. Of these the Périgord black truffle and the Piedmont white truffle are valued most highly and have a place in haute cuisine alongside saffron, caviar, foie gras, and the finest of wines.

As Périgord and Piedmont truffles can only be harvested at restricted times of the year (September to February in the Northern Hemisphere) and cannot be stored fresh, only preserved—or inferior species of truffles are available for the remainder of the year. There is therefore the opportunity for New Zealand to produce fresh Périgord and Piedmont truffles for out-of-season Nothern Hemisphere markets in Europe, U.S.A., and Japan.

In the mid-1980s a research programme on the Périgord black truffle commenced at Invermay. This paper presents a brief summary of this research (2), and covers the likelihood of black truffles being produced in New Zealand for the home and export markets. It also points the way to the possibility of producing other edible mycorrhizal fungi in New Zealand.

LIFE HISTORY OF THE PÉRIGORD BLACK TRUFFLE

Like the cap of the button mushroom, a truffle is the organ of the truffle fungus that produces the fungal spores. But there the resemblance ends, as the black truffle tends to be roughly spherical, has no stalk or gills, and is formed underground.

Throughout the year the black truffle fungus can be found forming a tight sheath (mantle) around the root tips of its host plants. This combined structure of root and fungus is called a mycorrhiza. Above ground this zone of infected root is marked by a circle of dead vegetation known as the brulé. It is in this zone that truffles are formed and harvested in winter with the aid of specially trained dogs or pigs.

TECHNOLOGICAL DEVELOPMENTS IN NEW ZEALAND

Research has been conducted at Invermay over the past three years to develop a routine technique for producing large numbers of seedlings infected with the Périgord truffle fungus. Although tens of thousands of black truffle-infected plants are produced annually in Italy and France, for commercial reasons the details of procedures used to produce them remain closely guarded. The New Zealand Ministry of Agriculture and Fisheries has also decided to adopt this approach. This is partly to ensure a return on its investment but also, through the careful quality control of the plants it sells; this will ensure that this potential industry has the very best chance of becoming established in New Zealand.

Research has also been conducted that has identified areas in New Zealand which should be suited to the establishment of Périgord black truffle truffières (truffle plantations).

CLIMATIC REQUIREMENTS OF THE PÉRIGORD BLACK TRUFFLE

The périgord black truffle naturally occurs on calcareous soils in France, Italy, and Spain and, less commonly, in Bulgaria, Portugal, and Yugoslavia, between latitudes 40° and 47°N. In France they are to be found in an incomplete arc to the southwest and east of the Massif Central. In Italy they are primarily found in the north and centre of the country in Emilia, Liguria, Marche, Piemonte, Trentino, Toscana, Umbria, and Veneto, while in Spain they are found in Alava, Cuenca, Guadalajara, Huesca, Soria, Valencia, and Zaragoza provinces.

The French black truffle growing areas are characterised by warm summers (16.5°C to 22°C mean daily temperature in July), cool winters (2°C to 8°C mean daily temperature in January), 600 to 1500 mm of rain per year and 1900 to 2800 hours of sunshine per year. Areas in New Zealand that have climates within these ranges

extend from North Otago in the South Island to Poverty Bay in the North Island.

SOIL REQUIREMENTS OF THE PÉRIGORD BLACK TRUFFLE

In Europe black truffles occur naturally and are grown artifically on rendzinas and brown earths (l). The principal characteristic of these soils is their high pH caused by the considerable quantities of limestone present in them. The ideal truffle soil should have a pH above 7.5 and with an optimum of 7.9.

In addition to the high pH, the soils in French truffières have moderately high levels of organic matter, high levels of available calcium and magnesium, and moderate levels of available phosphorus. The soils are also free-draining and have a well-aerated granular texture with neither an excess of silts, sands, nor clays. Similar soils can be found in New Zealand in, for example, North Otago and South Canterbury (e.g. Oamaru and Waikakahi soils), North Canterbury (e.g. Waikari soil), Marlborough and Nelson (e.g. Amuri soil), Poverty Bay (e.g. Waipaoa and Waihirere clay loams) and Northland (Arapohue soils).

The distribution of the ideal soils in these areas, however, tends to be very uneven and is most pronounced in North Canterbury where the soil map resembles a patch-work quilt. Great care therefore has to be taken in choosing a suitable site for a truffière.

While pH test paper and pH meters can be used to test soil pH, the other tests can be carried out only by a well-equipped laboratory. For this reason the Ministry of Agriculture and Fisheries Soil Fertility Service analyses and assesses the suitability of soils for the establishment of black truffle truffières as an adjunct to its comprehensive agricultural soil testing service.

Although a naturally high pH soil is probably the ideal, several truffieres have been established in New Zealand on normally acid soils augmented with large quantities of limestone.

COMPETITION FROM OTHER MYCORRHIZAL FUNGI

When selecting a site, care has to be taken to ensure that any competition from other ectomycorrhizal fungi is minimised. Truffieres should therefore be established well away from plants which might harbour competing ectomycorrhizal fungi. This includes pine, birch, alder, oak, hazelnut, Douglas fir, and beech. Gum, poplar, willow, manuka, kanuka, and macrocarpa (Monterey cypress) can sometimes also carry competing ectomycorrhizal fungi on their roots so establishing a truffiere where these occur should also be avoided.

FUTURE DEVELOPMENTS

The first black truffle truffières were established in spring, 1987, and by spring, 1989, approximately 7 ha of truffière were established. Given the right conditions, black truffle truffières begin producing at four to seven and, occasionally, 10 years after planting. Consequently, it is reasonable to expect that if all continues to go well, production in New Zealand would begin sometime between the winters of 1991 and 1994. It is anticipated that there will then be a dramatic increase in the number and size of truffières established. While it is expected that the bulk of the crop would be sold overseas, it is likely that high quality New Zealand restaurants would also be interested in extending their haute cuisine.

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MACRO AND MICRO PROPAGATION OF LEYLAND CYPRESS

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Abstract. Conventional propagation of Leyland cypress by stem cuttings is briefly reviewed; results are rarely consistent or reproducible. An alternative approach using micropropagation is outlined. Shoot tips (30 mm) from the lower branches of a 9-year-old hedge of 'Leighton Green' rejuvenated spontaneously after 3 months in Woody Plant Medium (WPM), or in WPM supplemented with 0.1 mg l^{-1} NAA, IBA, or TBA, or 2 mg l^{-1} BA or 2iP. The juvenile shoots were maintained on WPM for shoot elongation, or on WPM containing 2 mg l^{-1} BA plus 0.1 mg l^{-1} NAA, for bud proliferation. Roots were induced in 0.4% agar medium containing either 1 mg l^{-1} NAA or 1 mg l^{-1} IBA. Although results are encouraging, further work is required to perfect the technique

INTRODUCTION

Leyland cypress, × *Cupressocyparis leylandii* (Jack. & Dallim.) Dallim., a spontaneous hybrid between *Cupressus macrocarpa* Hartw., and *Chamaecyparis nootkatensis* (D.Don) Spach., was first described by Jackson and Dallimore (5). Separate hybridisations have resulted in several clones, some of which have received cultivar names (6, 9). Leyland cypress has become increasingly popular for a range of uses due to its fast growth and environmental adaptability. Propagation has been by stem cuttings, but marked inconsistency of rooting, especially in the "green" clones, has directed attention to the possibilities of micropropagation techniques.

MACROPROPAGATION

An extensive investigation of conventional propagation of Leyland cypress was made by members of the IPPS in the early 1970s and reported by Howard (4). This and later work (8) showed the strong influence of local factors on the rooting process and highlighted the lack of understanding of the plant mechanisms responsible. Published results covering most of the factors perceived as influencing rooting, including selection and pre-treatment of cuttings, time of year, rooting media, temperature and lighting conditions etc., reveal a range of results that are, overwhelmingly, neither consistent nor reproducible (Sturrock, unpublished). Some apparently refute physiological expectation: thus, records of better root initiation and faster root growth at lower rather than higher medium temperatures are paradoxical, and must indicate strong interactive effects among rooting factors.

Such complexity confounds inherent differences in rooting that may exist among Leyland cypress clones. A concensus view, nevertheless, suggests that rooting is easier in 'Haggerston Grey',

'Stapehill', and 'Ferndown' than in 'Leighton Green' and 'Naylor's Blue'. However, an experiment at Lincoln showed that the latter clones may, in some circumstances, root as well as or better than 'Haggerston Grey' (Figure 1). These graphs show that apparent differences among clones relate, at least partially, to differences in rates of rooting with the date of examination determining clonal rooting percentages. This result confirms an earlier conclusion reached by Deen (3) based on Dutch work. Within a single clone, rooting may take anywhere from five weeks to seven months. Undue delay in root initiation may have precluded clones with other desirable attributes from fuller commercial exploitation, e.g. 'Naylor's Blue' which has a tree branch structure superior to most other clones.

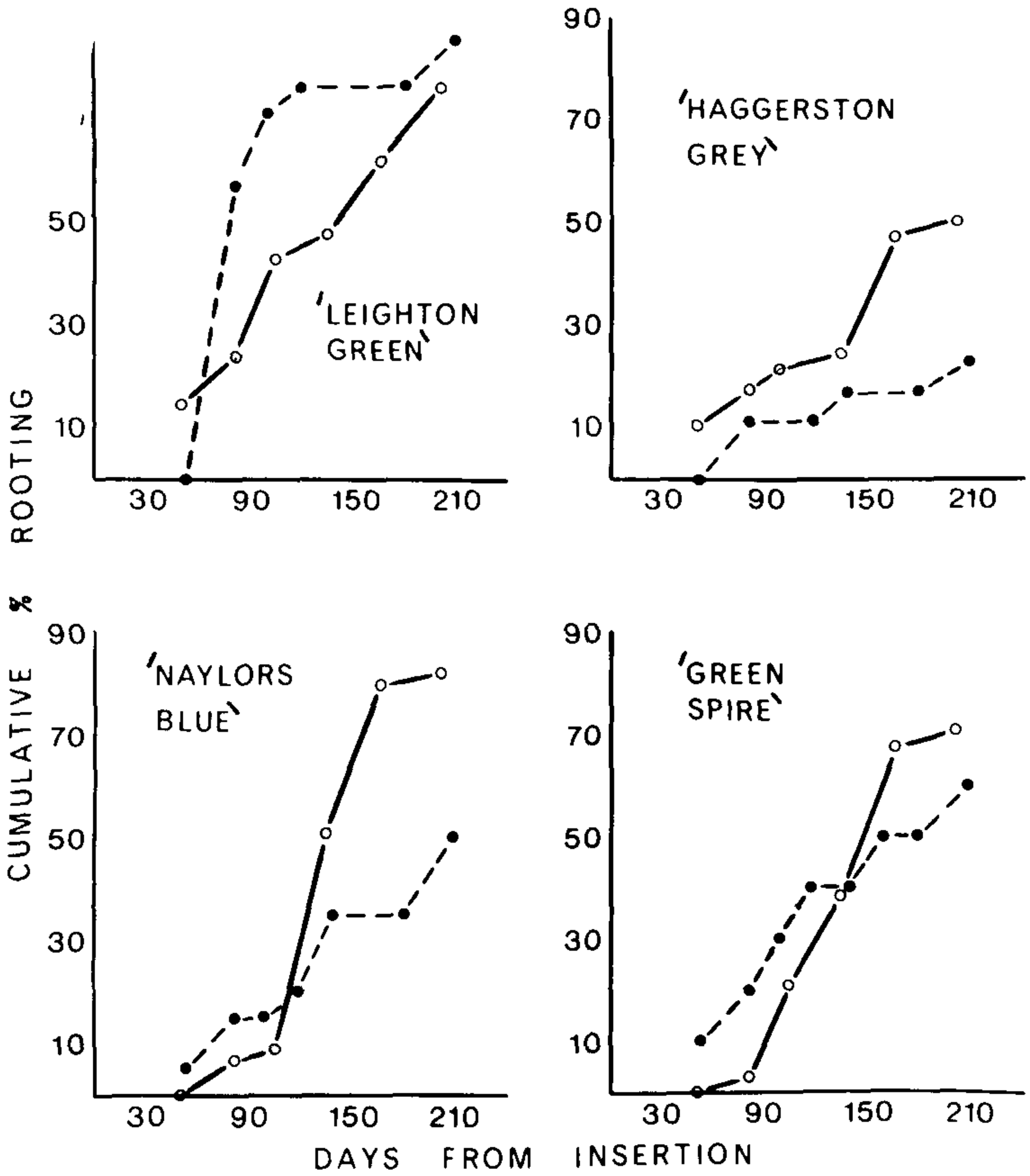

Figure 1. Cumulative rooting percentages in cuttings of four Leyland cypress clones inserted in spring (solid line) and autumn (dashed lines) Number of cuttings per treatment = 40

Successful micropropagation would be especially useful with such recalcitrant clones and generally allow greater reliability in mass production of Leyland cypress.

MICROPROPAGATION

Culture methods. Shoot tips (30 mm) were taken in April (autumn) from the lower branches of a 9-year hedge of 'Leighton Green'. Following surface sterilisation in 0.1% $HgCl_2$ for 45 min. they were placed in Woody Plant Medium (WPM) (7) with various added growth substances then cultured in a growth room at 24 °C with a 16 hr photoperiod of 28 μm^{-2} s^{-1}. Cultures were made in 100 ml Erlenmeyer flasks with cotton wool bungs, containing 50 ml of the medium. There were five replicates in each treatment with a sub-culture time of 12 weeks. The material has been in culture for 4 years.

Experiments and results. Forty percent of the apices were lost because of bacterial or fungal contaminants. The use of 0.01, 0.1, 1.0, and 10 mg l^{-1} indoleacetic acid (IAA), indolebutyric acid (IBA), naphthyleneacetic acid (NAA), 2,4-dichlorophenoxyacetic acid (2,4-D), or trichlorophenoxybutyric acid (TBA) failed to induce rooting although profuse callus was induced in the two higher concentrations.

Juvenile foliage was formed in a number of treatments and the orthotropic form present in the main axis of the parent tree was restored.

This juvenile form occurred in the basic WPM medium as well as in this medium containing 0.1 and 1.0 mg l^{-1} NAA or TBA. It appeared also in subsequent treatments including 2 mg l^{-1} benzyladenine (BA) or 2-isopentyladenine (2iP), with or without 0.1 or 1.0 mg l^{-1} NAA or IBA. Callus was often produced basally with axillary buds growing out through it.

The number of juvenile shoots was increased by inducing lateral bud growth in a medium containing 2 mg l^{-1} BA + 0.1 mg l^{-1} NAA, and shoot elongation was encouraged by alternate passages in basic WPM During the year, summer growth reached a maximum of 60 mm; in winter, growth was reduced to as little as 10 mm. The proliferating buds on decapitated stumps were a useful source of clonal material (Figure 2).

Figure 2. The juvenile form of an established culture showing lateral bud growth.

During the investigation, a possible alternative source of shoot material was noted as tiny adventitious buds developing on the swollen leaves of the basal buds of shoots in 3 ppm of a cytokinin. This has been noted in other gymnosperms (1, 2). However, they proved unsuitable substitutes for lateral shoots because of difficulty in culturing.

Roots have only been induced in soft 0.4% Difco agar medium containing 1 mg l^{-1} NAA or IBA. They developed after 6 weeks on shoots that had already acquired a callused base (Figure 3). They were thick, robust organs but their presence did not enhance the growth of shoots. Growth equalled that of unrooted shoots, about 25 mm in 3 months.

Figure 3. A rooted shoot in soft agar medium containing 1 mg per litre NAA.

Rooted specimens have just been transferred to soil and their suvival and growth have yet to be assessed.

CONCLUSIONS

The problems that arise with macropropagation of Leyland cypress viz: inconsistency and a long rooting period, have not yet been overcome by micropropagation. Although this first attempt at micropropagation has met with qualified success, further work is needed to refine the technique and test its practicality.

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A PLANT COLLECTIONS SCHEME FOR NEW ZEALAND

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There are few people today who are not aware of the major environmental problems facing the world. The greenhouse effect, loss of the ozone layer, and acid rain have become the major issues of the 1980s. Of particular concern to us as horticulturists, however, is the loss of genetic diversity in the plant kingdom due to the destruction of tropical rainforests and other natural habitats. To give you an idea of the magnitude of the problem a quote from a report written by Dr. Peter Raven, Director of the Missouri Botanic Garden, St. Louis, Missouri, U.S.A. is given below:

> "...40,000 species, or about a quarter of those found in the tropics, will probably persist in the South American tropics and Zaire beyond the middle of the next century. An additional 130,000 species, however, occur in the tropics but not in these regions-only in areas where the vegetation will be demolished during the next few decades. Liberally assuming that half these species may be weedy or persist in small pockets of vegetation, we come to the horrifying conclusion that more than 60,000 species of plants—fully a quarter of the world's total diversity are at risk of extinction in the tropics and sub-tropics during our lives and those of our children."(5)

Sobering figures indeed! However, the prospects for garden plants are little better. In Britain some 100 cultivars of *Crocosmia* have been recorded over the years, yet today only 23 are commercially available. *Paeonia*, even worse, with about 800 cultivars recorded yet only 152 commercially available. Of garden plants still in cultivation, many are at risk because of their limited availability. For instance, in the Hardy Plant Society's 1988 edition of the Plant Finder, 27,000 plants are listed as being available in the trade. Of these only 350 are listed as widely available (from more than 30 nurseries nationwide.)

This paper considers briefly the response of the world's horticultural and botanical community to this crisis and then outlines initiatives taken by the RNZIH and others to conserve plants by establishing a National Plant Collections Scheme.

BOTANIC GARDENS CONSERVATION SECRETARIAT (BGCS)

The BGCS was established on 1 January, 1987 and is located at the International Union for the Conservation of Nature and Natural

Resources (IUCN) Plant Conservation Office at Kew Gardens, Richmond, England. The main objectives of the BGCS are:

- To promote the implementation of a "Botanic Gardens Conservation Strategy".
- To monitor and coordinate *ex situ* collections of conservation-worthy plants.
- To develop a programme for liaison and training between gardens and arboreta, especially between gardens in developing and developed countries.
- To arrange a Botanic Gardens Conservation Congress every three years.

At the present time four New Zealand gardens and arboreta (Dunedin, Timaru, Eastwoodhill, and New Plymouth) are members of the BGCS. Membership links these gardens into a worldwide network of over 150 gardens, and enables them to implement plant conservation strategies within a global framework. They will also have access to a database on the cultivation and propagation of threatened plants currently being developed.

NATIONAL COUNCIL FOR THE CONSERVATION OF PLANTS AND GARDENS (NCCPG)

The NCCPG is an independent charity based at the Royal Horticultural Society's Gardens at Wisley, England. It was established in 1979 as a result of a conference on garden plant conservation organised by the Royal Horticultural Society.

The objectives of the NCCPG are concerned with the conservation of species, hybrids, and cultivars growing in British and Irish gardens. The work of the NCCPG covers many areas, and includes the establishment of National Collections. A National Collection aims to be a definitive collection of the species, hybrids, and cultivars within a particular genus or part of a genus. The reasons for establishing National Collections are threefold:

- To retain plants in cultivation regardless of their demand in the trade.
- To make it possible for keen gardeners to obtain plants that are otherwise unavailable. This may involve the collection holder cooperating with a nursery to make plants available to gardeners.
- For research use by horticulturists and botanists. For this to occur the collections must be well documented and comprehensive. Collections also assist in the correct naming of plants (especially cultivars).

There are currently about 450 national collections documented by the NCCPG and the number is still growing. Collections are held by botanic gardens, The National Trust, horticultural colleges, local authorities, nurseries, private individuals, and NCCPG member

groups. They cover a wide range of genera from *Narcissus* with 2000 taxa down to *Zelkova* with only six.

Collection holders must have a suitable level of knowledge on the genera they hold and agree to maintain the collection to an acceptable standard. The expense of maintaining a collection is borne by the collection holder and not the NCCPG. The NCCPG simply inspects and approves the collection initially and liaises regularly with collection holders from then on. The success of the scheme has been in its voluntary nature and resulting low cost structure.

The NCCPG also cooperates with other organisations such as the IUCN and recently began working through IUCN's rare and theatened plant lists to see how many of these plants were growing in British and Irish gardens. A search of the New Zealand list revealed that 27% (35 taxa) were in cultivation. Out of these, 15 plants considered garden worthy and hardy in parts of Britain and Ireland were chosen (Appendix A). Encouragement will be given to propagate these plants and make them more available to gardeners.

ORNAMENTAL PLANT COLLECTIONS ASSOCIATION (OPCA)

A scheme based on the NCCPG recently began operating in Victoria, Australia. The OPCA aims to maintain and increase the diversity of garden plants by registering reference collections of related plant groups. Of the many objectives, two of the most important are:

- To encourage and organise the reintroduction of ornamental plants lost from horticulture in Victoria and include them in plant collections.
- To facilitate the supply of propagating material from plants in reference collections to nurserymen, institutions, and other interested parties.

The association already has a part-time project officer working from the Royal Botanic Garden, Melbourne, who is helping to set up trial collections of ornamental plants. Currently there are 13 collections with three more close to establishment. Like the NCCPG they are developing a database which will be used by horticulturists, landscapers, and so on who wish to find information on particular species or cultivars.

The scheme is currently operating only in Victoria (although one collection is just over the New South Wales border), but it is hoped that similar schemes will shortly be established in other states.

A PLANT COLLECTIONS SCHEME FOR NEW ZEALAND

In New Zealand, there is an urgent need to co-ordinate our plant conservation efforts. While there are institutions and individuals

working very effectively in this area, there is no co-ordinated strategy to ensure that duplication and poor coverage are avoided, with expertise and resources available where they are needed. A Plant Collections Scheme needs to be established to cover collections of garden plants as well as threatened New Zealand plants National standards for the development and maintenance of these collections will be developed along with a database of all collections and their contents.

The NCCPG concept is very exciting because of its capacity to include documented collections of amateur plant collectors and growers, within a network that accommodates public and private organisations of a professional nature. We envisage any scheme established in New Zealand would run along similar lines.

Many will, no doubt, say that this proposal is not new and, of course, you would be right. David Given, the late Graeme Paterson, Peter Heenan, and others, advocated, in different ways, the coordination of plant collections albeit for rare and endangered species (1, 2, 3, 4). Their efforts were largely unsuccessful. So what will ensure this scheme gets off the ground where others have failed?

- The commitment of a national organisation such as the Royal New Zealand Institute of Horticulture (RNZIH) and other organisations and individuals with an interest in plant conservation.
- Successful schemes operating overseas which can be used as the basis for a New Zealand scheme.
- Timing: As mentioned before, there is now genuine concern over global environmental problems. Such a scheme can be seen to address some of these problems and will gain wide-ranging support.

As a first step, the RNZIH convened a workshop in Hamilton, New Zealand on 13 October, 1989, to investigate the establishment of a Plant Collections Scheme. The keynote speaker at the workshop was Tony Lowe, General Secretary of the NCCPG. The workshop provided an opportunity for those with an interest and/or involvement in plant conservation to hear about the development of the NCCPG and help develop an action plan for a New Zealand scheme.

The concept is exciting, but we are realistic enough to know that for such a scheme to succeed, a long term commitment is needed from the horticultural industry and the people working in it. The RNZIH has made its commitment. I hope others in New Zealand will do the same.

APPENDIX A

The fifteen New Zealand plants that were selected are:

Celmisia haastii, var. *tomentosa, C. hookeri, Chordospartium stevensonii, Cotula rotundata, Grammitis rigida, Hebe gibbsii, H. insularis, H. raoulii* var. *maccaskilii, Myoporum laetum* var. *decumbens, Notospartium carmichaeliae, N. glabrescens, Pittosporum dallii, Pratia physaloides, Solanum aviculare* var. *latifolium, Tecomanthe speciosa.*

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SELECTING ORNAMENTALS FOR FRAGRANCE

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INTRODUCTION

At first sight our sense of smell appears to be overlooked when we choose plants as consumers. Garden centres can be visual delights and garish extravaganzas of green and red, but they may not be consciously designed for fragrance. Presumably, in our choice of plants to propagate and grow we tend to reflect the perceived demands of the marketplace. We place overwhelming emphasis on appearance or other selection criteria before fragrance, which may come as a bonus except in the most emphatically scented plants.

We are drawn as bees are by a pleasant fragrance, ''home-in'' on the supposed source by eye, and verify that we have made the right contact by sniffing at close quarters. I will briefly review our understanding of the subject and speculate on the implications for:

1. breeding and selection programmes in which fragrance may be an important evaluation criterion;
2. how consumers select plants; we ''use'' scented plants to sell themselves but perhaps we do not ''design'' with odour to control its impact; and
3. how fragrance may be used to affect buyer preference or buyer behaviour in general in retail situations.

FRAGRANCE IS NEGLECTED

The sense of smell is ''not an intellectual faculty: odours can set free the emotions, diffused into a vaguely pleasurable state'' (2). Even though our sense of smell is less well developed than that of animals, it exerts a powerful control, reminding us of events or whole scenes from the past. It is our memory sense that can recall experiences pleasurable and frightful. It can bring to our attention our immediate surroundings alerting us to desirable or otherwise odiferous substances, and it can affect us below the plane of consciousness. It has been noted that ''a sweet scent can stir the instinct of courtship without evoking the idea of the natural end object of the instinct'' (2).

The sense of smell is not an intellectual faculty, therefore it has not been amenable to discussion. Most of us have no vocabulary to hold conversations about fragrance. Neither does odour suggest simple physical models of how it works unlike our senses of sight and hearing with their optical lenses and vibrating drums. Coupling this with

connotations of animal baseness it is not surprising that odour has been neglected.

CLASSIFICATION OF FRAGRANCES

Many attempts have been made to classify flower and other fragrances but this is very difficult with so many fragrances not fitting neatly into a single group, even within a single genus (1). However, although classifications are arbitrary, uncertain and fragile, we still need to make them and give categories within them titles into which plant fragrances can be fitted.

The perfumer, Rimmel, needed 18 classes of flower fragrance but even then some plant fragrances did not fit. Von Marilaun recognised 10 Groups, some of which were fairly well defined. For example, the Indoloid Group, characterised by a fetid odour reminiscent of fish or decayed meat, contained members in the genera *Arum, Aristolochia,* and *Amorphophallus;* plants in the Aminoid Group, which has an ammonia-like, stale odour, include *Pyracantha* and *Crataegus.* However the Heavy (or Sweet) Group (tuberose-type fragrance) has plants showing affinities with the Aromatic Group (Dianthus-type fragrance), and so on (3).

One of the most clearly set out classifications of odours is that of Wells and Billot (3) which recognises 9 groupings, such as, Floral, Woody, and Rustic, each of which is divided into sub-groups that can still be discerned by trained noses. The Floral Series sub-groups have flower names, such as, Rosaceous, Jasmine-like, and Violet-like.

The reasons for the problems of classification that have plagued people for centuries were revealed when chemical technology first separated and identified the principal odiferous substances, e.g., indole, putrescine, and trimethylamine in some of the foul scents; eugenol, ianone, geraniol, citral, and esters in the more pleasant, fruity, and aromatic ones.

We still fall back on terms like sweet, cloying, spicy, fruity, and earthy to label fragrances, having noses and minds that have not conjured up a simple way of saying what would amount to many complicated cocktails of chemical constituents. Wells and Billot (3) give some beautiful descriptions of odours. For example, ''ordinary, everyday lilac (*Syringa vulgaris*) has an odour characteristised by hydroxycitronellal and a rose odour against a rather heliotropin-like background, with a slight suggestion of hawthorn (anisaldehyde)''. We can assay chemical constituents but we cannot measure an odour.

FRAGRANCE QUALITIES

Armed with the odiferous constituents of flower fragrances, perfumery chemists have found it surprisingly difficult to produce

synthetically what a flower produces so effortlessly. Perfumes may commonly be composed mainly of artificially produced substances that are identical to those occurring within the plant but it is necessary to add natural (impure) fragrance to achieve a pleasant perfume, either with or without genuine floral effect. Natural fragrances are complex and their effect may depend on factors beyond the odiferous constituents.

Perfumers talk of fragrances having a certain tone, a genuine character which may be pointed, acute, and sharp, e.g. lemon oil, mild or medium, and geraniol, warm, low, or heavy. They have intensity and volume, the latter ranging from full-bodied to thin and poor. Their lift describes how far the odours carry, the most far-ranging having inodorous carriers with high oil solubility. Francis Bacon noted the difference between close-up and far-ranging fragrances and listed double violet, wallflower, clove pink, and honeysuckle in the latter category.

Aroids, like the stink cabbage and voodoo lily, broadcast their stench by the trick of elevating the temperature of their flowers by as much as 22 °C to increase evaporation of the malodorous compounds.

FRAGRANCE AND INDUSTRY

While perfume manufacture for personal use is a vast industry founded on analytical and synthetic chemistry and alchemy, fragrances and perfumes are all-pervading in the home and at work.

In the agricultural sector, perfumes are used to reduce the perception of offensive odors, whether by distraction or masking is unclear, e.g. close to piggeries and fertiliser plants. Horticultural products for home gardens can also have odour maskers suggestive of new-mown hay or fougere (earthy moss). Essential oils from *Backhousia, Melaleuca,* and other plants are used as activators of *Pyrethrum* insecticides.

There was a report last year of a Japanese construction company that has been conducting serious experiments in the area of ''environmental fragrancing''. They use fragrance to alter the mood of customers and to improve worker efficiency. Lavender and rosemary are soothing scents: jasmine and lemon scents drastically reduced keyboard errors. Further investigation revealed that the scents were used subtly to avoid nose fatigue or numbness to smells: microprocessor control varied the atmospheric concentrations so that people were effectively ''fragranced''.

CONCLUSIONS

When selecting a plant on the basis of fragrance, either as a consumer or as a professional selector, by far the best judge of quality will remain the nose, not the chemical laboratory Happily, noses can be trained, so that if you were breeding and selecting for more or differently-scented lines your skill might improve with experience. Conversely, of course, if selections were being made to identify which lines produced the highest yield of natural compounds, e.g., an essential oil for industrial extraction, chemical analysis would be essential.

Secondly, there is scope for designing for the nose. Perhaps we should be more mindful of how we site different plants in the garden, but more importantly, in retail locations. These may need to have changes of scent ''displays'' or it may be more useful to build a sense of place around a particular odour so that people are welcomed by its familiarity when they return However, this may not be a flower fragrance.

Lastly, we may have information soon on mood modification by fragrance that could be a means for increasing sales of plants. Visual impact must be the dominant sensory factor, but if a nursery smells of ''a woodland on a warm day'' either by using plants or by opening a bottle rather than a bag of fertiliser, people may show that they prefer it that way. It is unlikely that fragrances will be developed for plant sales outlets when there is so much scope for using plants for sight and smell to better effect, but the possibility is there.

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MICROPROPAGATION OF BLACK CURRANT (*Ribes nigrum*)

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Abstract. A method is described for the micropropagation of four selections of black currant (*Ribes nigrum*) The optimum multiplication medium contained Murashige and Skoog salts, Gamborg B5 vitamins, 20g l^{-1} sucrose, 0 5g l^{-1} casein hydrolysate, 0 5 mg l^{-1} benzylaminopurine (BAP) and 7g l^{-1} agar Varying levels of inositol, BAP, and indolebutyric acid (IBA) were tested. For shoot elongation and rooting, the BAP concentration was reduced to 0 25 mg l^{-1} and the effect of the addition of activated charcoal (Sigma No C—4386) was investigated For the selection P10, 100% rooting has been achieved, and plantlets transferred to soil. The other selections have been slower to respond and rooting percentages have not yet been assessed

INTRODUCTION

Four Scottish selections (P10, P7, 243, BS) of black currant from the Department of Scientific and Industrial Research (DSIR) Plant Protection collection have been selected by the Ministry of Agriculture and Fisheries (MAF), in conjunction with the New Zealand Black Currant Product Group, for either their high yield, good processing, or other favourable characteristics, such as flavour. These selections, and others, are in the process of being bulked up for field testing, using both conventional propagation techniques (10cm hardwood cuttings) and *in vitro* micropropagation.

The aim of this work was to produce 7000 plantlets for transfer to soil to increase the number of stock plants available for conventional propagation. The NZ Black Currant Product Group and MAF aim to have ¼ million plants by 1991 and 1 million by 1992 for distribution to growers for commercial scale trials.

Several researchers have reported successful techniques for the micropropagation of black currant *in vitro* (2, 5, 7, 8, 9). Our aim was to apply these techniques to obtain the numbers required as rapidly as possible. The protocol of Flegmann and Wainwright (2) for the cultivar Baldwin was initially followed, but much blackening and deterioration of shoots occurred. The addition of ascorbic acid and IBA, as reported by Mokra and Maliarcikova (5), was also unsuccessful. Thus a number of alterations were tested in an attempt to optimize media components.

MATERIALS AND METHODS

Initial explants were taken from dormant, field-grown material of the four selections:-P10, P7, 243 and BS. Nodal pieces were surface sterilized using a 96% ethanol shake (5 secs) followed by agitation

in 0.75% w/w sodium hypochlorite (20 mins) and 2 rinses in sterile distilled water. Dissected buds (5-10 mm) were placed in petri dishes on the initiation media—a modified Murashige and Skoog (MS) (6) basal medium containing 20g l^{-1} sucrose, 0.3 mg l^{-1} or 1.0 mg l^{-1} BAP and 6g l^{-1} Davis Bacteriological agar (2). Some sterilized canes were placed in jars with water, into the culture room to encourage new growth. This material was also surface sterilized, cut into single node pieces and placed on the modified media in vials (4.5 cm diameter, 5.5 cm high). Cultures were maintained at 25 °C, 16 hr day/8 hr night, 30μE m^{-2} s^{-1} light.

For subsequent experiments the medium used was MS salts, B5 vitamins (3) minus inositol, 20 g l^{-1} sucrose, 0.5g l^{-1} casein hydrolysate, 0.6g l^{-1} agar, and pH 5.8, with the following additions for shoot multiplication comparisons (in mg l^{-1}):

Treatment 1: 0.5 BAP + 100 inositol;
Treatment 2: 0.5 BAP + 10 inositol,
Treatment 3: 1.0 BAP + 10 inositol;
Treatment 4: 1.0 BAP + 10 inositol + 0.1 IBA.

For shoot elongation and rooting the additions were (in mg l^{-1}):

Treatment 1: 0.25 BAP + 100 inositol;
Treatment 2: 0.25 BAP + 100 inositol + 1000 activated charcoal.

Culture conditions were as above, and containers used were half pint glass Agee jars (9cm diameter, 10cm high) with clear lids. Shoot multiplication was assessed after the third and fourth subculture on the respective media. Subculture was at 4 weekly intervals. There were a minimum of 10 shoots per treatment for the shoot multiplication assessments, and 25 shoots per treatment for rooting.

RESULTS

Upon initiation, contamination rates were high (80%), not unexpected when using field-grown material. Shoots did not thrive on the initiation media. There was much blackening of shoots and leaves, and considerable exudation of phenolic-like substances. The addition of 50mg l^{-1} ascorbic acid to reduce blackening was detrimental, and the use of other salt media such as B5 and Woody Plant medium (4) resulted in further deterioration in growth. The addition of 0.5g l^{-1} casein hydrolysate—possibly supplying added nitrogen or essential amino acids—was beneficial in establishing, healthy multiplying cultures.

Table 1 shows the comparison of the multiplication media after the third subculture. When comparing inositol levels at 0.5 mg l^{-1} BAP, the selections showed very little difference in multiplication rates. For P10 the multiplication rate was 3.4 fold on both 10mg l^{-1} and 100 mg l^{-1} inositol, while for P7 it was 2.1 fold on 10mg l^{-1}, and 1.3 fold on 100 mg l^{-1} inositol. After the fourth subculture the multiplication

rates were 3.0 and 3.1 for P10, 2.4 and 2.5 for P7, and 2.7 and 2.8 for BS at 10 mg l^{-1} and 100mg l^{-1} inositol, respectively.

Table 1. Effect of inositol, benzylaminopurine, and indolebutyric acid on multiplication rate of four selections of black currant (minimum 10 shoots per treatment)

	Selection			
Treatment*	P10	243	BS	P7
1	3 4	2.1	1 5	1 3
2	3 4	1 9	1 8	2 1
3	3 7	2 0	1 9	3 5
4	3 1	2 0	1 8	**

* Treatments (mg l^{-1}) (1) 0 5 BA + 100 inositol, (2) 0 5 BA + 10 inositol, (3) 1 0 BA + 10 inositol, (4) 1 0 BA + 10 inositol + 0 1 ± BA

** No treatment due to lack of material

For the comparison on the two levels of BAP at 10mg l^{-1} inositol, again the multiplication rates showed little difference, except for the selection P7 which had a higher rate on 1.0mg l^{-1} BAP at 3.6 fold compared with 2.1 fold on 0.5mg l^{-1} BAP.

However, the use of 1.0mg l^{-1} BAP caused the shoots to become very suppressed and difficult to manage, particularly after the fourth subculture on this medium, when multiplication rates dropped to 1.6 fold.

Treatment 4 was only tested on selections P10, 243 and BS, due to the lack of material of P7. The addition of IBA did not improve multiplication. Moreover, the shoots looked abnormal with pale, narrow, crinkled leaves and petioles that pointed downwards.

Table 2 shows the effect of charcoal on rooting of P10 plantlets *in vitro*. There was 100% rooting on both plus and minus charcoal. However, on the medium without charcoal there were 7.7 roots per shoot with mean length 2.3 cm, while with charcoal there were 3.8 roots per shoot with mean root length of 1.1 cm.

Table 2. Effect of 1g l^{-1} charcoal on rooting *in vitro* of P10 black currant plantlets (Values are means ± standard error, n=25)

Treatment	Percent rooting	No roots per shoot	Mean root length (cm)
1. – charcoal	100	7 7 ± 1 7	2 3 ± 1 3
2 + charcoal	100	3 8 ± 1 9	1 1 ± 0 7
		ts = 7.65***	ts = 4.07***

*** represents significant differences among means at the 0 1% probability level, as determined by a t-test

DISCUSSION

Of the four selections P10 was the most vigorous in all the tissue culture regimes tested. In contrast, P7 and BS were much less vigorous. Other workers have had difficulties with blackcurrants using *in vitro* micropropagation (1; J. Seelye, pers. comm.). The only other successful reports were by Flegmann and Wainwright (2, 7, 8) but they used only one cultivar—Baldwin, and their medium was not suitable for our selections. Selection 243 has shown evidence of internal "white ghost" bacterial contamination which consequently affected its performance. The antibiotic cefotaxime (100mg l^{-1}) has controlled the contamination but this caused the multiplication rate to decrease.

Clearly, rooting was not a problem for the selection P10, as it rooted both with and without charcoal, and also without auxin. In fact P10 rooted better (i.e., more roots and longer) on the medium without charcoal that had 2.5 mg l^{-1} of cytokinin. The action of charcoal used in the medium is unclear, but in this case had an inhibitory effect on root number and length. Wainwright and Flegmann (7) used a two-step process for rooting their cultivar, Baldwin. The first step involved 4 days on a medium containing auxin followed by 37 days on a medium with no auxin. Our process effectively saves one subculture step thus making propagation of black currants in tissue culture more economically viable. However, further work will be necessary to optimize the tissue culture environment for the other selections.

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PROPAGATION AND NUTRITION OF DAPHNE CUTTINGS AND TISSUE CULTURE PLANTLETS

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INTRODUCTION

Due to an increasing demand for High Health (virus-free) stock plants of *Daphne odora* 'Leucanthe', the rapid bulking-up of cuttings using a small population of existing stock plants was investigated. Owing to a shaded growing environment, shoots of stock plants had become elongated and unbranched, unlike plants grown in the open.

The literature available on propagation of *Daphne* is limited compared with that for many other genera. Reports tend to stress that shoots of current season's growth should be used (1), or tip cuttings only, preferably terminated (2). One report states that stem cuttings are not used because the leaves can yellow and defoliate even though they are sound at the time of making the cuttings (2). However, this can also happen with tip cuttings. The acceptability of plants raised from cuttings taken from different parts of the parent plant needed to be studied under our conditions.

It has been stated that *Daphne* plants must have acid soil conditions to grow well. However, *Daphne genkwa* grows naturally in limestone areas and many others are found on alkaline soils. It has also been said that satisfactory plants can be produced over a wide range of pH values (1). In a second experiment the response to applications of dolomite and limestone to the growing medium used for raising *Daphne odora* 'Rubra' and 'Leucanthe' tissue-cultured plantlets was investigated.

MATERIALS AND METHODS

Plant material was collected as complete stems (30 to 40 cm) and cuttings were taken from three positions on the same stem:

1. the terminal shoot as a firm tip cutting;
2. the region below the terminal shoot, of more mature wood, taken as an internodal cutting referred to as a first nodal cutting; and
3. the region below the first nodal cutting, in a still more mature state, referred to as the second nodal cutting.

The cuttings were approximately 8 cm long and comprised of six nodes. The lowest two leaves were removed and the base lightly wounded. After wounding they were dipped in IBA (0.8%) in talc.

The cuttings were placed in individual containers (8 cm tubes) using a medium of peatmoss and pumice (50:50). They were then drenched with benomyl and placed in a propagation house, where

they were misted for five seconds every 40 minutes, given bottom heat at 21°C, and shaded to hold the ambient temperature at approximately 24°C. The trial was established in late summer (February 1, 1989).

The cuttings were observed every two weeks for ten weeks and the number of roots per cutting recorded. The rooted cuttings were potted in individual containers (90 mm diameter) using a peatmoss and pumice medium (80:20) containing slow-release fertilisers, and grown on a capillary sandbed in a greenhouse with a daily maximum temperature of 24°C. A record was kept of when the plants flowered and the number of new shoots growing away over the next 14 weeks.

In a second experiment, exflasked tissue-cultured plants of *Daphne odora* 'Rubra' and 'Leucanthe' were potted in a peatmoss and pumice medium (4:1) to which had been added 7 rates of either dolomite or limestone (0, 2.5, 5, 7.5 10, 15 and 20 g/l). In addition, all media contained exactly the same fertilisers, namely 18-2.6-10 long-term Osmocote (1.8 g/l, Sierra), 14-6.1-11.6 short-term Osmocote (0.55 g/l, Sierra) and PG Mix (1.8 g/l, Smiths Industries).

With five replicates of all treatments in a completely randomised design, the plants were grown on capillary matting in a greenhouse held at 18 to 24°C. The experiment was started late autumn (May 1), and concluded 20 weeks later. Shoot length and dry weight of tops were recorded and the pH of the growing medium measured, using the 1·1.5 by volume extraction method (3).

RESULTS

After 6 weeks the nodal cuttings had initiated roots, especially in the second nodal cuttings. After 10 weeks the terminal cuttings had produced a number of adventitious roots, but the nodal cuttings had greater numbers of roots per cutting (Table 1) and they were longer. Axillary shoot growth was in progress in nodal cuttings whereas there was no evidence of growth in the tip cuttings.

Table 1. Effect of cutting type on rooting of *Daphne odora* 'Leucanthe' cuttings

Cutting type	Percent of cuttings rooted	Average number of roots per cutting
Terminal shoot	90	9 4
First nodal	75	10 1
Second nodal	95	14 3

After a further 14 weeks plants raised from tip and first nodal cuttings had produced similar numbers of inflorescences (''flowers''), whereas those from second nodal cuttings produced relatively

few flowers. However, while the plants from second nodal cuttings were not flowering, shoot growth had started. Both first and second nodal cuttings produced plants with a large number of shaping branches (Table 2).

Table 2. Effect of cutting type on flowering and number of branches of rooted cuttings of *Daphne odora* 'Leucanthe'

Cutting type	Average number of flowers per rooted cutting	Average number of shoots per cutting
Terminal shoot	1 5	1 4
First nodal	1 3	4 0
Second nodal	0 3	4 3

In the experiment on the effects of dolomite and limestone on growth of tissue-cultured *Daphne* plantlets, both of these additives affected pH similarly The pH of the medium was raised from approximately 4.2 to a plateau value of 6.0 at rates of 10 g/l and above. Both cultivars responded well to the increasing pH, particularly for increasing height, although not so obvious as for shoot dry weight. Best growth by these measures was at pH values of approximately 5.5 for 'Leucanthe' and 6.2 for 'Rubra'. These were given by limestone or dolomite additions of 7.5 and 10 to 15 g/l, respectively.

A notable feature of the experiment was the unhealthy state of plants of 'Rubra', which showed tip necrosis at all rates of limestone or dolomite addition. This was in marked contrast to the plants of 'Leucanthe' which were all a healthy dark green.

DISCUSSION

From reports in the literature, the percent of cuttings rooted in these trials is satisfactory even for stem cuttings (2, 4). Although there have been reports that stem cuttings are unsatisfactory, under our conditions this material gave good results. The plants tended to have a better structure than those raised from terminal cuttings.

The pH trial showed that the two cultivars can behave as quite dissimilar plants, responding best at different pH values, with 'Rubra', unlike 'Leucanthe', exhibiting symptoms of what was believed to be iron deficiency. Further work is in progress to substantiate this suggestion.

Acknowledgement. The assistance of Dr. John Clemens in the preparation of this paper is gratefully acknowledged

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BROMINIZATION VS. CHLORINATION

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Chlorination has long been the accepted and proven method of controlling pathogens in irrigation water in nursery situations. In 1987 I was approached with a relatively new and possibly broader-spectrum method of control, bromination. I had heard it had been used in jacuzzis and swimming pools as a germicide in the water to stop "Legionnaires Disease." This peaked my curiosity as to what it could do for my plant material. The purpose of this paper is to compare bromine in solid form with chlorine gas for use in irrigation water to control pathogens.

PROCEDURES AND PRECAUTIONS

What is brominization? Brominization is the introduction of strong bromine solution into irrigation water to maintain a level of free bromine from 5 to 10 ppm. This is accomplished by diverting a small amount of irrigation water into a vessel containing bromine tablets, then reintroducing the strong bromine solution into the system at a rate that provides a level of 5 to 10 ppm of active bromine after it has cleaned up your irrigation water. Bromine is measured as free bromine using a simple titration kit. Bromine levels are regulated by controlling flow of a strong bromine solution into the irrigation system. Temperature of the irrigation water is the major factor that will affect the concentration of the strong solution. With a constant irrigation water temperature, strong solution levels should remain constant and not require compensation. This makes the demand of the irrigation water, or the amount of bromine necessary to clean it up, the primary factor that will require adjusting strong-solution flow rates to maintain 5 to 10 ppm free bromine.

Advantages of bromination. Bromine has a broader spectrum of activity than chlorine with activity against algae, bacteria, fungi, and viruses. Research shows very little phytotoxicity even on sensitive bedding and foliage plants at rates as high as 100 ppm. Bromine is less persistent in the environment than chlorine, therefore, it is less likely to contaminate runoff. Installation and operation of brominators is very easy and inexpensive compared to chlorinators. Maintaining the brominator is very safe. Adding bromine tablets to the tank requires far less training and safety equipment than changing chlorine gas bottles and must be done far less often than with a liquid chlorine injection system. Danger of

a spill with solid bromine and cleanup afterwards are also far less likely.

Precautions for bromine usage. Bromine is compatible with fertilizers; however, it must be added to the system separately from fertilizers—particularly, those containing ammonia. It is my experience that bromine applied at recommended rates does tie up or scrub fertilizer but in such minute quantities when injected upstream that plant quality is not adversely affected. Injection of bromine must be stopped during chemigation through sprinkler systems, in accordance with its label.

Summary of work in progress. Upon being introduced to bromine I was immediately interested in its bactericidal properties and have begun working with it on *Prunus laurocerasus* 'Otto Luyken', a popular plant that is plagued with *Xanthomonas prunii*, which forms an unsightly shothole effect on the foliage in the warm and humid environment at Carolina Nurseries. I have also put a tap-off on my brominator to supply a strong bromine solution that may be effective as a sterilant for cutting tools.

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CARL WHITCOMB: What about the exposure time needed for bromine to be effective?

BOB AUSTIN: Bromine seems to require less time than does chlorine.

UPDATE ON TISSUE CULTURE OF WOODY PLANTS

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We are pleased to relay some knowledge and experience gained from some 20 years of tissue culture work at Briggs Nursery. Our first experience with tissue culture was in the late 1960s with Dr. Wilbur Anderson of the Western Washington Research Station in Mt. Vernon. Dr. Anderson, an early student of Dr. Murashige of the University of California, Riverside, was very anxious to do tissue culture research with woody plants. He was hired to do research on field cole crops like cabbage and broccoli. We spent many hours with him and two other nurserymen to get a breakthrough on growing woody plants using tissue culture. My oldest son, who at that time was in junior high school, was very interested in research so we put him to work making tissue culture media. Along with fellow nurserymen, Les Clay and Bob Hart, we worked first on trying to get plants established in culture.

Among the problems in those early days was a lack of materials such as the cytokinin, 2iP. Actually, it is amazing how little we were off with woody plants compared to research that was being done with herbaceous plants. It was really a matter of adjusting techniques and refining the medium. Later Dr. Anderson received research grants, and through many tests he was able to refine the medium to determine the level of nutrients in which rhododendrons grew best.

It was certainly an aid to everyone to understand how the plant grows outside the laboratory and what its nutrient requirements are. Even with this knowledge, we were frustrated in not being able to produce rhododendrons from meristems. They turned brown almost immediately. Looking back, it was fortunate that our first cultured rhododendron was a dwarf hybrid, 'Rose Elf' With this plant the medium could be way off and the plant would still grow. After it is started it is possible to refine the medium so that the plant grows much better.

In the early days when Lydiane Kyte was with us, our work involved developing the correct medium on which to grow rhododendrons. We varied our growth regulators trying to get the maximum number of shoots. At times the plants looked almost like moss on the medium. We learned always to use the lowest cytokinin concentration that gives the shoot production wanted. This produces a plant superior to those produced on a higher cytokinin medium. What we are really concerned about is not how many

shoots or how many microcuttings we get from a jar, but how many plants from that jar grow into strong, healthy plants

As we progressed, rhododendrons did come out of the lab successfully. In addition to ourselves, three other nurserymen worked on growing them outside the laboratory. It was interesting because we all took a different approach and each of us succeeded in making our system work.

Our establishment system involved sticking microcuttings into a 4 in. pot having a well-drained soil. All our plants are graded when transplanted. Grading should be done, since plants coming out of the lab in one cultivar do not all grow at the same speed, nor are they the same initial size. We felt the pot size and drainage was important because we had two things to accomplish. First, we had to root the cutting, then we also had to continue growing that cutting in the same medium after it was rooted. Even though I know people report on rooting plants inside the lab, we prefer to root everything, if possible, outside the lab. In most cases, it's simply cheaper to root plants directly in the greenhouse.

We would like to make this process more mechanized. Although we feel we have a good system, using plugs might be more space- and labor-efficient. Plugs have a very small volume of soil, and if you do not follow good cultural practices, including growing on a capillary mat or sand bed, they dry out rapidly. We are still trying to devise methods of using a plug system. Whether it is in the lab or outside, one must prevent stress to have the best production. The key to producing a good final product is to start with quality and keep the plant continuously growing.

Many things have changed with time. We have more and better chemicals, and we have learned how to refine our media. We must have a culture that produces quality shoots of uniform growth so that the plant will continue to grow in a stabilized manner outside of the laboratory.

Shoot-tip propagation from tissue culture is just another propagation method and, in situations where it works, it certainly has its place. However, if it doesn't improve a situation, it may be wise to stay with conventional propagation methods because they also have a place.

I am amazed at how we have improved the uniformity and growth of our cuttings since the 1970s. However, we have not found a way to be absolutely clean. Many times the bacteria in the tube are not that harmful, but become very evident when put in cold storage or not subcultured often enough. We have tried many antibiotics, but at the present time we do not have any that effectively control bacteria in our shoot cultures.

One of the greatest tools we have in our laboratory is our cool room. We maintain a 10-x 8-x 24-foot room at a temperature of 5 °C and 60% relative humidity. The cool room acts as a stock block; when we produce enough plants for the year, they are held until we need more. Or, if our production gets ahead, we can store plants for a few weeks. Certain ones will not store very well, but we are learning more all the time about how to maintain plants through cold storage.

We have used many types of growing containers and still use some test tubes when studying new plants. Our main growing containers are baby food jars. We try to streamline all our production so that we can save man-hours in handling our product. We fit the jars into a basket, autoclave them, place them on carts to cool, transfer plants into them, and finally place them on lighted shelves in the growing room. They come out of this room in the same baskets, which saves a lot of moving of jars. As another example, we sterilize disposable paper towels in a towel holder in the autoclave. We then use the towel as a sterile cutting surface in the laminar hood.

Over the years we have found certain things that can help the process of rooting tissue-cultured plants, but this still remains an art as well as a science. One has to learn and acquire the ability to look at a plant and decide how to make adjustments and continue to make them. One must sense in some cases that just lowering the amount of light will help the initiation of roots. People in Europe vary day length to improve root initiation. This has helped rooting, especially with apples and some trees. We have not seen this positive response to light. However, Dr. Anderson has found that reducing the amount of light to less than 12 hours daily improved rooting of certain vegetable species.

We root and establish plants outside the lab using three different systems. We may go out to a plastic-tented area that is completely enclosed, especially in the winter. In the spring we may use a mist system on an open bench. In the summer we use a fog system. Most of the time we like to use mist in conjunction with either fog or a closed tent, to make sure that the cutting is not put under stress due to lack of water. The important thing in rooting tissue-cultured plants is to keep the plant growing. Do not let it go into a rest period because it may be difficult to get it back into active growth.

The main thing we have observed over the last 15 years we learned very early: do not stress a small tissue-cultured plant by putting it in a hot, dry, open field. Several years ago we planted very small tissue-cultured rhododendrons in the open field. They looked fine, they lived and eventually did well, but they were very slow to grow and were slow in changing from the juvenile to the adult stage, in which the plant produces large mature leaves and

has a normal flushing growth pattern. Some growers in the Portland, Oregon, area have found it helpful to grow tissue-cultured trees with drip irrigation. The drip tube is placed beneath the trees when they are planted in the field. The transition from controlled conditions within a greenhouse to the open field is the most troublesome stage in tissue-culture production.

Another important point is to grade all plants for uniformity so that growing conditions and water requirements will be the same. We encourage the bedding of plants at an early stage, or growing them in a greenhouse to develop a large enough root ball so the plant can sustain itself. As a result, we now do not see a lack of growth or uniformity within a field row.

Many plants from tissue culture will grow faster than from a cutting, but there are exceptions. Some of the outstanding plants from tissue culture are Exbury and other deciduous azaleas. They can be produced the year around, have higher survival rates, branch better, and grow faster. It does change the production schedule because you must do more shearing We shear many young plants; including rhododendron, azaleas, lilacs, and several others very low to make them compact.

Tissue-cultured lilacs seem to grow much faster and branch more than cutting-grown plants Young's Weeping Birch seems to grow tremendously out of the lab. However some trees, like *Styrax japonicus*, have been very hard for us to get the uniformity and habit of growth that we can get from other trees. We need to realize that not all plants coming from tissue culture respond the same. We have to focus on those plants that respond well to tissue culture and work on what is wrong with those that do not. *Kalmia* can be very difficult to grow. After years of growing this plant, we found that it needs to be pruned very heavily when it's small, fertilized often but not heavily, and grown in a well-drained soil.

We have advanced in the field of conifer tissue culture, thanks to many people within the industry and universities. These researchers are trying to answer questions as to why most conifers with episodic growth are more difficult to culture. *Thuja, Pinus taeda* (loblolly pine), and *Sequoia* respond very well, and production seems to be progressing on these plants.

Tissue culture can be a way to improve or possibly stabilize a plant as Dr. Mapes did with plants in the pineapple or bromeliad family. In the 1950s Dr. Mapes studied under Dr. Steward, one of the pioneers in single-cell research on carrots. I expressed my concern to him about stabilizing a single cell enough to have good uniformity. He told me that genetic uniformity can be greatly controlled by the medium and the chemicals that the plant is grown on. To me this was quite an insight. Many times a minor change can become major in the way it affects the quality and production

of a plant in the lab. I am sure many of those working on tissue culture can give examples from their own labs where this observation of Steward's is true.

In summary, we have come a long way. Many people have been involved, many ideas have been exchanged. The motto of this group, "To seek and to share", certainly has helped many of us. We should remember that the system is working well. Grow the best plants that you can and refine the growth medium enough to achieve quality. Always be aware of the plants in culture and restart them if problems appear. Many times quality lines can be improved by adjusting culture practices in the lab involving light, heat, media, humidity, contamination, and upgrading shoot tips. Remember, quality begins in the lab and ends with the grower of the product.

DOGWOOD ANTHRACNOSE

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Dogwood anthracnose was first reported in the northeastern United States on flowering dogwood (*Cornus florida*) in the early 1970s; about that same time, it was detected on the U.S. west coast, infecting Pacific dogwoods (*Cornus nuttallii*). Though not confirmed, it is believed that the fungus may have been introduced into the United States at ports of call in these two areas. The disease was confirmed in northern Georgia, western North Carolina, eastern Tennessee, western South Carolina, Alabama, Kentucky, and Virginia in 1987. The disease has now spread to 81 counties in these seven states. The disease occurs primarily in the mountains and foothills.

The fungus that causes dogwood anthracnose is a *Discula* sp. Dogwood anthracnose should not be confused with the very common disease, spot anthracnose (*Elsinoe corni*). Dogwood anthracnose causes foliage leaf spots, shoot mortality, stem cankers, and eventually significant decline or death of the tree. Initial symptoms include small purple-bordered leaf spots and large scorch tan spots, which may enlarge to blight the entire leaf. Blighted leaves will often cling to stems even after normal leaf drop in the fall. The fungus infects twigs and can move down the limb to infect the main stem. Cankers may form on the main stems and twigs, and they may be detected when the bark is peeled back. Cankers can be readily identified from the healthy cambium tissue by their distinct margins. Trunk sprouts are very common, especially in older dogwoods that have been infected two or more years. It may take up to three to five years to kill a mature dogwood. If trees are infected in the woods environment, there is very little that can be done to discourage the spread of the fungus; however, around locations such as homes and municipal buildings, fungicide applications will help discourage the spread of the disease.

Initially it is best to apply fungicides in early spring at bud-break. and at two-week intervals throughout the spring growing season, and at any time when adequate moisture is available for fungus infection. There is no quick-fix for this problem and, in many areas of the U.S. Northeast, 80 to 90% of the flowering dogwoods have been killed in the forest. As the disease has progressed down the

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east coast, urban and municipal areas have not been subject to the devastation observed in the natural woods environment. This observation has led to epidemiology studies to answer why. It seems the high moisture requirement for fungus infection is lacking in most urban situations because of the reduced overstory. The density of the dogwoods in the urban environment is significantly less than that in the natural woods environment. This may also affect the reduced spread of the disease in urban situations.

Recent research indicates that pH of the rain water has a significant affect on fungus infection. When flowering dogwood leaves are predisposed to acid pH solutions, then infection can be accomplished under laboratory conditions Additional research is presently being conducted on pH of the water and its relationship to onset of the disease.

At the present time the disease has been detected as far south as Atlanta, Georgia. In Georgia, research indicates that Benlate 50 WP at ½ Tbs/gal, maneb 80 WP at 1 Tbs/gal, and Daconil 2787 75% WP, at 1 Tbs/gal have all shown good control if applied at bud break, then applied at 14-day intervals to mid-June, and at any time sufficient moisture is present for infection. Other research indicates growth of the fungus is inhibited at temperatures above 75°F. Additional research is needed to try to anticipate disease development patterns in the southern states.

Do not transplant dogwood trees dug in the woods into urban areas. You may be transporting the disease into the area where it did not previously occur. In several cases thus far, it has been confirmed that this is how the disease entered an area which previously had not had a problem with this disease.

There are many other diseases that show symptoms similar to dogwood anthracnose. Isolation in the laboratory is the only way to confirm infection by *Discula* spp. For confirmation, contact the plant disease clinic at your local university Cooperative Extension Service. Observations indicate that the disease will continue to intensify in areas where it is currently found Damage has been observed to be more severe at higher elevations and in cool, wet areas.

Watersprouts around the base of the tree are extremely susceptible to fungus infection. It has been demonstrated that removing these sprouts may be beneficial. Mulching also appears to be beneficial to the overall vigor of the host. However, mulching may increase the potential for watersprout production. Trees should be monitored and watersprouts removed if this occurs.

The U.S. National Arboretum, Washington, D. C. has checked the resistance in over 60 selections of *Cornus florida* and, to date, no significant resistance has been observed in any of them. The Japanese dogwood, *Cornus kousa*, appears to be resistant to the

disease; however, one of the latest reports indicates that under ideal disease conditions, *Cornus kousa*, may be susceptible to fungus infection. Keeping the dogwood healthy is the best disease control. Below are listed ten steps that should be used to maintain healthy dogwoods:

1) Select healthy trees to plant.
2) Purchase trees from a reputable nursery. Do not transplant trees from the wild.
3) Select good sites for planting.
4) Use proper planting technique.
5) Prune and destroy dead wood and leaves yearly.
6) Water weekly during drought conditions. CAUTION: Do not wet the foliage.
7) Maintain a 4- to 6-in. deep mulch around trees.
8) Fertilize according to soil analysis. Use a low-nitrogen fertilizer on dogwoods infected with anthracnose.
9) Use proper insecticides and fungicides where appropriate.
10) Avoid mechanical and chemical injury to the trees.

EVALUATION AND PROPAGATION OF *LIQUIDAMBAR STYRACIFLUA* 'ROTUNDILOBA'

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The American sweetgum is recognized in many parts of the world, as well areas of the United States into which it has been introduced, as a choice ornamental shade tree. Adaptable to a wide range of sites, this member of the Hamamelidaceae family is characterized by a pleasing pyramidal shape, attractive glossy foliage, and often spectacular fall color. Its landscape use, however, in its native range has been restricted as a result of a preoccupation with the negative aspect of its spiny fruit, which often obscures its many positive attributes. Suggestions are usually ignored that there are many non-pedestrian areas where the sweetgum would make an excellent choice (1).

ORIGIN AND HISTORY OF *L. styraciflua* 'Rotundiloba'

With the only significant negative feature of the sweetgum being its fruit production, introduction of a fruitless form would greatly expand the range of suitable landscapes for use of this fine ornamental tree. Unknown to much of the gardening public, as well as the nursery trade, a true fruitless form has in fact been in existence for some 60 years.

The tree was first identified in 1930 by Mr. R. E. Wicker of Pinehurst, N.C. who found a sweetgum with round-lobed leaves. It was sent to the Arnold Arboretum in Boston, and a description was published in the *Journal of the Arnold Arboretum* in 1931 (2). The plant was described as a botanical form of *Liquidambar styraciflua rotundiloba* Rehder and was propagated and sent to a few botanical gardens. It remained relatively hidden for decades until it was noticed in 1968 that one of the original trees distributed to the Coker Arboretum at the University of North Carolina had never produced fruit. It has subsequently been determined that the fruitless characteristic and the round-lobed leaf are genetically linked and not simply a juvenility issue.

EVALUATION

The fruitless sweetgum was initially evaluated with a number of other cultivars in trials by the Saratoga Horticultural Foundation in California beginning in 1968. It was not deemed worthy of

further propagation and distribution because it was felt that the tendancy of this cultivar to form two or more leading shoots would result in narrow branch angles subject to storm damage (3). However, the original tree in Chapel Hill, which is now 90 ft. in height, as well as a 45-ft. tree on the North Carolina State University campus in Raleigh, both exhibit good form. In addition, neither tree has exhibited significant damage from several devastating ice storms in recent years. In our observations of younger, developing trees the formation of inordinately narrow branch angles has not been a significant problem.

Much of the more recent evaluation of the fruitless sweetgum has been conducted by the North Carolina State University Arboretum in Raleigh, North Carolina. One of the primary functions of the collection, under the direction of Dr. J. C. Raulston, is to evaluate promising new plants for use in the mid-Atlantic and southeastern United States. As part of this program, the fruitless sweet gum has been under evaluation for a number of years with plants distributed to different geographic areas for observation.

The form, 'Rotundiloba', in addition to its fruitless nature, differs from the species in the appearance of its leaf, which one would scarcely recognize as *Liquidambar*. The leaf is star-shaped with five lobes; however, as the name implies, the leaf margin is gently rounded In addition, the fruitless form is late to color in the fall, displaying excellent coloration in shades of yellow, crimson, burgundy, and purple.

Growth rates have been rapid in the field where, with ample moisture and nutrition, four feet of growth may occur in established plants. Growth rates have been somewhat slower in containers, with early spring grafts or June-budded plants in No. 1 containers averaging 18 in. of growth the first year. Growth rates increased to 24 to 30 in. the second year following potting.

Perhaps the major question regarding *L. styraciflua* 'Rotundiloba' concerns its hardiness. The species itself is found naturally occurring from Connecticut to Florida and west to Illinois (USDA Zones 5-9). The trees in Chapel Hill and Raleigh (Zone 7) have been hardy to -15 °F. However clearly the tree is very late to go dormant. On the U.S. East Coast, the cultivar is probably not reliably hardy much farther north than the Raleigh, N.C. area. Plant distribution and observation is continuing in this area.

Liquidambar styraciflua trees generally are best-suited for neutral or acid soils. They do not grow well on alkaline soils.

PROPAGATION

Because of the relatively small amount of 'Rotundiloba' stock available, we have utilized several techniques in an effort to determine the propagation method and timing that best suits our existing production schedule and also maximizes our success rate.

Bench grafting. Bench grafting of 'Rotundiloba' is best done in late February and early March on two-year, 1/4-in. caliper seedlings potted in deep, bottomless band pots. The understock is brought into an 60 °F greenhouse and drenched with Subdue 2E three to four weeks prior to grafting.

In our bench grafting we have predominantly utilized the familiar side-veneer graft. The carpentry is familiar (4) thus I will mention only specific modifications we have employed. Terminal scionwood containing three to four buds is used whenever possible. The use of non-terminal wood frequently results in a liner characterized by a "dog-leg" growth habit of the leader, versus the straighter central leader resulting from the use of terminal shoots.

The graft is made 1 to 2 in. above the soil level of the potted stock and wrapped with a 1/4- x 5-in. rubber budding strip, leaving gaps between each turn for subsequent callus formation. The entire graft union, as well as the scion, are then wrapped completely with Parafilm (American Can Co.). A high humidity seal for both graft union and scion is thus provided. Within two to three weeks the emerging new growth easily penetrates the film which, with time and warm temperatures, begins to break down. The rubber budding strip, however, is removed prior to any girdling of the stem.

We begin to head back the understock two to three weeks following emergence of the new growth. The process continues over a period of weeks until by late spring the understock is completely removed. Our success rate has been 95% in bench grafting the fruitless sweetgum.

Chip budding. We have also chip-budded (4) 'Rotundiloba' on 1-gal. seedling understock in mid-June as well as in late August to early September. Others have reported good success in budding other sweetgum cultivars with the more conventional T-bud. We utilize chip budding exclusively in our operation for several reasons. One important reason is the extended interval during which we can bud since the bark does not have to be slipping as is necessary in T-budding.

The bud union is wrapped with ½-in. polyethylene strips. We have found with high summer temperatures the Parafilm, if stretched too thin, may break down before adequate development of the bud union. The poly strip is cut or untied three to four weeks after June budding, and the understock is cut back to just above the upper edge of the callused union. At this time, a bud clip is

attached to the stem just below the bud union facilitating the development of a straight central leader on the young tree. For fall-budded trees the understock is headed back the following spring prior to bud break.

Cuttings. In limited trials we have propagated the fruitless sweetgum under mist from softwood cuttings taken in June. For us, however, percentage takes have been low and we have encountered difficulty in overwintering rooted cuttings. Plants from cuttings have also been inferior in growth form and vigor to budded or grafted plants.

Tissue Culture. Individual numbers of desirable sweetgum cultivars will probably be more rapidly increased in the future through tissue culture. Selected *Liquidambar* clones have been micropropagated from excised buds of mature specimens, with complete plants able to be acclimatized to the greenhouse without difficulty (5). 'Worplesdon' is a cultivar with attractive finger-like foliage and rich autumn color currently available on its own roots through micropropagation.

SUMMARY

As the evaluation of *Liquidambar styraciflua* 'Rotundiloba' continues it appears that there is the potential for its widespread use, at least in the southeastern part of U.S. Its hardiness range and growth form will continue to be evaluated in future years. A number of nurseries are currently building up stock of the tree so that increasing numbers of plants should begin to appear in the trade in upcoming years.

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VOICE: We have propagated 'Rotundiloba' using softwood cuttings, but the percentage take was low, and overwintering was a problem. The plant seems less vigorous than the regular sweetgum.

MIKE BRACKEN: Could graft incompatibility be a problem?

STEPHEN BURNS: Dick Birr, North Carolina Extension Ornamental Crop Specialist, noticed graft incompatibility. He felt that the use of the cleft graft might be the problem. His technician felt it might be the graft carpentry, a poor match of stock and scion, but we have had no other reports of graft incompatibility.

THE CHANGING WORLD OF CRAPEMYRTLE

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Wonderful work to change the world of *Lagerstroemia* is being carried out at the U. S. National Arboretum, Washington D. C., by Dr. Donald Egolf. His effort, begun in the 1960's is coming into fruition with the introduction of new and exciting choices featuring beautiful flowers, handsome exfoliating bark, many different habits of growth, and badly needed disease resistance.

Byers Nursery Company has been involved with this work since the 1950s, before the first four selections were distributed to the industry. The comments I make today are my own opinion and the result of 30 years of observations and conversations, not the result of carefully designed, scholarly experimentation.

The new selections I am discussing today are all *Lagerstroemia indica* × *fauriei* hybrids. These crosses were made possible when Dr. John Creech of the National Arboretum staff found wild specimens of *Lagerstroemia fauriei* in the mountains of Japan in 1957 and brought home the potential for many new and varied hybrids.

'Muskogee' and 'Natchez' were the first of these to be named and released in the late 1970s. They were followed by 'Tuscarora' and, then in 1986, 'Tuskegee', 'Acoma', 'Hopi', 'Pecos', and 'Zuni'. Nine more were released in 1987. They were 'Biloxi', 'Miami', 'Wichita', 'Apalachee', 'Comanche', 'Lipan', 'Osage', 'Sioux', and 'Yuma'. Three more will be released soon.

Here are my favorites, listed by heights:

5 to 10 feet

'Hopi' has medium pink flowers and a semi-dwarf, densely branched compact form with orange-red fall foliage color. It is very hardy, surviving -20°F without damage in Washington, D. C.

'Pecos' blooms are clear medium-pink with bright yellow stamens for about 100 days. It is a globe-shaped tree with fine, dark brown bark.

10 to 15 feet

'Acoma' has a different spreading habit with many clear white flowers. This excellent crapemyrtle has purplish-red fall color.

'Apalachee' is a strong favorite of Dr. Egolf's, with light lavender blooms and excellent foliage. The fall color is orange and red with the older bark showing a cinnamon-brown color.

'Comanche' holds its coral pink, 6 to 8 in. flowers very upright following the erect growth pattern.

'Lipan' is an exceptional crapemyrtle. It is very hardy with light lavender flowers and white exfoliating bark, comparable to sycamore. It grows to be tall and spreading.

'Osage' flowers with many soft clear pink blooms and, because of its loosely open habit, sometimes weeps due to the weight of the flowers. This graceful specimen has a good late color effect, often blooming for about 100 days

'Sioux' is a plant for those who insist on many showy flowers. It often has six or eight baseball-size, true pink blooms on a stem for about 110 days and has a strong densely upright structure with dark foliage. It is an excellent plant with attractive bark.

'Tuskegee' is very hardy with excellent mildew resistance. It puts on a show with dark pink to almost red flowers for nearly 100 days. It has a distinctive horizontal branching habit and mottled light gray defoliating bark.

'Yuma' has light lavender, fading to white, softball-size flowers, many on a stem with the petals so tightly fitted that they appear to be double. Other features of this fine selection are high mildew resistance, hardiness, pretty bark, and a long, late blooming period.

16 to 30 feet

'Biloxi' is vase-shaped with outward-arching branches and has light pink flowers. The bark is an outstanding dark-brown, mottled color and the plant seems as vigorous as 'Natchez'.

'Miami' will probably be one of the best. Pink to dark-pink flowers for about 110 days, lush dark green foliage with good winter hardiness, and high mildew resistance assure this crapemyrtle's success. It has elegant chestnut-brown bark and an upright growth habit.

'Natchez' is the most widely known of this group today. Its vigor, white flowers, and beautiful cinnamon bark have been highly praised throughout the South. A specimen in the National Arboretum nears 30 ft.

But the best is yet to come. New hybrids are in the pipeline, some involving *Lagerstroemia subcostata* and *Lagerstroemia limii*. No plant in our nurseries and gardens of today can give us all the things that crapemyrtle can. It gives us tall trees to very dwarf compact forms, breathtaking flowers from red to white, and pink and lavender, magnificent exfoliating barks in many colors and wonderful showy fall foliage colors.

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BRUCE BRIGGS: Are any of these crapemyrtle suitable for growing in the Pacific Northwest?

DAVID BYERS: They can be grown but bloom is poor. There are really no good ones for that area.

WILLIAM WELCH: What do you do about seeds and seed formation?

DAVID BYERS: We do not want much seed formation because when seed are allowed to form, the total bloom is reduced. Characteristics of seedling plants are, of course, influenced by crossing, and are undesirable unless you are interested in breeding crapemyrtle.

MILTON SCHAEFER: What about hardiness?

DAVID BYERS: These plants are in general hardy to zone 5 or 6. They are being tested at both the U. S. National Arboretum in Washington, D. C., and at the Chicago Botanical Garden.

FIRE ANT CONTROL IN NURSERY STOCK

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Fire ants are a unique pest, causing a variety of problems depending upon the ecosystem involved. Before we consider specifically about how to control fire ants in nursery stock, I would like to review briefly the history of fire ants in the United States.

EARLY HISTORY

The first collections of the imported fire ant (IFA) in the United States were made by W. S. Creighton in 1928. Creighton identified these ants as *Solenopsis saevissima* var. *richteri*. H. P. Loding, a USDA employee and amateur entomologist, estimated they were introduced into the port of Mobile, Alabama, around 1918, possibly as ballast or dunnage discarded from ships (4) Dunnage is matting constructed from vegetative matter in South America and used on coffee ships. Until the enactment of the Plant Quarantine Act of 1912 it was a common practice to discard dunnage once the ship was unloaded and there was no further need for the mats (1). For a number of years after its introduction into the United States, very little spread of *S. richteri* occurred. By 1931 these ants were found in three other small communities in Mobile County, Alabama, in Fairhope, Alabama, and in neighboring Baldwin County, Alabama (6). Between 1933 and 1945, a second fire ant species, later to be named *S. invicta* (2), invaded the Mobile area. The new invader proved to be more adaptive and rapidly displaced *S. saevissima* var. *richteri*. By 1949 it was by far the dominant species of imported fire ant (7).

Spread or range expansion by the ant was accomplished in two different ways:

1 Steady expansion of the main population outward from its center at Mobile through mating flights (natural dispersal) and,
2. Establishment of isolated secondary infestations through movement of infested nursery stock (5).

Infestation maps from 1950, 1960, 1970, and 1980 dramatically illustrate the rapid spread of the IFA in the United States. As of 1987, the IFA occurred in 11 states, plus the Island of Puerto Rico. We can only speculate upon the ultimate range, but most experts agree that spread throughout irrigated areas of the U.S. Southwest will occur and, if introduced into the West Coast, favorable conditions will be encountered, with parts of California, Oregon,

and Washington subject to infestation. Throughout its current range, the prime habitat of the IFA is pastures, fields, and recreation areas. However, the abundance of favorable microhabitats within cities and towns north and west of the current infestation may mean that the IFA will become more of an urban pest in these areas.

FEDERAL QUARANTINE PROGRAM

As we have seen, the fire ant is a very successful hitchhiker, and artificial or accidental spread by man accounts for most long-distance transport to new areas. However, a direct link between plant nurseries and IFA spread was not established until 1953 (5). At that time, the artificial spread of IFA through commercial shipments of infested items such as grass sod and nursery stock was well documented.

In response to mounting public concern, the U S. Congress appropriated $2.4 million for IFA control and eradication on August 28, 1957. As part of the plans for control and eradication, a quarantine to slow or prevent artificial spread was proposed On May 6, 1958, Federal Quarantine 301.81 was invoked (3) and regulations governing the movement of the following articles were issued:

1 Soil and unprocessed sand and gravel
2. Forest, field, or nursery-grown woody or herbaceous plants with soil attached
3. Plants in pots or containers
4. Grass sod
5. Unmanufactured forest products such as stump wood or timber if soil is attached
6. Any other article or product capable of harboring ants

Prior to shipment outside the fire-ant infested area, certificates authorizing movement of these articles must be issued by quarantine officers when it has been determined that the articles are free of infestation. In general, this means the article will have been treated with an approved insecticide. Uncertified articles transported into non-infested areas are subject to confiscation and possible legal action by State and Federal regulatory officials.

Today almost all nursery-stock treatments are based upon the insecticide chlorpyrifos (Dursban®). Dose rates and formulations used are varied according to the use pattern.

Sod. For grass sod, a 10% granular formulation of Dursban® is applied at 6 lb. a.i./acre. Only a single formulation is registered at this time. When applied at this rate, 10 weeks of certification is achieved. A lower rate of application (4 lb. a.i./acre) provides a four week certification. It is important to note that this treatment may

not eliminate mature colonies. On grass sod, we assume that the greatest pest risk is associated with newly inseminated queens rather than mature colonies, and therefore, the Dursban® treatment is primarily for new queens.

Potting media. Potting media in which containerized plants are grown can either be drenched with a Dursban® solution, or a 2.5% granular formulation can be blended or incorporated into the potting medium. Several EC formulations are labelled for the drench, but only one granular formulation is labelled. Incorporation of granular Dursban® into potting media is undoubtedly the most commonly used fire-ant treatment for nursery stock. In order to be effective, thorough incorporation of 1.0 lb. of 2.5G/cu.yd. of a potting medium is necessary. This rate of application is considered effective for 24 months.

Field-grown stock. Field-grown nursery stock can be certified in two ways: 1) It can be root-dipped in a chlorpyrifos solution (4 fl. oz. 4EC/100 gal. water), or 2) A combination treatment employing both a bait and granular chlorpyrifos can be used in the field prior to harvest.

The combination treatment is based on the concept that the bait application (either Logic® or Amdro®) will eliminate colonies existing at the time of treatment while the granular Dursban® (applied broadcast at 6.0 lb a.i./acre) will protect against reinfestation by new queens for at least 12 weeks.

In addition to these approved quarantine treatments, we strongly advise that all nursery environs be treated with a registered bait material to minimize IFA populations in the nursery. Bait treatments are not required as part of the quarantine but will definitely augment and support quarantine treatments. Both Amdro® and Logic® are registered for use in nurseries. Both materials should be applied broadcast at 1.0 to 1.5 lb. bait/acre. Application equipment suitable for use with fire-ant baits is very specialized and not commonly used for any other purpose. The very low labelled rates of application can be difficult to achieve with conventional granular applicators. One type of commercially available equipment that can be calibrated to deliver 1 to 1.5 lbs. bait per acre is the Herd Seeder® , Model GT-77A.

Proper timing is critical with any bait application. In order to be effective, the bait must be fed upon by foraging workers and the active ingredient in the bait passed on to other colony members. Ants do not forage when the soil surface temperature is less than 68 °F, or when it is very hot and dry. We recommend that twice yearly applications be made as follows: The first applications should be as early in spring as possible (generally February/March), with a follow-up treatment between August 15 and September 15.

By design, baits are very slow in activity. It normally takes 6 to 12 weeks for colony mortality to occur following a spring application.

RECENT CHANGES IN THE QUARANTINE PROGRAM

For the past 30 years, the U. S. Department of Agriculture has been responsible for administering and enforcing the Federal Fire Ant Quarantine Program, which regulates the interstate movement of regulated articles. However, in 1987 a major change occurred Through a series of cooperative agreements with the affected states, USDA authorized state cooperators to perform most enforcement activities of the quarantine and to provide funding to the states to support this effort. This means that closer scrutiny by recipient states to the north and west of the present affected areas has definitely increased in recent months.

The effectiveness of quarantine programs is sometimes questioned because of the rampant spread of the IFA. Recent infestations in plant nurseries near Phoenix, Arizona; Santa Barbara, California; Oklahoma City, Oklahoma; Laredo, Texas; Charlotte, North Carolina; and St. Croix, U.S. Virgin Islands, are known to be due to importation of infested nursery stock. State regulatory officials detected these small infestations and quickly eliminated them. Therefore, we must also wonder where the IFA would be today if there had never been a quarantine program. Due to the uncertainty of the ultimate range of the IFA, it seems appropriate that we continue with the enforcement of a strong program to slow or prevent further spread of this pest.

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PROPAGATION OF ORNAMENTAL GRASSES ADAPTED TO GEORGIA AND THE U. S. SOUTHEAST

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Abstract. From the world collection of 350 ornamental grasses, 17 were rated as superior, low-maintenance performers in climatic zone 8A Their propagation modes were studied simultaneously with evaluation as landscape plants All annual grasses propagated readily from seeds with the exception of crimson fountain grass, which is sterile. Many of the perennial grasses are sterile, making division the usual form of vegetative propagation, but four grasses root readily from stem cuttings; blue lyme, crimson fountain, ribbon, and sea oats. Tissue-culture techniques have been developed for *Miscanthus* and pampas grass cultivars.

INTRODUCTION

Clump-forming ornamental grasses have been grown for centuries in Europe where they were used in informal designs, naturalistic settings, and as specimen plants. Only pampas grass, fountain grass, and blue sheep fescue have been used to an appreciable degree in the U.S. Since limited landscape maintenance budgets, resource conservation, and environmental concerns in recent years are making low maintenance plants more popular, ornamental grasses are receiving attention and acceptance from landscape architects, nurserymen, and home gardeners. These grasses are ideal low-maintenance plants since they have low water and fertility requirements and are pest tolerant. In addition, most of them produce plumes that are ideal for dry flowers, making them dual-purpose plants. Their landscape uses include perennial and shrub borders, informal landscapes, and naturalistic areas (3, 4, 5, 6, 7).

MATERIALS AND METHODS

In 1969 to 1975 a collection of all ornamental grass germplasm from domestic and foreign sources was begun. During these years over 350 grasses were collected and evaluated (1). Seeds of annuals were sown in greenhouse flats using the usual techniques of artifical soil mixes and liquid fertilizers for producing bedding plants from seeds. Perennial materials were usually received as divisions which were potted and grown for 4 to 6 weeks until sufficient root and top growth developed.

Transplants were established in field plots by early summer. Plants were irrigated when water stress occurred during the growing season. An application of 500 pounds per acre of 10-10-10

fertilizer was made in early summer and fall. Seeds of dubious germination capacity were harvested, cleaned, stored, and germinated according to recommended treatments for related grasses.

Preliminary experiments were conducted to evaluate the effect of Hormodin No. 1 and Hormodin No. 3 on the rooting of stem cuttings of sterile grasses under intermittent mist. Tip and basal cuttings with 2 to 3 nodes from mature non-flowering stems were stuck in a well-drained medium. Tissue-culture propagation was investigated for *Miscanthus* cultivars and seed-sterile *Cortaderia selloana* 'Pumila' (2, 8).

RESULTS AND DISCUSSION

Table 1 provides a compilation of propagation modes for 17 superior-rated ornamental grasses. The grasses are a taxonomically diverse group of annuals and herbaceous perennials with a wide array of plant sizes, textures, colors and forms. Characteristics and cultural requirements are given in Table 4. Annual grasses are propagated readily from seeds with the exception of crimson

Table 1. Propagation modes of superior ornamental grasses

Scientific name	Common name	Persistence	Propagation Seeds	Propagation Vegetative
Arundo donax var. *versicolor*	variegated giant reed	Perennial		X
Calamagrostis acutifolia	feather reed grass	Perennial		X
Chasmanthium latifolium	upland sea oats	Perennial	X	X
Cortaderia selloana	pampas grass	Perennial	X	X
Cortaderia selloana 'Pumila'	dwarf pampas grass	Perennial		X
Elymus glaucus	blue lyme grass	Perennial		X
Erianthus ravennae	Ravenna grass	Perennial	X	X
Festuca ovina var *glauca*	blue sheep fescue	Perennial	X	X
Miscanthus sinensis 'Gracillimus'	maiden grass	Perennial		X
Miscanthus sinensis 'Variegatus'	variegated miscanthus	Perennial		X
Miscanthus sinensis 'Zebrinus'	zebra grass	Perennial		X
Pennisetum alopecuroides	Dwarf fountain grass	Perennial	X	X
Pennisetum setaceum	fountain grass	Annual or Peren.	X	
Pennisetum setaceum 'Rubrum'	crimson fountain grass	Annual or Peren		X
Pennisetum villosum	feathertop grass	Perennial	X	X
Phalaris arundinacea var *picta*	ribbon grass	Perennial		X
Uniola paniculata	sea oats	Perennial	X	X

fountain grass (*Pennisetum setaceum* 'Rubrum'), which is sterile and grown as an annual in areas with frost. For the fertile annuals, germination occurred in 2 to 3 weeks and gallon-sized plants were produced in 3 to 4 months. Reproduction of variegated grasses from seeds failed in all cases since seedlings reverted to normal green foliage. In tissue culture all variegated clones retained the variegated patterns of the parent plant.

Table 2. Early spring production schedules for annual, perennial, and divisions of ornamental grasses

Taxa	Hardiness zone	Weeks to Germination	Weeks to Marketable plants
Arundo donax var *versicolor* variegated giant reed	7	-	10
Calamagrostis acutifolia feather reed grass	4	-	16
Chasmanthium latifolium upland sea oats (river oats)	5	4	10
Cortaderia selloana pampas grass	8a	3	12
Cortaderia selloana 'Pumila' dwarf pampas grass	7b	-	12
Elymus glaucus blue lyme grass	4	-	16
Erianthus ravennae Ravenna grass	5	3	12
Festuca ovina glauca blue sheep fescue	4	3	14
Miscanthus sinensis 'Gracillimus' maiden grass	4	-	10
Miscanthus sinensis 'Variegatus' variegated miscanthus	5	-	10
Miscanthus sinensis 'Zebrinus' zebra grass	5	-	10
Pennisetum alopecuroides dwarf fountain grass	5	2	12
Pennisetum setaceum fountain grass	10	2	12
Pennisetum setaceum 'Rubrum' crimson fountain grass	10	-	8
Pennisetum villowsum feathertop grass	8	2	12
Phalaris arundinacea var *picta* ribbon grass	4	-	10
Uniola paniculata sea oats	8	3	10

Among the perennials, pampas grass (*Cortaderia selloana*) propagates readily from seeds. However, the plants are dioecious and wind pollinated, resulting in a high degree of seedling variability. Other perennials propagated by seeds are upland sea oats (*Chasmanthium latifolium*), Ravenna grass (*Erianthus ravennae*), blue sheep fescue (*Festuca ovina* var. *glauca*), dwarf fountain grass (*Pennisetum alopecuroides*), feathertop (*Pennisetum villosum*), and sea oats (*Uniola paniculata*).

Plant division is the usual technique for propagating sterile grasses (Table 2). Since this is a slow process for some grasses, a preliminary experiment was conducted to evaluate the effects of two concentrations of IBA on rooting tip and basal stem cuttings of sterile grasses. Results are shown in Table 3. Basal cuttings of *Elymus* rooted readily while tip cuttings failed. Both tip and basal cuttings of *Chasmanthium, Pennisetum, Phalaris,* and *Uniola* rooted readily. IBA had no effect on the rooting response. *Miscanthus* cultivars had the only stem cuttings with pronounced nodes that showed no inclination to root. Tissue culture may be a feasible alternative for propagation of sterile grasses that regenerate slowly from division.

Table 3. Stem-cutting rooting response of eight ornamental grasses to two concentrations of Hormodin

		Percent rooted cuttings*		
Name	Type Cutting	Control	Hormodin No 1	Hormodin No 3
Cortaderia selloana	Tip	0	0	0
pampas grass	Basal	0	0	0
Elymus glaucus	Tip	0	0	0
blue lyme grass	Basal	100	100	100
Miscanthus sinensis	Tip	0	0	0
miscanthus, eulalia grass	Basal	0	0	0
Miscanthus sinensis 'Gracillimus'	Tip	0	0	0
maiden grass	Basal	0	0	0
Miscanthus sinensis 'Zebrinus'	Tip	0	0	0
zebra grass	Basal	0	0	0
Pennisetum setaceum 'Rubrum'	Tip	100	100	100
crimson fountain grass	Basal	100	100	90
Phalaris arundinacea var *picta*	Tip	100	100	100
ribbon grass	Basal	100	100	100
Uniola paniculata	Tip	100	90	100
sea oats	Basal	100	100	100

*Mean of 100 cuttings

Table 4. Characteristics and culture requirements of some ornamental grasses

Annuals.

3-ft plants, need monthly grooming fountain grass— *Pennisetum setaceum*, perennial in mild climates

crimson fountain grass—*Pennisetum setaceum* 'Rubrum' Sterile seeds, perennial in frost-free areas

Perennials.

Main cultural requirements involve cutting back to ground at end of winter and dividing every 3 to 4 years

variegated giant reed—*Arundo donax* var *versicolor* 10-ft height, mature foliage may revert to normal reed green, somewhat invasive, zone 7

feather reed grass—*Calamagrostic acutifolia* Not adapted to deep south, erect 4-ft plants, zones 5 to 7

upland sea oats—*Chasmanthium latifolium* 3-ft plants, very versatile, zone 5

pampas grass-*Cortaderia selloana* Queen of grasses, but dioecious and variable, zone 8B

dwarf pampas grass—*Cortaderia selloana* 'Pumila '' 6 foot, silver female, seed sterile, zone 7B

blue lyme grass—*Elymus glaucus* Unusual blue color, slightly invasive, 3 ft, zone 4

Ravenna grass—*Erianthus ravennae* ''Hardy pampas grass'', not pampas grass-quality plumes, but vigorous and hardy to zone 5

blue sheep fescue—*Festuca ovina* var *glauca* Dainty groundcover, that does best with shade and adequate moisture, zone 5-8A

maiden grass—*Miscanthus sinensis* 'Gracillimus ' Best of the miscanthus group, dark green, fine textured, 6 ft, zone 4

variegated miscanthus—*Miscanthus sinensis* 'Variegatus' Slightly shorter than maiden grass, and with typical variegation, zone 5

zebra grass—*Miscanthus sinensis* 'Zebrinus' Unusual banded variegation, susceptible to athracnose leafspot, zone 5

dwarf fountain grass—*Pennisetum alopecuroides* 3 ft, needs monthly grooming, zone 5

feathertop grass—*Pennisetum villosum* Creamy panicles on a 2-ft plant that blooms only in July, zone 8

ribbon grass—*Phalaris arundinacea* var *picta* Highly variegated groundcover, grows well in shade and with very moist soil, zone 4

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TREE PRODUCTION IN CONTAINERS

BEN DAVIS, II

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H. J. Judkins and Son Nursery was established in 1940 as a retail, direct-selling firm. Gradually, it evolved into a bare-root, wholesale-only operation. Until 1985, the nursery grew only bare-root stock and marketed most of its stock packaged in poly bags or in "peat balls". The owners had been aware for some time that the trend in the firm's markets was toward an ever-increasing market share for container plants. The company was perceived by the trade to be a producer of high quality bare-root stock, with strong emphasis on fruit trees. Management recognized that if the firm did not move into production of container plants, it would begin to lose market share.

Therefore, in September, 1985, the owners invited me to join the firm to help them establish a container-growing operation. Our basic strategy was to concentrate on production of deciduous trees in 5-gal. containers, for which we believed there was a large, unmet demand. The trees would be sold by the company's well-established sales force, shifting emphasis away from poly-bagged and peat-balled trees, and toward container-grown shade and ornamental trees. To maintain profitability, the firm would continue to keep overhead low, utilizing a small but effective staff of leaders and a core of highly motivated employees. Management planned to set a level of quality, service, and price in the southeastern United States that would be the competition that other firms would have to meet.

Since the company had no facilities for container production, it was a rare opportunity to build a facility and train a staff, starting from scratch. From the outset, the container personnel were trained in the most efficient methods that management could devise, and instructed that only excellence was acceptable. Personnel were instructed in proper procedures, given the reasons for the procedures, and given feedback so that they would know when they were doing the task right. Management operates under the philosophy that if you expect the best from employees, you tend to get their best effort.

Construction was begun in September, 1985, on the first growing beds for the container operation. The initial facility consisted of 2½ acres, with ¼-acre being devoted to production of seedlings in an air root-pruned system. The seedlings were to be used as one source of liners for the container operation. The remainder of the

area had a capacity of approximately 40,000 five-gallon trees. Potting the first year was done by hand. With the completion in October, 1989, of the latest addition to the growing facility, the company has a capacity of approximately 500,000 trees. The addition of mixing and potting machinery makes possible the potting of better than 1,000 five-gallon trees per hour.

Liners for the container operation come from four sources. First is the air root-pruned seedling operation; second, bare-root trees from the field operation; then purchases from other field growers, both local and in the Pacific Northwest; and last, purchases of micropropagated tree liners. Whatever the source of the liners, a rigorous quality standard is maintained A poor quality liner cannot be made into a high quality tree. From the seedling operation, the largest 40 to 50% of the liners are fall-shifted direct into 3- or 5-gal. containers. The next largest, approximately 40%, is shifted to 1-gal. pots to be grown for one more year before being shifted to threes or fives. The remaining 10 to 20% are destroyed as culls. The fall-shifted liners are placed can-to-can on the growing beds and mulched with wheat straw for the winter. Bare-root liners are potted in the spring, roughly from February 1st to May 15th. These liners are graded for straightness, and root-pruned as necessary ahead of potting time. Most bare-root liners are whips or are very lightly branched and vary in size from 3 to 4 ft. up to 5 to 6 ft. Liners are not top pruned until they are set out on the growing beds. At that time they are all topped to a uniform height.

Fall-potted and spring-potted plants are spaced on the beds in the spring on a triangular spacing, in beds 8½ ft. wide, with an 18-in. aisle. This allows four beds to be placed between sprinkler heads, which are 40 ft. apart. Five-gallon trees are given center-to-center spacings of 17½ in., 20 in., or 23 in., depending on the growth habit and density of foliage of each species. Besides the topping of the tree whips, a summer-long program of pruning is carried out. Leaders and side limbs are headed back to develop well-branched, symmetrical tops.

The trees are subjected to a high fertility regimen, with the objective of growing a salable tree after one summer in the 3- or 5-gal. pot. Dogwood and deciduous magnolia are grown in 3-gal. pots, with a goal of at least a 3- to 4-ft. tree with a heavy top. All other trees are grown in 5-gallon pots with an objective of 5 to 6- or 6- to 8-ft. trees with appropriate caliber as set forth in the *American Standard for Nursery Stock* (1).

During the last four years, we have developed three different mix formulas to meet varying needs. All of the mixes contain 80% fine-ground pine bark and 20% concrete sand, the differences being in the nutrients added. For fall-potting most species, we add to each cubic yard 8 lbs. of dolomitic lime containing at least 10% elemental

magnesium, 6 lbs. of gypsum, 1½ lbs. of Micromax, and 5 lbs. of 12-6-6 nursery fertilizer that is compounded by a local supplier. If fall-potting extends past October 1, we eliminate the 12-6-6-fertilizer. Oak species use the same mix except that the dolomitic lime is reduced to 4 lbs. per cubic yard. Dogwood, whether fall-shifted or spring-potted bare-root take the following formula: 8 lbs of dolomitic lime, 6 lbs. of gypsum, 1½ lbs. of Micromax, and 12½ oz. of Subdue 2G per cubic yard. We add no fertilizer of any kind to the dogwood mix. Dogwood trees are hand fertilized after bud break in the spring with Sierra + Minors 17-6-10, at the medium rate recommended on the label. For all other bare-root trees that are spring-potted, we use the formula first listed previously, except that we substitute 8 lbs. of Osmocote 18-6-12 for the 5 lbs. of 12-6-6 nursery fertilizer. All of the trees that are fall-potted and mulched in straw, are uncovered in early spring, spaced, and fertilized by dibbling in Sierra + Minors 17-6-10 at the medium label rate for each pot size.

Beginning about June 1st, all plants receive supplemental feeding through the irrigation system. A solution of 15-3-9 + 5% sulfur is used for this. Initially, plants were fertilized once per week at the rate of 500 ppm N. However, when we began recycling our runoff water, we experienced an excessive build-up of nitrogen in our irrigation water. This necessitated a reduction in frequency of application to prevent nutrient imbalances that caused yellowing of foliage. We also experienced some herbicide damage from using recycled water. We had been using Rout herbicide almost exclusively because it was very effective in controlling our types of weeds. We noticed distorted leaves and stunted growth on some species. Lab testing revealed that enough Goal (one component of Rout) had dissolved in our runoff water to cause this problem. We were forced to revert to using Ronstar and supplementing its use with some hand weeding. Ronstar is applied with a hand-cranked spreader immediately after potting and 6 to 8 weeks thereafter. The label rate for container-grown woody ornamentals is used. Weekly water samples of runoff water and irrigation water, as well as random weekly samples of container medium, are sent to a commercial testing lab for analysis. We make adjustments in our fertility program and other chemicals used, as indicated by the test results.

Pest control materials are applied as needed. This usually means at least weekly application of fungicides, which are rotated to prevent a build-up of resistance by disease organisms. Insecticides must usually be applied about every two weeks unless some specific problem requires immediate attention. Insecticides are also rotated. A log is kept of all pesticides used and the dates applied, so that we may keep track of our materials rotations. All pruning residue is

cleaned up and hauled away each day so that it does not encourage disease organisms. Employees are continually made aware that we require the container beds to be kept neat and orderly at all times.

During the months when the trees are in an active stage of growth, they are watered from one to two hours per day, depending on temperature and wind conditions. The sprinkler system discharges about ¼ in. of water per half-hour. If certain areas show signs of heat stress, these will receive additional five or ten minute periods to cool the foliage.

Wind is also a problem with container trees. To stabilize the trees, we drive a rod through the container and into the ground approximately 12 inches deep. Pots on the perimeter of each bed, as well as every fifth row across the bed, receive stakes. We use a galvanized stake that is 3/8 in. in diameter by 24 in. long for this purpose. Nevertheless, we usually have to stand up the unstaked trees six or seven times each summer.

Winter protection begins after two or three frosts in the fall. Fall-shifted plants are placed can-to-can and mulched with straw. The salable plants are stored in a 2.3 acre over-wintering house. This structure is a gutter-connected unheated greenhouse, and it will hold approximately 340,000 five-gallon trees stacked three deep. The over-flow is heeled-in in sawdust-covered beds outside. As the plants are being moved to winter storage, they are graded and labeled with picture labels. Plants that have light tops and/or light caliber stems, are held over for late spring shifting to seven or ten gallon pots. Crooked, broken, or extremely undersize plants are hauled to the dump.

Throughout the whole production process the staff tries to recognize and remove inferior plants that have no chance of meeting our quality standards.

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VOICE: Would you give the details of your method of dibbling the fertilizer?

BEN DAVIS: One crew makes three or four holes with a tool purchased from A. M. Leonard. A second crew puts the fertilizer in the holes. The plants get Sierra and minors at the medium label rate.

CHARLES PARKERSON: Why do you change from 18-6-12 to Sierra and minors?

BEN DAVIS: The 17-6-10 formation contains Micromax. In the spring all plants in the nursery that were fall-potted or carried over receive Sierra and minors.

POTENTIAL "NEW" PLANTS FOR U.S. SOUTHEASTERN LANDSCAPES

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Dr. Michael Dirr, University of Georgia, suggested the following plants for consideration in the U.S. southeastern states. He gave extensive information on each of these with suggestions on their propagation. For further details, contact Dr. Dirr:

Acer rubrum 'Edna Davis'
Nyssa sylvatica
Ulmus parvifolia 'Emerald Isle', 'Emerald Vase', 'Burgundy', 'Milliken'
Magnolia grandiflora 'Spring Grove #16', 'Spring Grove #19', 'Spring Grove #43'
Photinia × *fraseri* 'Dudley Nursery Variegated'
Hydrangea quercifolia 'Alice', 'Alison'
Cornus kousa 'Select'
Cornus mas 'Spring Grove'

GROWING DOGWOODS IN CONTAINERS

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Turtle Creek is a 16-year-old nursery growing a wide selection of shrubs and trees on about 25 acres. We employ mainly female labor to handle our container production of 3- to 20-gal. plants. We also grow about eight acres of field-grown hollies, crape myrtle, and selected trees.

Several years ago we started growing container trees, predominantly dogwoods, since that was the most popular tree we were selling. We were successful enough so that we decided to specialize in growing container dogwoods and other selected trees. Most of the comments made for dogwoods also apply to the other trees we grow.

The largest markets for our plant material are garden centers and landscapers in the Baltimore, Md., Washington, D. C., Richmond, VA, and Norfolk, VA areas. We also have a cash-and-carry trade of local landscapers and a retail outlet on our premises.

We grow white and pink seedling dogwoods; 'Cherokee Chief', red; 'Cherokee Princess', white; 'Cloud 9', white; 'Cherokee Sunset', red with variegated foliage; 'First Lady', white with variegated foliage; and 'Milky Way', *C. kousa*, white. Dogwoods are marketed in 5-gal., 7-1/2-gal., and some 10-gal. containers. Some of the smaller-growing cultivars are not grown in 10-gal. size. We purchase one-year field-grown liners for most potting and some 2-year buds for our 10-gal. potting.

There are seven main factors in growing high-quality container trees—especially dogwoods:

1). Buy good liners, free of disease, and with a good root system,
2). Pot early because you cannot reconstruct new roots and grow tops at the same time,
3). Keep the soil fertility rate up, even in August and September,
4). Keep plenty of moisture available, but be sure to maintain good drainage,
5). Keep plants clean of spot anthracnose with good air circulation and preventative spraying,
6). Choose the correct pot size for projected growth,
7). Finish off in one growing season.

All of these points must be followed to assure maximum growth and development in a container dogwood.

In purchasing our liners, we think it is important to know our growers. Years of experience dealing with a good nursery usually

gives us less problems with plants. We buy one and two-year North Carolina seedlings and Tennessee budded dogwood liners. We buy for uniformity. We tried row-run, but got no uniformity in our finished product, so now we buy graded plants. We like our liners to have good root systems, and we think that is promoted by root pruning the liners. It is especially important to buy clean liners with no hidden disease from the prior season.

Protecting liners when they come in can be the difference in life and death. We stress to our suppliers immediate shipment and proper care after digging. We immediately heel our liners in sawdust when they come in. We pot by hand as early as we can get our liners. We like to pot in late November and December since we have student labor available then. We use a well-drained soil mixture that we blend ourselves. The components of our soil mix are in Table 1. We dip the roots of all trees in TerraSorb wetting agent just before potting to keep the roots from drying out. We put our newly-potted dogwoods right outside pot-to-pot, since we have had little problem with cold damage on newly-potted plants. We fence the entire bed with 36-in. high poly around the outside border of the bed. By late May we spread the dogwoods to 18 to -25 in. centers, depending on the size pot. We do winter-protect our second season dogwoods (9 to 10 months old after potting) in white plastic-covered cold houses. We stack every other row across the bed to conserve space. It is more important to winter-protect cherries over dogwoods, since their root systems are more cold sensitive. We have built four large coldframes by putting in greenhouses using 6-ft. ground stakes. These are 15-ft. high and work nicely for larger 14 and 20-gal. plants. These houses require 48-ft. white poly to cover them, which is somewhat difficult to get.

Table 1. Soil mix for container dogwood plants

60% bark	0-20-0 superphosphate
20% coarse sand	pellet lime
10% peat moss	Micromax
10% perlite	

The fertilizer level is especially important to sustain the accelerated growth we experience. We usually start to fertilize our trees in April. Once we get them growing, we try to keep them from going dormant or shutting down growth. Dogwoods can be kept in continual growth all summer if you work at it. Our fertilizer mixture and rates are listed in Table 2. We dibble this mixture in one spot on 5-gal. and two opposite spots on 7½- and 10-gal. containers. The dibbling is done mainly to keep from losing the Osmocote if the plant is blown over. We have found no significant difference in dibbling and top dressing. We supplement our granular fertilizer

with fertigation of 46-0-0 urea dissolved in cold water and injected through our irrigation system. We fertigate early in the season if our granular fertilizer is a little late going on and, particularly, in August and September, when our granular feed is waning. During the summer we fertigate biweekly in early evening to avoid sun scald. In August and September we hand-apply Peters 21-7-7 Azalea Neutral through our Geva Fertilizer injector directly into the pot for an extra flush of growth. Our growth rate during August and September will match the growth from April through July. This is why we must keep the fertility up during the latter part of the growing season. Table 3 gives the rate of fertilizer applications.

We have tried our dogwoods on drip and under overhead irrigation. Overhead is best for us. We water for two hours every other day, putting out about one inch of water. During extreme heat situations, we will run 30 min. cool-downs when needed. We try to be finished watering dogwoods by mid-afternoon, especially as the weather cools so that the foliage is dry by dark. We think our water schedule helps cut down on spot anthracnose.

Table 2. Fertilizer mix for container dogwood plants

By weight		By volume
100 lbs	cottonseed meal	2 parts
150 lbs	Osmocote (18-6-12) regular	2 parts
75 lbs	10-10-10	1 part

Table 3. Rate of fertilizer application

5-gal container	⅓ cup
7½-gal container, or 10-gal container	⅔ cup

We control fungus on our dogwoods by spraying with Benlate and captan. We use Daconil 2787 for an alternate spray. Orthene or Maverick is used in the same spray for insects, which are not a major problem with dogwoods. We start spraying by May first and spray every four to six weeks until late October. For weed control in all our containers we alternate Rout and Ronstar. Our dogwoods have shown no ill effects from either one.

Once we have grown our dogwoods to a finished size, we have to market, sell, and ship them. See Table 4 for the beginning-to-finished size ratio of our dogwoods. At least 75% of our dogwoods are sold in the fall, just 9 to 10 months from pottings. We ship on

tractor trailer, closed van, and local pickup trucks. Dogwoods and other trees bruise easily, so we use carpet squares wrapped around the trunk when stacking them.

Table 4. Beginning-to-finished size ratio of container-grown dogwoods

Size potted	Pot size	Finished plant size
12 to 18 in	5 gal	3 to 4 feet
24 to 30 in	7½ gal	4 to 5 feet
30 to 36 in	7½ gal	5 to 6 feet
36 to 42 in	10 gal	5 to 6 feet
3 to 4 ft	10 gal	6 to 7 feet

We choose to grow dogwoods in containers because they give almost 100% liveability for our customers. They look good, having nice fall foliage and a good plant-to-pot ratio. Container dogwoods sell well for us and for our customers We think it is important to grow a good plant, sell a good plant, and certainly to deliver a plant to your customer in good shape.

EFFECT OF HEAT STRESS ON CONTAINER-GROWN PLANTS

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Reduced growth rate, leaf chlorosis and wilting, abnormal branching habit, root death or injury, and reduced flower number and quality in container-grown plants are symptoms of heat stress on roots. These symptoms occur even when fertilization, irrigation, and other production inputs are maintained at near optimum levels. Root injury or death decreases water and nutrient uptake, disrupts hormone synthesis and translocation patterns, and alters biochemical reactions. Physiological and biochemical processes such as photosynthesis, respiration, flower initiation and development, apical dominance, and shoot extension are influenced by high root-zone temperatures. Economic ramifications of heat stress to roots of nursery crops include increased production time, reduced plant quality, and ultimately, increased production costs.

Container medium temperatures substantially above air temperature are possible due to direct solar radiation on container walls. Container medium temperatures in excess of 130 °F (54 °C) are common in the southern regions of the United States, and temperatures above 110 °F (43 °C) may be maintained for more than 5 hours daily (2, 3, 7). Cultural practices aimed at reducing the incidence and/or absorption of direct solar radiation on container walls warrant consideration. Such practices include altering spacing schedules, container color, radiation shields for containers, and overhead shading.

Not only is it important to evaluate techniques for reducing temperatures in container media but also it is imperative to determine critical temperatures for essential plant processes such as photosynthesis, respiration, and nutrient and water uptake. Knowledge of critical temperatures provides a ''yard stick'' with which to measure the potential benefits of modifying cultural practices. Such knowledge may also lead to identification of critical reactions in physiological processes and possible techniques for altering these processes to increase plant heat tolerance. Upon examination of the problem, one can readily see the need for both basic and applied research.

TEMPERATURE FLUCTUATIONS IN CONTAINER MEDIA

Temperature fluctuation patterns in container media differ with time of year and latitude. A southern exposure receives more direct solar radiation in late fall and winter months than during June and July and, therefore, roots on the south side experience higher temperatures during the fall and winter. Eastern and western exposures receive more direct solar radiation during the summer months and temperatures above 125 °F (52 °C) are common (9). In fact, temperatures above 100 °F (38 °C) are often routinely maintained for six hours per day in the majority of container media in full sun during summer months.

Temperature in a given zone of a sun-exposed container can remain below critical levels during one season but may elevate above these critical temperatures for other times of the year. Roots actively growing in favorable conditions during one period may die later in the year due to higher temperatures.

We are currently using mathematical modeling with computers to characterize temperature fluctuations in container media. Whereas earlier research was limited to recording temperatures at 5 to 7 points in the container profile, computer modeling now enables the researcher to predict the thermal behavior at 1164 positions in a container medium under any environmental condition. This expanding knowledge could lead to pracitcal and economically feasible strategies for reducing container medium temperatures.

CRITICAL ROOT-ZONE TEMPERATURES

The absolute temperature causing disruption of root cell membranes varies with exposure duration (4). Such disruption of cell membranes is a direct, irreversible injury that results in death of the cell, much the same result as steaming vegetables. The lethal temperature for a 30-min. exposure of *Pittosporum tobira* roots was predicted to be 126 °F (52 °C), while the lethal temperature for a 3-hr. exposure was only 118 °F (48 °C) (4). The lethal temperature for all plants studied to date decreases linearly as exposure duration increases exponentially.

Lethal temperature regimes also differ among plant genera and species. Predicted lethal temperatures for a 30-min. exposure for several ornamental plants are presented in Table 1. One can determine the relative thermal tolerance of root membranes by comparing these predicted lethal temperatures. *Ilex vomitoria* 'Schellings' tolerated a higher temperature for a 30-min. exposure than *Ilex crenata* 'Helleri', and exposure duration was more critical for the 'Helleri' holly. It would appear that roots of citrus rootstocks, *Dracaena marginata*, and *lxora coccinea* remain viable

at higher temperatures than roots of the *llex* spp. or the *Juniperus* spp. tested. However, the relative tolerance of root membranes to high temperatures is not necessarily an indication of the ability of a plant to withstand long-term exposure to supraoptimal temperatures below those causing direct injury.

Table 1. *Predicted lethal temperatures for roots of selected ornamental plants for* a 30-minute exposure

Plant	Predicted lethal temperature (°F)
Ixora coccinea	>132
Dracaena marginata 'Tricolor'	131
Musa sp 'Grande Naine'	127
Citrus rootstocks 'Swingle'	129
sour orange	126
carrizo	126
Magnolia grandiflora 'Glen St Mary'	126
Ilex vomitoria 'Schellings'	127
Ilex crenata 'Helleri'	124
Ilex crenata 'Rotundifolia'	118
Ilex cornuta 'Dwarf Burfordii'	115
Illicium parviflorum	124
Juniperus chinensis 'Parsonii'	118

High root-zone temperatures can reduce photosynthesis, even though air temperatues are near optimum. This reduction can be caused indirectly by heat-induced water stress, even though adequate water is present in the container medium. Such reductions have been found in banana (*Musa* spp.), *Dracaena marginata*, and *Ixora coccinea*. As a result of water stress, stomata usually close to reduce water loss through transpiration. This closure inhibits exchange of gases necessary for photosynthesis. However, not all reductions in photosynthesis by high root-zone temperatures are caused by water stress. *Ilex crenata* 'Rotundifolia' photosynthesis was reduced by 32% by a 6-hour daily root-zone temperature of 92 °F (33 °C) compared to 82 °F (28 °C) treatment, and stomata remained open (1). Therefore, physiological and/or biochemical factors other than stomatal closure must be involved in such cases. Subsequent research has revealed no evidence of stomatal inhibition as root-zone temperature increased in 'Rotundifolia' holly up to 108 °F (42 °C). However, decreased chlorophyll levels and differences in photosynthetic enzyme activity indicated that 'Rotundifolia' holly was able to alter metabolism at higher root-zone temperatures to maintain photosynthetic rates (10).

Root respiration generally increases with increasing root-zone temperatures, up to a temperature causing direct root injury.

Respiration involves release of energy stored in carbohydrates and fats that is necessary to maintain cell integrity and support growth. As root-zone temperature increases, the percent of available energy necessary for maintaining existing tissues increases. This means that less energy is available for growth. Root respiration in 'Rotundifolia' holly increased 80% during a one week period as the root-zone temperature was increased from 82 °F (28 °C) to 104 °F (40 °C) (1). However, a three-week exposure to temperatures up to 108 °F (42 °C) did not affect respiration rate. Root-zone temperatures have been shown to influence where photosynthates were transported and utilized (10).

Synthesis of plant hormones, such as cytokinins, usually occurs in the roots with translocation to other parts of the plant. In many physiological process, the ratio of hormones is as important as the absolute concentration of each. Therefore, altering the synthesis, compartmentalization, degradation, or translocation of hormones can affect the hormonal balance in the plant. Such imbalances can delay flower initiation and development, disfigure flowers, and alter branching habits. Flower number and size of *Magnolia grandiflora* 'Glen St. Mary' were reduced by root-zone temperatures of 100 °F (38 °C) and 108 °F (42 °C) maintained for 6 hours daily (unpublished data). The critical root-zone temperatures for hormone synthesis and translocation are currently unknown for woody plants.

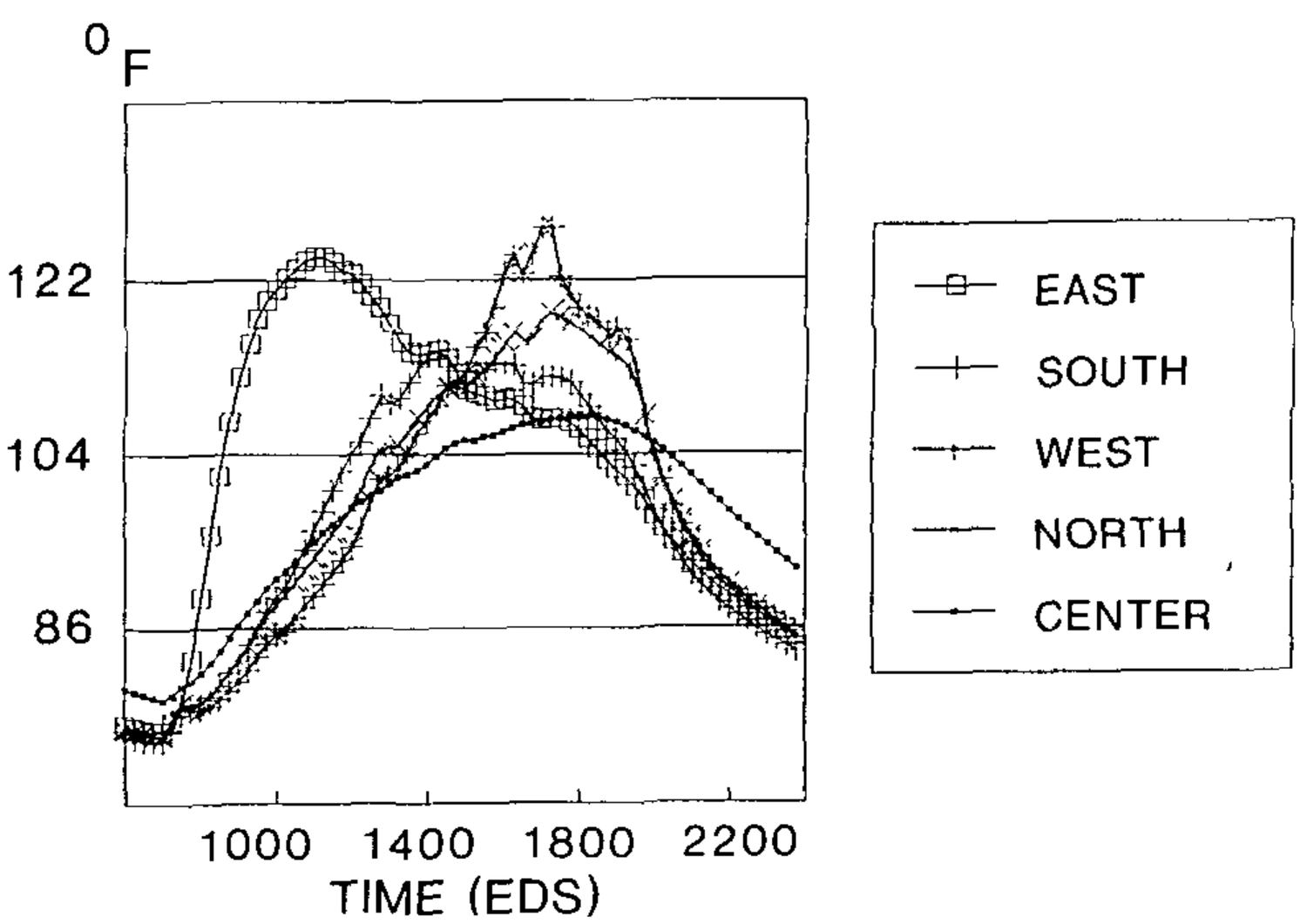

Figure 1. Temperature fluctuations in growth medium of a 3-gallon container 0 4 in. (1 cm) from the wall on the east, south, west, north and center coordinates Data were recorded on July 7, 1989 in Gainesville, Florida.

CULTURAL PRACTICE MODIFICATIONS

Reports of research results over the last few years have increased the awareness of nursery operators to the causes and effects of heat stress in container-grown plants. Although there is much room for refinement of cultural practices, many innovative nursery operators and researchers have developed unique ways to reduce heat load to containers.

Generally, cultural practices that reduce the incidence of direct solar radiation on the side of containers warrant consideration. These practices include spacing containers together and separating them as canopies of adjacent plants touch (5, 6, 8, 9). Plant canopies not only provide shading for containers in which they are being grown but also provide shading of walls of adjacent containers. If containers are initially spaced can-tight until canopies touch and are then spread to a "final" wide spacing, root-zone temperatures can be high enough to kill roots near the exposed container wall. Therefore, sequential spacing of containers as canopies grow is advisable.

Placing a container in another container to create a shield from solar radiation has also been effective in reducing plant heat stress (5). Although the practicality of this procedure may be questionable, the principle may be applied in other innovative ways. Placing discarded containers or some type of insulated barrier on the periphery of container beds will reduce heat stress to containers on the outside rows. Container orientation has been studied (6), but optimum orientation for one container to shade another differs with time of year due to the changing angle of the sun.

Ground cover color also affects the temperature regime in container media. A white ground cover reflects more light energy up into the plant canopy and onto the side of containers, thus increasing the heat load (7). A black ground cover absorbs more incoming radiation and re-radiates it as long wave radiation over several hours. Therefore, a black ground cover contributes less to the heat load on containers.

Preliminary experimentation suggests that a midday irrigation is more effective in reducing temperature extremes than early morning watering. Usefulness of applied irrigation in removing sensible heat appears to correlate with the temperature of irrigation water, volume of water added, and growth medium pore space and thermal properties. Enough water should be added to at least replace the current water in the medium. Syringing container-grown plants in the afternoon may not appreciably affect container medium temperature. Irrigation scheduling should be considered as a tool in managing container medium temperatures.

In summary, heat that injures roots of container-grown plants results from direct solar radiation on container walls and can result in several different types of symptoms. Reduced plant growth and plant quality increase production costs and ultimately alter profitability and competitiveness of Florida's nursery industry. Some cultural modifications will reduce the heat load and thus maximum temperatures in container media.

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CHARLES PARKERSON: How do you determine the extent of root damage in the plants?

DEWAYNE INGRAM: We test the electrolyte leakage from root tissue, which changes when the plant's root is damaged.

EFFECTS OF CONTAINER SIZE AND FERTILIZER RATE ON GROWTH OF *RHODODENDRON* 'FORMOSA' AND *ILEX* 'NELLIE R. STEVENS' PLANTS

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INTRODUCTION

The production of woody landscape plants in containers began to gain in popularity in the early 1950s. Production has primarily been limited to small containers ranging from 3.8 to 18.9 L. The demand for plants in containers greater than 18.9 L has increased in recent years (1). There is a great volume of literature concerning production practices on smaller container sizes, but little is available concerning production practices in larger containers.

Slow-release fertilizers are applied to container plants by incorporation during blending of growth medium components, top-dressed, or applied in a dibble hole directly beneath the transplanted liner. Rates are determined on a volume (cubic meter) basis (2, 7, 8 10). Methods of incorporation during blending and dibble application may only be used at planting. Subsequent slow release fertilization is accomplished by surface application. Regardless of the method of application, fertilization on a volume basis results in greater amounts of fertilizer per plant as container size increases. Greater per plant amounts of fertilizer may not be justified with increasingly larger containers, especially with containers with capacities greater than 18.9 L.

Laiche (6) found no difference in plant size or foliage color of azalea 'Formosa' grown with 4.2, 5.6 and 7.1 kg of slow-release 18.0 N-2.6P-10.0K/m^3 in 11.4 or 18.9 L containers. Goodale and Whitcomb (3), with four container sizes ranging from 2.2 to 5.8 L, and fertilizer rates of 11.4 to 31.8 grams/container-plant, found that growth varied among the six species tested.

Elaeagnus increased in size as fertilizer rate increased, but not as container size increased. Juniper and pyracantha increased in size as fertilizer rate and as container size increased. No difference, and only slight differences, were obtained with dwarf Burford holly and aucuba, respectively. Barberry did not grow well in the larger containers. Tilt, *et al.* (9) obtained a 2-fold increase in top dry weight of three test plants as container volume increased from 3.8 to 11.4 L.

Amendments, including 3.75 kg/m³ of 18.0 N-2.6 P-10.0 K were added to the growth medium during the blending procedure. Hanson, *et al.* (4) found that container size and shape influenced oak seedling growth. More shoot and root dry weight was obtained in 15.4 x 36 cm containers than in smaller containers but growth was not increased in 15.4 x 110 cm containers.

Seedlings were fertilized in proportion to container sizes and all received the same amount of fertilizer per unit volume of potting medium. Keever, et al. (5) reported increases in plant size due to increased container size with three woody ornamentals fertilized weekly with soluble fertilizer applied to container capacity.

The objective of this study was to determine the effects of container size (5.7 to 45.4 L), and of 17 N-3.0 P-10.0 K slow-release fertilizer rates (0.6 to 9.5 kg/m³ in 1987 and 0.8 to 12.8 kg/m³ in 1988, on the shoot and root growth of two woody landscape plants.

MATERIALS AND METHODS

Liners of *Rhododendron* 'Formosa' and *Ilex* 'Nellie R. Stevens' (*Ilex aquifolium* × *I. cornuta*) growing in 0.33 L containers were transplanted into 5.7, 11.4, 22.7 and 45.4 L containers on April 29 and on May 18, 1987. The growth medium was 100% pine bark. One day after planting an amendment mixture plus complete fertilizers of 20.0 N-2.2 P-8.3 K and 17.0 N-3.0 P-10.0 K, were surface applied and the growth medium cultivated 5 to 8 cm deep.

The amendment mixture consisted of 0.9 kg of dolomitic limestone, 0.2 kg of Micromax (Sierra Chemical Company, Milpitas, CA 95035), and 0.2 kg of simple superphosphate (0 N-8.6 P-0 K) applied at the rate of 1.8 kg/m³. This amendment mixture was reapplied without media cultivation on August 19, 1987, and on April 5 and July 6, 1988.

A complete fertilizer, 20.0 N-2.2 P-8.3 K (Parker Fertilizer Company, Sylacauga, AL 35150), was applied one time in a circular band 13 to 15 cm from the liner ball at 5 g per container plant.

Treatments of 17.0 N-3.0 P-10.0 K slow-release fertilizer (Sierra Chemical Company, Milpitas, CA 95035) were reapplied without medium cultivation at the rates described in Table 1 on April 5, 1988 and at ⅓ this spring rate on July 6, 1988. Plants were grown in full sun and irrigated as required with overhead sprinklers.

The experimental design for each cultivar was a split plot with 12 replications. Main plots were four container sizes. Subplots were six fertilizer rates. Experimental units were one container plant, with the exception of the 5.7 L container size, which consisted of two container plants. Three replications selected at random were sacrificed on August 18 and December 3, 1987 to obtain root and shoot growth data. The study was terminated on November 21, 1988.

Data collected included visual foliage color ratings on November 6, 1987, and on October 19, 1988; visual root ratings on August 19 and December 3, 1987 and November 21, 1988; and shoot fresh weight on August 18 and December 3, 1987, and November 21, 1988. Foliage color ratings were 4 = excellent, and 0 = very poor. Visual root ratings were 10 = roots completely surrounding the rootball bottom to top, and 0 = no root growth evident on the surface of the rootball. Plants were severed at the growth medium surface to obtain shoot fresh weight.

RESULTS AND DISCUSSION

Fertilizer rates used in this study were on a volume basis. Therefore, the amount of fertilizer applied per container plant increased as container size increased. Compared to 5.7 L containers, fertilizer applied per plant in the 11.4, 22.7, and 45.4 L containers was 2, 4, and 8-fold, respectively. Comparisons in Table 1 of fertilizer rates were made on a volume basis and comparisons in Table 2 between container sizes were made between only those plants with identical fertilizer rates per unit plant and not per unit volume. For brevity, only fresh-weight data from both species collected 19 months after transplanting is included in tabular form.

Table 1. Effects of container size and slow-release fertilizer rate (volume basis) on plant fresh weight (grams) of *Rhododendron* 'Formosa' and *Ilex* 'Nellie R Stevens' 19 months after transplanting.

Species	Fertilizer Rate	Container size (liters)			
		5 7	11 4	22 7	45 4
	kg/m³	grams			
R 'Formosa'	0 8	83	150	387	757
	1 6	168	348	789	1503
	3 2	309	691	1898	2713
	6.4	572	1062	2642	3893
	9.6	624	1392	2808	2417
	12 8	908	1680	2756	2849
	Linear	**	**	**	**
	Quadratic	NS	**	**	**
	R^2	0 89	0 90	0.84	0 43
I 'Nellie R. Stevens'	0 8	185	279	442	761
	1.6	263	444	749	1357
	3.2	364	628	1260	2062
	6.4	515	783	1472	2031
	9.6	599	928	1487	2228
	12 8	570	956	1607	1798
	Linear	**	**	**	**
	Quadratic	**	**	**	**
	R	0 80	0.86	0 66	0.61

NS, *, ** Nonsignificant or significant at the 5% or 1% level, respectively

Comparisons—Fertilizer rates per unit volume. Fresh weight of *R.* 'Formosa' plants at 4 months increased quadratically by both fertilizer rate and container size. An interaction occurred at 7 months in which maximum fresh weight for plants fertilized at 0.6 kg/m^3 was observed for plants in the 22.7 L containers and in the 45 L containers for all other fertilizer rates. At 19 months after transplanting, fresh weight increased either linearly (5.7 L containers) or quadratically by increased fertilizer rate (Table 1). A linear increase was obtained with container size.

Root quality of *R.* 'Formosa' plants at 4 months increased quadratically by fertilizer rate only in 5.7 L containers and decreased quadratically by increasing container size. Root quality was not affected at 7 months by increasing fertilizer rates, and decreased quadratically by container size. At 19 months root quality increased quadratically by fertilizer rate and was similar for all container sizes.

Foliage-color rating of *R.* 'Formosa' plants increased with increasingly higher fertilizer rates and container sizes at 7 and 19 months.

Fresh weight of *I.* 'Nellie R. Stevens' plants was not affected by either fertilizer rate or container size at 4 or 7 months after transplanting, with the exception of a linear increase after 4 months by fertilizer rate in 5.7 L containers. Fresh weight increased quadratically by fertilizer rate in all container sizes (Table 1) and linearly by container size 19 months after transplanting.

Root quality of *I.* 'Nellie R. Stevens' plants was only affected linearly 4 months after planting and quadratically 7 months after planting in 5.7 L containers, and linearly in 45.4 L containers 7 months after planting by fertilizer rate. Root quality was reduced quadratically by increasing container sizes 4 and 7 months after planting. Root quality was similar after 19 months for all container sizes and fertilizer rates.

Foliage color of *I.* 'Nellie R. Stevens' plants 7 and 19 months after planting improved with higher fertilizer rates and larger container sizes.

Comparisons—Fertilizer rates per unit plant. Growth of *R.* 'Formosa' plants 4 months after planting decreased in fresh weight, with larger container sizes at fertilizer rates of 0.055, 0.027 and 0.014 kg/plant. At higher rates with *R.* 'Formosa', and at all rates with *I.* 'Nellie R. Stevens' plants, growth was generally similar with all container sizes. Seven months after planting, fresh weight of *R.* 'Formosa' plants, at 0.027 kg/plant, decreased in 45.4 L and, at 0.109 and 0.218 kg/plant, growth decreased in smaller containers. Fresh weight of *I.* 'Nellie R. Stevens' plants decreased

in 5.7 L containers at 0.055 kg/plant and was similar at all other fertilizer rates and container sizes.

In general, 4 and 7 months after planting, root quality (in relation to container size) decreased with both species as container size increased. At 19 months high root quality ratings were obtained with both species with only slight differences among treatments. A trend of decreased foliage color rating was obtained at low fertilizer rates with larger containers with both species, 7 but not 19 months after planting.

Nineteen months after planting, at fertilizer rates of 0.009 to 0.036 kg/plant of 17.0 N-2.2 P-8.3 K, there were no differences in fresh weight due to container size for either species (Table 2). At higher rates, plant growth was restricted by smaller container sizes with both species. At 0.072 kg/plant, less growth was obtained in 5.7 and 11.4 L containers, compared to 22.7 and 45.4 L containers with both species although the growth obtained with *R.* 'Formosa' plants in 11.4 L containers was not different than growth obtained in 45.4 L containers. At 0.144 kg/plant, less growth was obtained in 11.4 L containers compared to 22.7 L and 45.4 L containers with *R.* 'Formosa' plants. At 0.144 kg/plant growth of *I.* 'Nellie R. Stevens' plants was reduced by container sizes of 11.4 L, compared to 22.7 L, and in 22.7 L compared to 45.4 L. At 0.288 kg/plant, less growth was obtained with both species in 22.7 L containers, compared to 45. 4 L containers (Table 2).

In summary, results on a per plant basis with both species indicated that optimum growth was obtained in larger containers only in the presence of sufficient quantities of fertilizer. At low fertilizer rates/plant, growth in large containers was not increased. At high fertilizer rates/plant, small container size restricted growth. Fertilizer rates applied per plant at which growth reductions occurred have a common rate when given on a volume basis. For example, growth of *R.* 'Formosa' plants in 11.4 L containers and *I.* 'Nellie R. Stevens' plants in 22.7 L containers was reduced at 0.072 and 0.144 kg/plant respectively, rates equivalent to 6.4 kg/m^3. Similarly, growth reductions that were obtained with both species in 5.7, 11.4 and 22.7 L containers at 0.072, 0.144 and 0.288 kg/plant, respectively, are equivalent to 12.8 kg/m^3.

In this study, conducted for two growing seasons with two plant species, growth was restricted by container size in 5.7, 11.4 and 22.7 L containers when 17.0 N-2.2 P-8.3 K fertilizer rates were increased to a range beginning at 6.4 to 12.8 kg/m^3.

Table 2. Effects of container size and fertilizer rate (per plant) on plant fresh weight (grams) of *Rhododendron* 'Formosa' and *Ilex* 'Nellie R Stevens' 19 months after transplanting.

Species	Fertilizer Rate	Container size (liters)			
		5.7	11.4	22.7	45.4
	(kg/plant)	grams			
R					
'Formosa'	0.004	83			
	0.009	168 a[z]	150 a		
	0.018	309 a	348 a	387 a	
	0.036	572 a	691 a	789 a	757 a
	0 054	624			
	0 072	908 c	1062 b	1898 a	1503 ab
	0 108		1392		
	0.144		1680 b	2642 a	2713 a
	0 216			2808	
	0 288			2756 b	3893 a
	0.432				2417
	0 576				2849
I. 'Nellie R Stevens'	0 004	185			
	0.009	263 a	279 a		
	0 018	364 a	444 a	442 a	
	0.036	515 a	628 a	749 a	761 a
	0 054	599			
	0 072	570 b	783 b	1260 a	1351 a
	0 108	928			
	0.144		956 c	1472 b	2062 a
	0 216			1487	
	0 288			1607 b	2031 a
	0.432				2228
	0 576				1798

[z] Mean separation within rows by least significant difference ($P < 0.05$).

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ROOTING RESPONSE OF *MAGNOLIA GRANDIFLORA* 'GLEN ST. MARY' AS A FUNCTION OF CUTTING HARVEST DATE AND EXOGENOUSLY-APPLIED HORMONES

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Abstract. Terminal stem cuttings from field-grown, non-irrigated stock plants of *Magnolia grandiflora* 'Glen St Mary' were harvested and basally treated with 0 5%, 1 0%, 2 0% K-IBA (potassium salt of indole-3-butyric acid), or Dip'N-Grow (1 0% IBA plus 0 5% 1-naphthaleneacetic acid) on 5 cutting harvest dates during the summer of 1987, and 0, 0 5%, 1 0%, or 2 0% K-IBA on 8 cutting harvest dates during the summer and fall of 1988 During 1987 rooting percentages for all hormone treatments were higher from 10 August propagation than those in July Across harvest date, rooting percentages ranged from 6 (1 0% K-IBA, 1 July) to 89 (1 0% K-IBA, 10 August) During 1988, rooting percentages exceeding 80% were observed for harvest dates of 15 June, 1 and 15 August, and 1 September For all harvest dates in 1988 rooting percentages for treatments ranged from 0 (0 K-IBA, 15 August) to 92 (2 0% K-IBA, 1 September) Mean root number per cutting ranged from 1 0 (0 K-IBA, 1 October) to 12 7 (1 0% K-IBA, 15 June) and was greatest with 2 0% K-IBA treatments on 6 of 8 harvest dates For field-grown, non-irrigated stock plants, rooting response as a function of applied hormone appeared to correlate with the physiological age of the cutting (time after growth flush)

Southern magnolia is a native landscape specimen tree generally considered difficult to propagate by cuttings (9). Rooting success requires application of synthetic auxins and may be cultivar-specific (1). Harvest date recommendations vary from July through November (2, 4, 6). Conflicting reports exist in the literature regarding the type and concentration of hormone used to promote root formation (2, 3). Rooting percentages exceeding 50% generally are considered acceptable (5).

Magnolia grandiflora 'Glen St. Mary', a popular selection for use in southeastern United States landscapes, has lustrous deep-green foliage with dense brown pubescence on the leaf under-side. Flowers are cream-white in color, large, and fragrant. Grafting or budding techniques are often used; however, this process is labor intensive.

Determination of appropriate harvest dates and hormone levels to facilitate rooting of cuttings would provide nursery operators with valuable information for use in production scheduling. Therefore, a two-year study was conducted at the University of Florida, Gainesville, Florida, in conjunction with Glen St. Mary

Nursery Co., Glen St. Mary, Florida 32040, to evaluate rooting responses of 'Glen St. Mary' magnolia as a function of harvest date and exogenously-applied hormones.

MATERIALS AND METHODS

1987. Cuttings were collected randomly from 15 non-irrigated, grafted stock trees during early mornings (0630 to 0900 HR) in Glen St. Mary, Florida. Stock trees were 5 to 25 ft. in height. Rainfall distribution patterns for the northeast Florida area during the summer of 1987 ranged from less than 50% of normal from April to mid-July, to normal for late July and August (7). Terminal stem cuttings 6 to 10 in. in length, were harvested on 5 dates at 2-week intervals from 1 July to 25 August and were placed inside an ice-cooled, styrofoam chest for transport from the field to the propagation greenhouse. All cuttings were stripped to 2 or 3 leaves, trimmed to 6 in by a 45° diagonal cut and basally wounded. Wounding utensils and cuttings were sterilized between cuttings in a solution containing 0.5% Physan disinfectant. All cuttings were quick-dipped for 5 to 10 sec. in 0.5%, 1.0%, or 2.0% K-IBA, or Dip'N-Grow (Alpkem Inc., Clackamas, OR 97015).

Cuttings were placed in individual 2¼ in. black polyethylene, square rose-pots containing 100% perlite rooting medium, and located under 50% shade on elevated, wire-meshed benches. A 2½ sec. mist was applied every 5 min. during 10 hrs. daily. The mist interval was increased to 10 min. on 15 October and to 15 min. on 15 November. The misting cycle was discontinued on overcast days during October and November. All cuttings were drenched twice monthly with Benlate at the rate of one tbs/gal. Greenhouse temperatures ranged from 103°/75°F, day/night during early July, to 82°/60°F day/night during late November. Bottom heat was not applied.

Evaluation of root development commenced 8 weeks after the cutting harvest date and continued twice-monthly for 8 additional weeks. Criteria for rooting evaluation included firmness of the cutting in the medium and/or the presence of roots at the container drainage holes.

1988. The experimental procedure was similar to the previous year except where noted. Rainfall during 1988 in northeast Florida during June to mid-August averaged 50% below normal and increased to 200% greater than normal for September (8). The eight cutting harvest dates were the 1st and 15th days of each successive month from 15 June to 1 October. All cuttings were quick-dipped (5 to 10 sec.) into 0 (control), 0.5%, 1.0%, or 2.0% K-IBA.

The 1987 and 1988 experimental designs were a harvest date by hormone factorial arrangement in a randomized complete block

with 4 replications per treatment and 9 cuttings per replication. Data collected included percentage rooted and number of roots per cutting. Statistical comparisons were made for rooting percentages by analysis of variance. Mean separation of hormone treatment within harvest date was made by Tukey's HSD following significant F tests. Comparisons of root number per cutting were made by analysis of variance using least square means.

RESULTS AND DISCUSSION

1987. Harvest date and exogenously-applied hormones interacted to affect root formation on stem cuttings of 'Glen St. Mary' magnolia (Figure 1). Rooting percentages ranged from 6 (1.0% K-IBA, 1 July) to 89 (1.0% K-IBA, 10 August). Hormone treatment did not affect rooting on 1 July or 15 July when rooting percentages were below 40%. Hormone treatment did affect rooting on 28 July, 10 August, and 25 August (Figure 1).

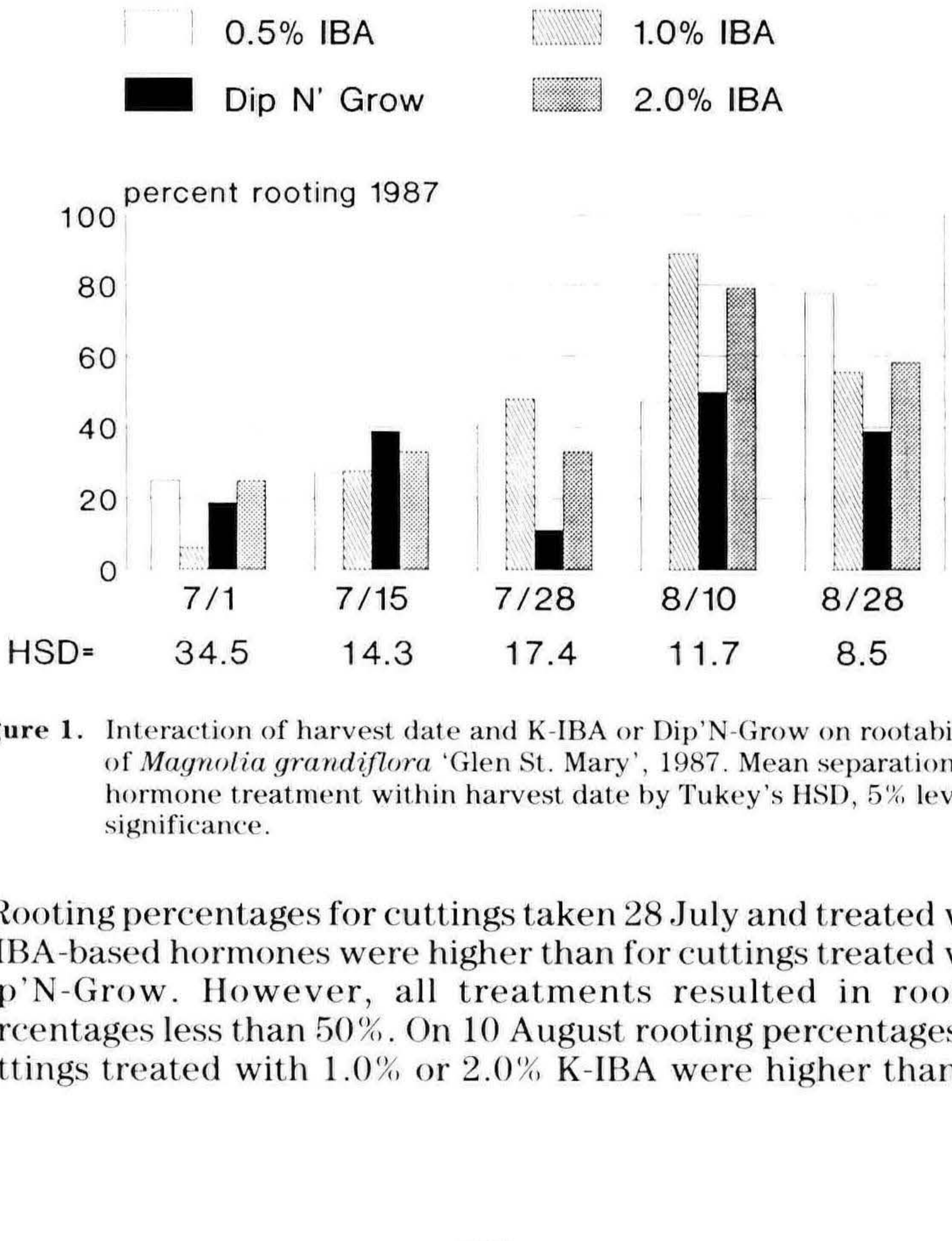

Figure 1. Interaction of harvest date and K-IBA or Dip'N-Grow on rootability of *Magnolia grandiflora* 'Glen St. Mary', 1987. Mean separation of hormone treatment within harvest date by Tukey's HSD, 5% level of significance.

Rooting percentages for cuttings taken 28 July and treated with K-IBA-based hormones were higher than for cuttings treated with Dip'N-Grow. However, all treatments resulted in rooting percentages less than 50%. On 10 August rooting percentages for cuttings treated with 1.0% or 2.0% K-IBA were higher than for

cuttings treated with 0.5% K-IBA or Dip-N-Grow. Cuttings treated 25 August with 0.5% K-IBA had the highest rooting percentage (78%) and rooting percentages were higher for cuttings treated with 1.0% and 2.0% K-IBA than cuttings treated with Dip'N-Grow. Rooting percentages for all treatments were increased on 10 August compared to harvest dates during July. The increase in rooting percentage during August coincided with increased precipitation (Figure 2), suggesting that rooting response as a function of hormone may be affected by stock plant moisture status.

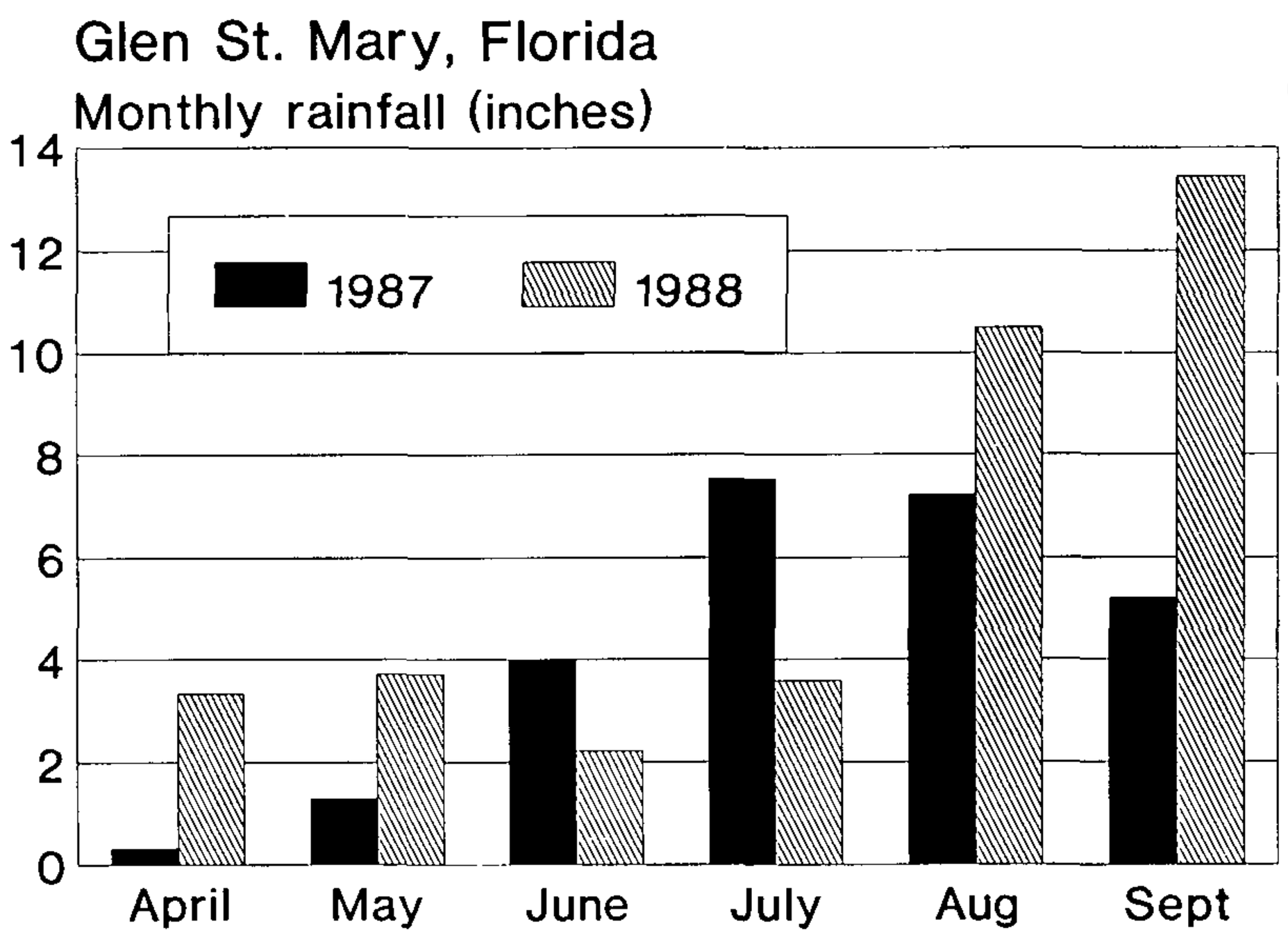

Figure 2. Monthly rainfall for Glen St Mary, Florida, during summer 1987 and 1988 (National Climatic) Data Center United States Department of Commerce, Asheville, NC 28801)

1988. Hormone treatments were modified based on results obtained during 1987. Harvest date and exogenously-applied hormones interacted to affect both rooting percentage (Figure 3) and mean number of roots per cutting (Table 1).

Across harvest date rooting percentages ranged from 0 to 92 (Figure 3). Rooting responses to the three K-IBA concentrations were similar but greater than the control for the cutting harvest dates of 15 July, 1 August, and 1 and 15 September. On 15 June, rooting percentages using 0.5% and 1.0% K-IBA were greater than for the control; however, increasing hormone concentration to 2.0% resulted in rooting percentages that were similar to the control. On 1 July rooting percentages were highest, using either

1.0% or 2.0% K-IBA compared to 0.5% and the control. On 15 August, rooting percentages increased as hormone concentration was increased. On 1 October rooting percentages were highest using 1.0% K-IBA, with 0.5% and 2.0% K-IBA resulting in higher percentages versus the control.

Table 1. Interaction of harvest date and K-IBA[z] on mean root number per cutting of *Magnolia grandiflora* 'Glen St Mary', 1988.

	K-IBA			
Date	0	0.5%	1 0%	2.0%
6/15	1.9 ± 1.6[y]	6 9 ± 1 1	12.7 ± 1 1	7.4 ± 1 3
7/1	1.5 ± 1 4	7.4 ± 1.3	7.0 ± 0 9	11 4 ± 0 8
7/15	3 5 ± 3.0	8.0 ± 1.1	7.5 ± 1 3	12 5 ± 1 1
8/1	1.9 ± 1.8	9 6 ± 1 3	11 3 ± 1.3	11.1 ± 1.3
8/15	0[x]	3 7 ± 1 5	9 6 ± 1 1	11 0 ± 0.9
9/1	2 2 ± 1 2	5 2 ± 0.8	7.2 ± 0.8	11 0 ± 0.8
9/15	2 3 ± 1 4	5 3 ± 0 8	7.2 ± 0.8	9 0 ± 0.7
10/1	1 0 ± 0 8	4 1 ± 0 7	4.8 ± 0.6	5 8 ± 0.7

[z] Differences due to K-IBA within each harvest date are significant at the 1% level
[y] Least square means
[x] Cuttings did not root

Mean number of roots per cutting was greatest using 2.0% K-IBA on all cutting harvest dates except 15 June and 1 August (Table 1). On 15 June the mean number of roots per cutting using 1.0% K-IBA was 71% greater than 2.0% K-IBA. On 1 August the mean number of roots per cutting for 1.0% and 2.0% K-IBA treatment were similar. On all cutting harvest dates the mean root number per cutting using K-IBA was greater than the control. Root number per cutting was greater for harvest dates on or before 1 September, compared to 15 September and 1 October, regardless of hormone treatment (main effects data not shown).

Rainfall distribution patterns in the southeastern United States during the summer months are characterized by extreme local variation. Rooting percentages for cutting harvest dates during July 1987 were relatively low when compared to July harvest dates during 1988. Early to mid-summer precipitation deficiencies for 1987 appeared to relate directly to the lower rooting percentages observed.

Field-grown magnolia typically experience a flush of growth during early to mid-summer after flowering. However, heavy rainfall during early September, 1988, after below normal rainfall initiated a second flush of growth during September. During 1988, rooting exceeded 80% on cuttings harvested 15 June and was greatest on 1 October using 1.0% K-IBA) Cuttings harvested on these dates were succulent, without having set terminal buds.

Rooting response for cuttings harvested on 1 and 15 August and 1 September exceeded 80% using 2.0% K-IBA. These cutting harvest dates were during or immediately following a period of below normal rainfall, and cuttings were from hardened wood that had resulted from growth flushes during early summer.

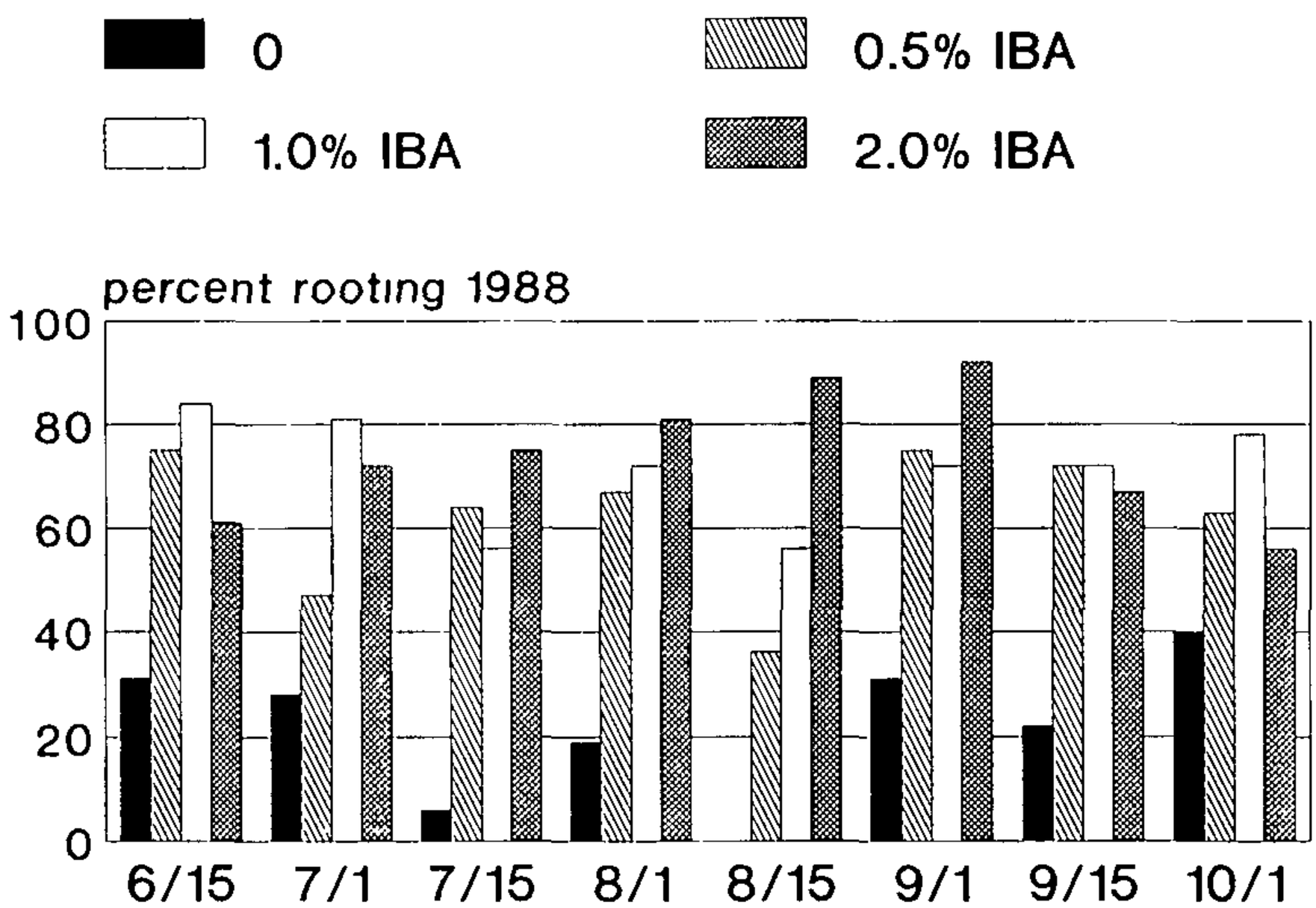

Figure 3. Interaction of harvest date and K-IBA on rootability of *Magnolia grandiflora* 'Glen St. Mary', 1988 Mean separation of hormone treatment within harvest date by Tukey's HSD, 5% level of significance.

In summary, rooting percentage and root number of 'Glen St. Mary' magnolia stem cuttings were a function of hormone concentration and may be correlated to the physiological age of the cutting wood. The rootability of succulent wood that has not fully hardened may be facilitated by using K-IBA concentrations of 0.5 to 1.0%. However, an increase in hormone concentration may be required to improve rootability of cutting wood that has hardened. Selecting the best rooted cuttings for stock trees and maintaining stock tree vigor may reduce the applied hormone concentration necessary to initiate root development.

Acknowledgement: The authors express appreciation to Lin Tabor and the employees of Glen St. Mary Nursery Co. for their cooperation and assistance

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MICHAEL DIRR: What concentration of K-IBA did you find best?

CHRIS MARTIN: With good moisture 1% was satisfactory.

IS YOUR NURSERY COMPLYING WITH THE TEXAS RIGHT-TO-KNOW LAW?

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In order to cover the basic requirements of this law in an organized way I will use the quick guide for employers that has been prepared by the Texas Department of Agriculture. This guide is presented below:

What's it all about? In 1987 the Texas legislature passed the Agricultural Hazard Communication Act (Right to Know). The purpose of this law is to give farm workers access to information about pesticides used on Texas crops, their health effects, and ways to reduce pesticide risks to themselves and their families.

Who is covered by this law? You are a covered employer by this law if you meet both of the following criteria:

1. Use, store, purchase, or cause to be used, more than the threshold amount of any one covered chemical.

2. Hire agricultural laborers and pay them more than the "payroll thresholds."

The terms "pesticide threshold" and "payroll threshold" are defined below.

Who meets the pesticide threshold?

A. Persons who use, store, cause to be used, or purchase more than 55 gal. or 500 lb. in a calendar year.

To calculate the chemical threshold amount:

1. Include fungicides, insecticides, herbicides, rodenticides, fumigants, and growth regulators.

2. Include any chemicals applied by commercial applicators on your farmland. If your business is a packing shed, include all products used on your farm(s) in which your field workers are present.

3. Add any products that contain the same active ingredient.

4. Add liquid and dry products that contain the same active ingredients. If necessary, use a conversion factor of 9.09 lbs/gal to convert dry formulations to liquid equivalents or 0.11 gal/lbs to convert liquid formulations to dry equivalents.

Who meets the payroll threshold?

A. Agricultural employers who:

1. Hire agricultural laborers for seasonal or migrant work and have annual payroll expenses plus labor-agent expenses of $15,000 or more for those laborers.

2. Hire agricultural laborers for purposes of year-round employment and have annual payroll of $50,000 or more.

How does an employer calculate gross annual payroll?

A. Include all wages paid to these workers:

1. Workers of covered employers, whose job performance routinely involves potential exposure to a covered pesticide chemical, for example:

- contact with treated crops or plants
- contact with covered chemicals
- application and handling of chemicals or handling chemical containers
- handling of treated seed or seed plants

2. Office workers, cooks, maintenance workers, security personnel, and non-resident management

3. Workers in packing sheds, seed-conditioning plants or canneries, if the crop production operation meets the payroll threshold and causes its workers to be present in workplace(s) that *together* exceed the threshold amount of any one covered chemical.

B. Do not include wages paid to these workers:

1. Farm and ranch laborers working *solely* with livestock.

2. Persons working *solely* in the retail sales component of a business.

3. Mechanical harvesters who do not have substantial contact with the crop and who *only* work with the crop once the relevant re-entry interval has expired.

4. Employees of licensed commercial applicators who only perform work in the application of other producer's crops.

What are your responsibilities? If you meet the pesticide and payroll thresholds indicated above then you have several responsibilities:

A. Maintain the workplace chemical list.

1. Maintain an annual log, a Workplace Chemical List (WCL), of covered pesticides applied, used, or stored in excess of threshold amount. You may seek help from the farmer(s) with whom you contract for produce.

2. Send your WCL (with attachments) to TDA each year, by January 31st, or keep it at your principal place of business for 30 years.

3. Inform workers (orally or in writing) where you keep the WCL.

4. Make the Workplace Chemical List accessible to workers, designated representatives, treating medical personnel, or members of the community, within 5 days. **In an emergency provide the information immediately.**

B. Attach material safety data sheets

1. Get the most current material safety data sheet (MSDS) from pesticide dealers for each covered chemical you use, buy or store.

2. Attach MSDS's for each covered chemical to WCL. If not available, substitute a product label.

C. Provide crop sheets to workers

1. Get crop sheets and other health and safety information from TDA and provide this information to your workers on the first day of the work season or the first day of their employment.

2. Read the crop sheet(s) to your workers in Spanish or English, whichever is appropriate, or you can play a recording of someone reading the crop sheet.

3. When the crop sheet is read, workers (including workers assigned to a new crop/job) must be informed of pesticides last applied or those pesticides scheduled to be applied. Let workers know the product name, and the expiration relevant re-entry intervals.

D. Provide emergency response information

1. Notify your local fire chief (in writing) about pesticides stored on your property if the storage facility is within¼ mile of three or more residences. Include a phone number and name of person(s) to contact in case of an emergency.

E. Provide information to a designated representative

Give a copy of your Workplace Chemical List to a worker's designated representative, upon request. A designated representative is an individual or organization to whom an agricultural laborer gives written authorization to exercise the workers rights under RTK.

a) You are required to recognize a requestor as a designated representative after receiving notice from TDA that (s)he has been certified by the department.

b) A collective bargaining agent who has been authorized by a government agency to represent workers in matters of wages and working conditions is not required to have written authorization from the agricultural laborers (s)he represents.

F. Release information to a member of the community, upon request

If requested, provide a copy of the Workplace Chemical List to any individual who resides, is employed, attends school, or is a parent of a child attending school, or is being treated in a nursing home within a ½ mile radius of a nursery operation, or within a three mile radius of any other covered employer's workplace.

CHARLES PARKERSON: Is one inspector checking for compliance with both EPA and OSHA regulations?

SANDRA MARTINEZ: This person would probably check only for compliance with the Right-to-Know requirements. The pesticide inspector makes sure that pesticides are being used correctly.

TED RICHARDSON: Is it necessary to keep crop sheets for fertilizers?

SANDRA MARTINEZ: Nothing in the regulations really fits fertilizers at this time. Just make sure you comply with Right-to-Know requirements.

A GROWERS' APPROACH TO PLANT PATENTS AND TRADEMARKS

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DEFINITIONS

Plant Patent: A plant patent is granted to provide the patent owner control over the propagation, use, and sale of a plant during the 17 year life of the patent. A patent is intended to cover a specific plant to protect the rights of the inventor to the plant patented and provides a specific basis for preventing the propagation, growing, and distribution of said plant.

Trademark: A federal trademark is "any word, name, symbol, or device or any combination thereof adopted and used by a manufacturer or merchant to identify his goods and distinguish them from those manufactured or sold by other." A trademark identifies the source or origin of a product. It lasts for 20 years and may be renewed without limit. A trademark is established to cover a class or broad selection of items or plants and to disclose the origin or source. Economic rewards to owner is a basic reason.

WHO CAN PATENT A PLANT?

Whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly-found seedlings other than a tuber-propagated plant, or a plant found in an uncultivated state, can patent a plant. They must comply with conditions and requirements of the patent law.

WHO CAN OBTAIN A TRADEMARK?

Anyone who selects a name, device, or symbol *not already registered* to identify a broad class of his goods and their source, and said trademark had been used in commerce.

PLANT PATENTS

Points to be considered. New plants must be sufficiently different from existing cultivars and specifically any other patented plant to merit introduction to commerce and a plant patent.

A. Growth habit
   1) Branching habit
   2) Growth rate (vigor)
   3) Ultimate size and form
B. Trunks and stems
   1) Color
   2) Texture
C. Leaves
   1) Size
   2) Shape
   3) Color (summer to fall)
   4) Luster
   5) Persistence
D. Flowers
   1) Size
   2) Shape
   3) Color
   4) Quantity
   5) Substance
   6) Fragrance
   7) Season of bloom
E. Fruit
   1) Size
   2) Shape
   3) Color
   4) Quality
   5) Edibility
   6) Persistence
   7) Value for wildlife
F. Insect and disease resistance
G. Adaptability to specific areas and sites

Requirements for obtaining a patent.

1) Must submit a written document comprising a petition; specification and claims describing and defining the new plant; an oath or declaration; a drawing, if possible, or a photograph; and payment of the filing fee. Application must be made only in the name of the actual inventor, but may be assigned.
2) When color is a distinguishing factor, the drawing or photograph must be in color and the color described by reference to an accepted color fan or dictionary.
3) The description of the plant should be very complete and detailed, expressed in botanical terms.
4) The origin (location geographically) must be described in detail to establish that it was not found in an uncultivated state.
5) The method of asexual propagation used must be specified.
6) The fact must be established that the invention has not previously been described in any publication in the United States or foreign country.
7) Patience. A properly filed petition usually takes two years to receive approval or disapproval.
8) Costs. All costs vary widely, depending on time involved by professionals to prepare, submit, and support the petition. I suggest a figure for consideration of $3,000 to $5,000 per patent, depending upon complexity of petition.

Conclusions regarding a plant patent. The only way to protect your right to propagate and sell a newly discovered plant is to patent it. You can protect your patent rights through the courts. If you have a patentable plant, it is best not to sell it or distribute plants before the patent is received, unless you have signed agreements acknowledging your ownership.

When attempting to patent a plant the services of a professional horticulturist and a plant patent attorney are invaluable, not legally required but well worth the cost, and increases your chances immeasurably. Sometimes the services of a professional photographer and/or artist are also necessary.

TRADEMARKS

A name registered as a cultivar name should not be confused with a trademark. A trademarked plant must also have a generic name by which it is commonly known. In past years trademarks in the nursery trade have been improperly used very widely. The proper trademark use is properly illustrated by:

- Siebenthaler's trademark, 'Moraine', Moraine locust, Moraine ash, Moraine ginkgo.
- Stark Bros. trademark 'Starkspur' used on a number of fruit tree cultivars.
- Conard-Pyle's blue hollies: 'Blue Princess'; 'Blue Maid'. Clonal trademarks in the trade today probably could not be successfully defended in court. There are several types of trademarks, but for any multistate protection the Federal Trademark Registration is the one we are talking about.

A trademark registration is good for 20 years and can be renewed unlimited times. A plant patent is for 17 years and generally cannot be renewed. Usually several years of the 17 are used up in establishing the worth of the new cultivar, hence the desirability of having both a patent and a trademark becomes evident.

Since a trademark cannot be issued for a generic or cultivar name but identifies the source of a class or group of plants, it is advisable to expand its use to more than one cultivar. Thus, the courts may protect a trademark owner's position and may enforce the owner's right to exclusive use of the trademark. Although the trademark protection afforded the owner is completely different from the plant patent protection, the ultimate value to the inventor is greatly increased by having the dual protection afforded by both the plant patent and the trademark registration.

Requirements to obtain a trademark registration

1) The requested trademark registration should apply to a group or class of plants and identify their source or origin.
2) The trademark must be used in commerce.

3) It is deemed in use in commerce when placed in any manner on the goods, containers, tags or labels, or invoices, affixed thereto and the goods are sold or transported.
4) It is advisable, though not legally required, to have the services of experienced counsel not only to file the application but to determine if the requested trademark is already in use. The patent and trademark office will not assist in this. They maintain a digest of all registered trademarks in their library, but a search is necessary before filing to expedite the application.
5) The time frame involved in a ruling on a trademark is roughly the same as a patent application.
6) The cost involved is appreciably less—maybe $1,000 to 2,000.

Conclusions regarding plant trademarks. Trademark rights enhance the value of plant material. They do not prohibit others from propagating and selling the material under its generic or some other name. Hence, anytime a trademark name or brand is used in marketing plants its generic cultivar name should also appear on labelling or catalog listing.

Due to the wide misuse of trademark names in horticultural commerce, it is important to educate the nursery trade to their proper use. Trademark registration does prevent the use by others of the trademark unless licensed by the trademark owner.

Use of a registered trademark gives some protection to the inventor/owner beyond the 17 years of the patent.

SUMMATION

1) A patent on a new plant cultivar is the best protection obtainable. While the patent is in force (17 years) nobody can legally reproduce the plant under its patent name, another name, or under no name at all.
2) A trademark offers less protection as it protects only the name. Anyone can grow the trademarked plant under another name but, if properly used, a trademark can offer some protection beyond the 17-year life of the patent.
3) Violation of plant patent rights are often very difficult to enforce by the courts. Plant fingerprinting and chromosome studies offer some hope in this area. Violations of trademark rights are much easier to prosecute. However, enforcement is time-consuming, expensive, and may not be worth the effort.
4) In the pursuit of plant patents and trademarks, professional help is generally necessary though not legally required.

5) The proper use of plant patents and trademarks together gives the inventor/owner the maximum protection available under current law. It offers the opportunity of economic gain to inventor/owners and should serve to encourage the development and introduction of improved cultivars, thus helping to upgrade our horticultural industry.

REFERENCES

Individuals, organizations, and government offices

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1250 I Street
Washington, D C. 20005

2) American Bar Association
Section of Patent, Trademark and Copyright Law
750 North Lake Shore Drive
Chicago, IL 60611

3) American Intellectual Property Law Association
2001 Jefferson Davis Highway
Arlington, VA 22202

4) Galle, Fred
Horticultural Consultant
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5) National Association Plants Patents Owners
Clay Logan, President
Stark Bros Nurseries
Louisiana, MO 63353

6) Patent and Trademark Office
U.S. Department of Commerce
Washington, D. C 20231

7) Frank B. Robb, Atty
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(216) 951-2211

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Article "Plant Patents and Trademarks What's the difference?"
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SUPERIOR NATIVE TEXAS WOODY ORNAMENTAL PLANTS WEST OF THE 98TH MERIDIAN

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Except for the east Texas forests and the basin and range land of the Trans-Pecos, Texas is a prairie state. In the timberlands to the east are pocket prairies of a few to several hundred acres. All but the highest areas of the west-Texas mountains were once a rich grassland (1, 2, 4, 7, 12, 18). Texas is a state rich and diverse in its floral canopy. However, many more species of trees are found in eastern Texas, while coastal, central and western Texas abound in grasses, shrubs, and various herbaceous annual and perennial wild flowers.

In other words, Texas has a rather distinct "eastern" and "western" flora, and the boundaries of these two plant regions occur at an almost mystical line of demarcation—the 98th meridian. To the east of the 98th lie Dallas, Fort Worth, and Austin; to the west, Wichita Falls and San Antonio, while the city of Lampassas sits astride. Curtis Fletcher Marbut's line (11) closely parallels this meridian and to the east of that line (to the Atlantic Ocean) the soils will generally be high in sesquioxides of iron and aluminum, will have no layer of lime carbonate in their profile, and will usually have a strong acid reaction. These soils were termed "Pedalfers' by Marbut. To the west of Marbut's soil division line, the profiles contain a layer of lime carbonate, are basic in their reaction and are called "Pedocals."

The 98th meridian is also a dividing line on rainfall, with over 30 in. annually east and less than 30 in. annually west (15). Here then, for practical purposes, the forests, and even woodlands, are found only in protected valleys or higher mountain slopes. Tallgrass prairies give way to midgrass prairies to shortgrass prairies to desert brushlands (12). The animals are different. There are more jackrabbits west than cottontails, and squirrels nest in the ground instead of trees (24).

Relative humidity becomes low and surface evaporation far exceeds the annual rainfall. Webb even considered the 98th as an institutional fault line. Ways of life and living changed. To the east prosperity was built around land, water, and timber, but in this grassland only the land was readily available. Buffalo chips were gathered for fuel, and completely different water laws had to be written. In Montana short grass would grow on 14 in. of rainfall; in Colorado it required 17, while 21 in were needed in Texas.

Although many reasons can be given for why a prairie exists instead of woodland, the explanations usually are controversial (23). There is little doubt, however, that Marbuts' line exists because there is not enough rainfall to leach the lime-carbonate layer out of the soil profile.

Moisture becomes more critical as one heads west of the 98th, and in the El Paso area there is a mere 6 to 8 inches of rainfall annually. Plants become more drought tolerant, and, to some, more interesting. As one crosses the 100th meridian, going west, leaves become smaller, sometimes are shed at the first hint of low rainfall, become hairy, change to gray instead of green, and are sometimes resin-coated. They are usually shorter, will be protected from browsers with thorns or prickles, and are widely spaced. All of the above help the plants escape the ravages of recurring droughts.

Researchers and nurseries are selecting these plants because of their beauty and desirability as well as their reputed drought tolerance. Care must be taken for these plants have growth requirements not easily met in higher rainfall areas. They generally need excellent drainage, minimum irrigation and soil fertility. They grow best with a low relative humidity, sharp air movement, and full sunlight. Almost certainly, unless carefully regulated, automatic lawn sprinklers are their death knell.

Propagation of these western plants is no more difficult than with plants in the trade today (14). Many tools are available to assist in understanding this more western flora. For help in identification and ecology needs at the 98th meridian see references (10, 19); at the 100th meridian see references (5, 6, 9). For the Trans-Pecos, Warnock's (20, 21, 22) works are outstanding. Soils and geology are covered by (1, 3, 16), the oaks are elucidated by Muller and Simpson (13, 17, 18) with a synopsis of the flora statewide in (2, 4, 8).

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PRODUCTION AND MARKETING OF NEW PLANT INTRODUCTIONS

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An exciting and potentially profitable research area for a wholesale nursery is the collection, evaluation, production, and release of *new* plant materials. "New" does not necessarily mean unknown but may include any wild or cultivated plant of merit that can be collected and commercialized. Thus, a primary goal of our research program is the introduction of new ornamentals, including native and exotic plants.

PROGRAM OBJECTIVES

Any introduction program should be guided by clear objectives. Innumerable plants can be obtained from wild habitats or through exchange programs; however, resources to evaluate and maintain collections are usually limiting. Programs without clear purposes may end up with random collections of materials that may have little sales potential. While this approach may be acceptable in a botanical garden, it does not work in a profit-motivated commercial nursery. Major program objectives at our nursery include the following:

1. Serve as a center for receiving new materials from U.S. and foreign sources and via our own collecting and breeding programs.
2. Develop a logical propagation and production system so that collections become a source of new materials for our industry, and ultimately the public.
3. Release new ornamentals worthy of trademarks and patents.
4. Produce promotional and production information to growers, customers, sales staff, and the public.
5. Encourage landscape architects, contractors, retailers, governmental agencies, companies, and individuals to utilize new materials.
6. Make the program profitable.

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[1] Director

COLLECTION POLICIES

The second step in a sound introduction program is the establishment of collection policies. Plant collecting should not be a random process, rather it should be based on strict acquisition criteria. What will be collected and why?

The following questions guide our collecting program:

1. Can the plant be grown successfully at our nursery and is it adapted to our market area, present and future?
2. Is the plant a ''new'' addition to the trade and/or is it ''better'' than selections already available?
3. Does the plant have some special ornamental characteristics, landscape uses, or other merits worthy of commercialization?
4. Is the plant of particular interest such as for breeding programs, to complete a collection, for research, or to preserve the genetic pool of a species?
5. Is the plant without objectionable characteristics?
6. Do we have the time, space, and means to evaluate and produce the plant?
7. Does the plant have significant sales potential, and can it be profitably produced?

Before seed, cuttings, or plants are brought into the nursery we try to answer ''yes'' to most or all of these questions.

SOURCES OF PLANTS

''New'' plants can be obtained from many different sources. All possibilities should be considered but in some priority order which attempts to ensure that what is acquired will thrive at the production site and in a given market area. As long as collection policies are clearly stated and followed, the process should operate effectively.

The following sources of plant materials should be considered:

1. Native habitats in your state and other states with similar climatic and edaphic situations.
2. Arboreta and botanic gardens.
3. Governmental agencies.
4. Commercial companies, such as other nurseries.
5. Individual plant experts, collectors, and private gardens.
6. Internal company collecting from native or cultivated sites.
7. Internal breeding programs and selection from production stock.

PROPAGATION, PRODUCTION AND EVALUATION OF NEW PLANTS

Following collection or introduction of a plant not previously grown, a series of research steps are followed in propagation and production. It is also desirable to evaluate the plant for adaptability to the market area and to observe landscape performance. These steps may require two to five years before release, or may end more abruptly if we cannot determine an economical method to produce the new plant.

Propagation. We generally will try several methods depending on the plant and propagules available. Propagation references are consulted whenever possible to get a lead on ways to propagate a new species. If the plant is unknown in the literature, we basically have to start from scratch. For seed we will try planting fresh seed in various media; cold or warm storage with subsequent seeding at various time intervals; scarification treatments if seed appears hard; and any other technique we can dream up. As you can imagine, this can be a hit-or-miss experience.

Vegetative propagation is even more complicated because of the many variables involved. In addition, it may be difficult to collect cuttings over many months and get the material back to the nursery in good condition. This is especially true if collecting from the wild in remote areas of Texas, other states, or foreign countries. Cuttings are selected, treated with many different rooting compounds, stuck in different media and placed under varying mist regimes The procedures may be repeated several times a year if material is available.

The propagation scheme can be simply outlined as follows:

1. Seed, cuttings, other methods.
2. Special treatments, including stratification, storage, scarification, and treatment with rooting hormones.
3. Media trials.
4. Misting or watering sequences.
5. Time allotments.
6. Research data on propagation percentage, quality, speed, transplant success, etc
7. Special problems, especially diseases.
8. Economic analysis of propagation techniques required.

Production. Once a successful and economical propagation method is determined, the plant moves into simulated full-scale production. This is done in the R&D nursery since the production method is still very much experimental.

The entire production schedule is determined for each plant to be produced in whichever size it is to be marketed. Production data includes these items:

1. Media, fertilization, water requirements, pruning, and other maintenance requirements, especially pest problems.
2. Growth and transplanting schedules.
3. Initial evaluation of plant performance in containers and under production regimes.
4. Any special requirements or problems.
5. Formulation of a crop-production schedule including timing to produce a saleable size plant.
6. Economic evaluation of the entire system.

Adaptation evaluation. Evaluation of a new plant in growing conditions of a large marketing area is a difficult problem for a grower. Plants need to be distributed to responsible evaluators who will see that the materials are planted and maintained properly and observed for landscape performance. We try to send new plants to universities, parks departments, and even to customers to have them evaluate the material for adaptability to the varying conditions in our market region. While we can do reasonable evaluations at our nursery, there is no substitute for widespread distribution and performance evaluation by other cooperators in different parts of the state and region.

INTERNAL RELEASE FOR COMMERCIAL PRODUCTION

Once a new plant has survived the research program we must convince both our Production Department and Sales Department that we have a "winner" for the company. Either department can stop the release at this point, ask R&D to hold it for further evaluation or future consideration, or agree with our recommendation that we should commercially produce the plant and offer it for sale. This is a tough hurdle that the plant must overcome but is an important part of the process.

Sales must agree that the plant is better than or different from other species already available and that the sales potential is great enough to be profitable. If they buy-in to the release they must then commit people, time, and resources to the promotion and sale of the new plant. Once Sales agrees, they meet with staff in Production to decide numbers, sizes, and product availability. All parties have to agree and work cooperatively to see that the program succeeds from this point onward. This is most important because it links Production and Sales. It is relatively easy to find and grow new plants. Selling them is often more difficult. It's

absolutely essential to have a marketing plan even before the new plant is available. If not, a nursery can end up with hundreds of plants that no one knows and no one buys. This can ruin a small grower and a lot of good plants.

SUMMARY

In summary, a plant introduction program should start with well-defined objectives and collecting criteria. Research on propagation, production, and regional evaluation, if successful, may result in internal release of a new plant. The Production Department takes the plant and produces the quantities and sizes that are stipulated by the Sales and Marketing Department. Any needed sales and promotional releases, publications, and programs must be prepared before sale of the new product. While R&D can provide the technical information and serve in a consulting capacity, it becomes the responsibility of Sales to really promote and sell any new plant.

The key to the entire program is that it will be well-organized, technically sound, with a cooperative effort among Research, Production, and Sales. Also it must be profitable in the long run or the company will not be able to continue to support the release of new plants.

A successful program ultimately means that landscapers, the industry, and the public have access to new plants to enjoy and to beautify our many landscapes.

PHOTOSYNTHESIS AND GROWTH DURING ROOT INITIATION AND ROOT DEVELOPMENT IN POINSETTIA CUTTINGS

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Abstract. Net photosynthesis of apical stem cuttings of poinsettia (*Euphorbia pulcherrima Willd. ex Klotzsch*) was studied during the development of adventitious roots. Photosynthesis in cuttings was low before root primordia formation, increased slightly upon root initiation and increased rapidly upon root emergence. Dedifferentiation and root initiation was apparently independent of photosynthetic rate while photosynthetic rate increased with the development of adventitious roots. There appears to be no benefit from using higher light intensities under mist propagation until after poinsettia cuttings have initiated roots

INTRODUCTION

The range of 400 to 450 μmol $m^{-2}s^{-1}$ PPF (80 to 90 W m^{-2}, or 2700 to 3000 footcandles) has been suggested as the optimum light intensity for rooting of poinsettia cuttings (8, 9). Use of relatively high light intensity is based on the assumption that photosynthesis by cuttings enhances rooting. However, the recent review by Davis (2) indicated that there is limited evidence to support or reject this assumption. Researchers (7, 11) have suggested, but did not document that higher light intensities would be beneficial only after root initiation. To date no studies have separated out the effect of light intensity and consequent photosynthesis, or growth regulator concentrations, on the developmental stages of rooting. Hence, if adventitious root formation is only being evaluated at the termination of a propagation experiment, the potentially higher light needed for later root development may be masking potentially lower light requirements needed during earlier root initiation stages.

The few studies evaluating light levels during rooting of poinsettia have found better rooting with lower light treatments (1, 4). However, these studies did not distinguish light intensity from photosynthetic or growth regulator effects on the separate processes of root initiation and root development.

The objective of this research was to determine the relationship of photosynthesis with the discrete developmental stages of adventitious rooting in poinsettia.

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MATERIALS AND METHODS

Stem tip cuttings (11.5 cm) of 'V-10 Amy' and 'Lilo' poinsettia were inserted into 6.25 cm pots containing a fully moistened perlite:peat (3:1 by volume) medium. Rooting compounds were not used, and leaves were not removed from the cuttings.

Cuttings were rooted in a growth chamber having the following environmental conditions: 24 °C day/night temperature; 380 ± 10 ppm ambient CO_2 concentration; 16-hr uninterrupted photoperiod; 180 μmol m^{-2} s^{-1} (36 W m^{-2}) PPFD, increased to 250 μmol m^{-2} s^{-1} (50 W m^{-2}) on day 16; 95% or greater day/night relative humidity, reduced to 80 ± 8% on day 16. Light was supplied by cool-white fluorescent lamps, plus 80-watt incandescent bulbs.

Before measurement of photosynthesis cuttings were removed from the growth chamber and acclimated for 30 min. under a high-pressure sodium lamp filtered through a 10.0 cm water filter. Gas exchange was measured under environmental conditions of: 22.1 °C ambient temperature; 382.7 ± 9.4 ppm ambient CO_2 concentration; 423.7 ± 5.5 μmol m^{-2} s^{-1} (85 W m^{-2}) PPF; and 30.7 ± 5.8% relative humidity. Foliar net photosynthesis of the abaxial leaf surface was measured on the leaf nearest the apex having at least 4 cm^2 of surface area using a LI-COR LI6200 portable photosynthesis system (LI-COR, Inc., Lincoln, Nebraska, USA). After 10 cuttings of each cultivar were measured, cuttings were harvested to determine cutting dry weight and percent rooting.

The experiment was a completely randomized design. Photosynthesis data was similar for both cultivars, so the data were pooled and then analyzed for significant change by day using analysis of variance and orthogonal linear contrasts. Least squares means and standard errors were used to present the data.

RESULTS

Net photosynthesis was initially very low and remained low until 12 days after cuttings were stuck (Table 1). If unrooted cuttings were measured at 160 μmol m^{-2} s^{-1} instead of 423 μmol m^{-2} s^{-1}, there was no difference in the photosynthetic rate (data not shown), suggesting that Pn was saturated at or below 160 μmol m^{-2} s^{-1}.

Table 1. Photosynthesis, percent rooting, and total dry weight during adventitious root formation of poinsettia cuttings

Day	Percent rooting	Photosynthesis (μmol m^{-1} s^{-2})	Total dry weight (g)
Day 1	0	0 94 ± 0 42	0 49 ± 0.08
Day 4	0	1 21 ± 0 42	0 50 ± 0 08
Day 6	0	1 25 ± 0 42	0 60 ± 0 07
Day 8	0	1 21 ± 0 42	—[z]
Day 10	0	1 35 ± 0 42	0 58 ± 0 07
Day 12	0	2 12 ± 0 42	0 67 ± 0.08
Day 16	77	8.01 ± 0.42	0.79 ± 0.07
Day 23	100	9.01 ± 0.42	0.83 ± 0.07
Orthogonal contrasts			
Day 4 differs from day	NS[y]	NS	NS
Day 6 differs from days 1-4	NS	NS	NS
Day 8 differs from days 1-6	NS	NS	—
Day 10 differs from days 1-8	NS	NS	NS
Day 12 differs from days 1-10	NS	*	NS
Day 16 differs from days 1-12	***	***	**
Day 23 differs from days 1-16	***	***	**

[z] Data not available.

[y] NS, *, **, ***, indicate not significantly different or different at the 5%, 1%, or 0 1% levels, respectively

Visible roots were not observed until day 16, indicating that a significant increase in Pn occurred prior to visible root emergence (Table 1). On the day that photosynthesis started to increase, microscopic analysis of cross-sections of the rooting zone of the cuttings revealed the presence of root initials and primordia, but no primordia elongation. Rooting was 70% and 85% for 'V-10 Amy' and 'Lilo', respectively, on day 16. All cuttings had rooted by day 19 or 23 for 'Lilo' and 'V-10 Amy', respectively.

Growth continued in all parts of the cuttings as indicated by steady increases in dry weight (Table 1). The carbon fixed from the low rates of photosynthesis may have been required for growth processes.

DISCUSSION

Previous studies have indicated that net photosynthesis in cuttings steadily declines, and then rapidly increases upon visible root emergence (2). Similarly, stomatal conductance of *Cornus alba* cuttings remained low until after root emergence (3). In the present study the steady initial decline in photosynthesis was not observed, and net photosynthesis increased prior to visible root emergence. The difference in initial response could be due to differences in

species, cutting growth habit, species-cutting stomatal sensitivity, environmental conditions used (particularly light levels), and techniques used to measure photosynthesis. An increase in photosynthetic rate prior to root emergence has been previously reported for bean leaf cuttings but without anatomical observations. (5).

Temporary increases in the net photosynthesis of leaves of intact maize plants was correlated to the emergence of nodal stem adventitious roots and paralleled increased cytokinin activity (6).

Jesko (6) suggested that hormones exported from the newly emerging roots are the main factor controlling the temporary changes in photosynthesis. A similar explanation could resolve the photosynthetic response in cuttings. Regardless of the presence of visible roots or preformed root initials, an increase in cutting photosynthetic rate could be correlated to the newly developing roots' ability to export hormones. Variability in cytokinin export from roots would explain why cuttings of different species have increased photosynthetic rates, either before or after root emergence. Any temporary shortage in available carbohydrate upon root elongation is probably avoided by mobilizing the photosynthetic apparatus prior to the high carbohydrate demand needed for rapid root growth.

Since unrooted poinsettia cutting photosynthetic rate was the same at 160 μmol m^{-2} s^{-1} and 423 μmol m^{-2} s^{-1} of light, and since photosynthetic rate before root emergence was low, it appeared that lower light levels (which reduce water stress) could be used during the early stages of root initiation, and higher light intensities used just prior to root emergence to maximize adventitious root formation. Hence, in poinsettia there appears to be no benefit from using higher light intensities during propagation until after the cuttings have initiated roots. This research gives scientific evidence for current recommendations for poinsettia propagation (4, 10).

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PROPAGATING AND COOLING WITH FOG

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In April, 1988 Buds & Blooms Nursery purchased a fogging machine. Our decision was based on the fact that we had begun producing our own tissue-cultured rhododendron and mountain laurel plants. We could not get satisfactory results using mist and tents in our climate.

At the nursery we have eleven double-poly propagation houses that are 14 x 96 ft. They are all vented using a W. W. Grainger 24-in. exhaust fan and a 37 x 63 in. Acme intake shutter. Both of these units are controlled by a thermostat set at 80 to 85 °F We use two layers of 40% white shade cloth over these houses when propagating. This is available from V-J Growers Supply. In the winter these houses are heated with Modine gas-fired heaters.

Two of the eleven propagation houses are used as fog-houses for tissue-cultured plantlets. In these greenhouses we use ½ in. copper tubing suspended from the center purlin which is approximately 7 ft. from the floor. We used eight nozzles in the first house, spaced 10 ft. apart. The nozzles were attached (pointing down) at 30-degree angles away from the tubing with every other nozzle aimed in opposite directions. In the second fog-house we set up, we used nine nozzles and placed all of them facing straight down rather than on a 30-degree angle, which we find to be superior.

We also have a fog line outside the greenhouse with 10 fog nozzles running the width of the house behind the air-intake shutter. When the exhaust fan is running, these 10 fog nozzles create a large cloud of fog which is pulled through the greenhouse. This additional cloud of fog helps to cool as well as humidify the hot, dry air being pulled through the house that normally tends to dry out the plants near the air-intake shutters.

The fog system we purchased is a Mee 1000. The fog nozzles are made of stainless steel and have an impact pin that breaks up the water into much finer particles than something like a Baumac ULV nozzle, or an oil-burner nozzle that some folks use for fogging. These nozzles also have a replaceable filter built into them. The system is engineered to run at 1000 PSI, however, we have overloaded it with extra nozzles and it is currently running at about 700 PSI. We find the system still runs satisfactorily and continues to produce an ultrafine fog.

The system is controlled by a humidistat set at 95%. We have found that the placement of the humidistat will greatly affect the frequency of the running time of the fog system. The best placement of the humidistat for us is at the air-intake shutters. With the placement of the humidistat next to the air-intake shutter, the fogging machine will run most of the time on hot sunny days. This will keep a cloud of fog steadily pulled through the greenhouse so that mild temperatures are maintained.

We have also hooked up a Dosmatic Injector to the water input side of the fogger and use it for injecting bromine and fertilizer into the fog.

After installing this fog system for our tissue-culture plantlets, we saw that it may also be helpful and practical to use fog for cooling, in combination with intermittent mist, for all our propagation. This is especially true since much of our propagation is taking place during the summers when it is very hot—90 to 100 °F.

Currently we are using the fog/mist combination in five houses to propagate cuttings of azalea, rhododendron, and pieris. We adapted the use of the fog to help cool and humidify our cutting propagation houses by placing a fog line with 10 nozzles behind the air-intake shutters, just as we did in our fog houses. However, inside we continued to use intermittent mist rather than fog. By doing this we helped cool down the greenhouse immensely and greatly reduced our misting intervals. On an average summer day, the mist intervals will be only once an hour for 10 sec. and, on a very hot day, we might reduce it down to every 30 min. for 10 sec. We are using a Phytotronics misting controller and EGT misting nozzles that are available from Hummert Seed Co. and other horticultural suppliers.

Some benefits of this fog/mist combination are that it will hold temperatures in the 80s even on the hottest summer day. We also found less incidence of disease, probably due to the reduced misting intervals. Another big advantage about this combination is that each system acts as a backup for the other should one fail.

We feel that the combination of fog for cooling and humidifying, along with intermittent mist and the use of white shade cloth has helped our propagation tremendously. It creates what we feel is the perfect environment for propagation: warm, but not hot temperatures, and a humid but not wet greenhouse. We have also cut down on production time, increased our rooting percentages, and produced stronger, healthier plants with the use of this system.

REDISCOVERING PERENNIALS FOR SOUTHERN GARDENS

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Colorful landscapes are not just a local trend. They are blossoming on an international scale. The relatively immediate visual impact and low cost of annuals and perennials have fueled their popularity. Their use enables homeowners to update landscapes quickly and economically while making the home more appealing for personal enjoyment or for marketing it to buyers.

Annuals are plants that complete growing and flowering processes in one year or less. In the South's hot and often humid climate, most annuals last for a season or three to four months at most. Perennials, however, are plants that return from the same root part each year. Consumers are fascinated by plants that provide color yet do not have to be purchased and replanted each year.

Once a mainstay of our gardens, perennials lost favor during the last 50 years. Their new prominence has resulted in numerous catalogs offering a broad range of plants. The problem is that few of these sources are in the southern United States, and many of the beautiful perennials they offer are poorly adapted in our growing conditions.

Many perennial species, however, are so well adapted to the south that they are appropriate for use in xeriscape and low maintenance settings. Xeriscape gardens require only small amounts of supplemental moisture. They are gaining favor rapidly in parts of the country where water conservation becomes more important and sensible each year. Plants suitable for xeriscape plantings are far more numerous than the cacti and yuccas commonly associated with this concept.

Early southern gardens often had colorful and beautiful landscapes before sprinkler systems and garden hoses were available. Abandoned homesites and cemeteries attest that many of these plants reliably return each year with little or no assistance from gardeners. Examples include some of the old daffodil and narcissus cultivars as well as crinums (milk and wine lilies), certain salvias, lantanas, verbenas, daylilies, irises, and others.

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USING PERENNIALS EFFECTIVELY

Perennials are versatile plants that may be used widely throughout the landscape. They make attractive borders, mixed borders, cutting gardens, container plants, cottage or woodland gardens, or pockets of color. For the homeowner interested in quickly livening up a landscape, pockets of color can be created easily with perennials.

Most home landscapes have enough evergreen shrubs to avoid a totally bleak look, but they offer little seasonal change or flower color. By enlarging planting areas in front of evergreen shrubs, modest sized spaces for clumps or drifts of seasonal color may be designed. A quantity of the chosen flower must be planted, however, so that the effect is not just a "spot" in the overall picture. Shrubs and nearby trees may have laced the potential planting area so completely with their roots that their removal is necessary to allow flowering plants to thrive.

For most homeowners, the space they can maintain comfortably in annuals or perennials is relatively small. It seems sensible to concentrate plantings where they will be seen and enjoyed most. Possibilities for pocket planting include masses or borders of low growing daylilies or irises in front of evergreen shrubs. Entrance areas are another logical place for welcoming arrays of color.

For pockets of color around outdoor living areas, swimming pools, and entrance courts, containers offer the answer. Portability is a special asset of container plants because they usually can be moved to a less prominent location when not at their best.

With long growing seasons and relatively short winters, landscape maintenance in the South becomes an almost year-round affair. By selecting well-adapted perennials and placing them in strategic places, year-round color can be practical

CHOOSING LOW-MAINTENANCE PLANTS

A major cultural requirement of most perennials is division. Some species require annual division while others need to be undisturbed for several years. A good rule of thumb for deciding when to divide is that most perennials thrive best when divided in the season opposite their peak flowering. Therefore, spring-flowering species should be divided in fall, and summer-flowering types in winter or early spring.

Many perennial species are suitable for southern landscapes (see Table 1). With careful selection, every season can include flowering perennials. Perennials generally require less maintenance than annuals. Because they do return each year, they can be a wise gardening investment.

Table 1. Perennials with potential for the U S. southern states

Scientific name	Common name	Exposure[1]	Flower color	Flowering season	Height
Aquilegia hinckleyana	Hinckley's columbine	Sh	yellow	spring	18 in
Bletilla striata	Chinese ground orchid	Sh	purple, white	spring	1-2 ft
Crinum bulbispermum	milk and wine lilies	E	pink, white, striped	spring summer, fall	3-4 ft.
Dianthus spp	garden pinks, carnations	E	pink, red purple	spring	1-2 ft.
Gladiolus byzantinus	hardy gladiolus	S	purple, white	spring	2-3 ft.
Hamelia patens	firebush	S	red-orange	spring, summer, fall	3-4 ft
Hippeastrum bifidum	oxblood lily	E	red, rose	late summer, fall	1 ft
Hippeastrum Johnsonii	× hardy red amaryllis	S	red	spring	2 ft
Iris fulva × *I giganticaerulea* × *I brevicaulis*	Louisiana iris	E	many	spring	3 ft
Iris orientalis	spuria iris	E	yellow, white	spring	3-4 ft
Lycoris radiata	red spider lily	E	red	fall	1-2 ft
Muhlenbergia lindheimeri	Lindheimer's muhly grass	S	blue-gray foliage	3-4 ft.	
Narcissus spp.	narcissus	E	yellow, white	spring	1-2 ft
Oxalis crassipes	oxalis	E	pink, white	fall, spring	1 ft.
Penstemon cobaea	wild foxglove	S	purple, lavender	spring	1-2 ft.
Schizachyrium scoparium	little bluestem	S	blue foliage	3-5 ft	
Tulbaghia violacea	society garlic	E	lavender	spring, summer, fall	18 in
Viola odorata	sweet violet	Sh	purple	winter spring	6-8 in

[1] Key. S = Sun Full or Partial, SH = Shade, E = Either shade or sun

Table 1 includes perennial plants that appear to have considerable potential for the South. Propagation of bulb-forming perennials is often slow and uneconomical. The key to success with many of these is finding crops to propagate commercially and grow them for profit.

KEEPING KEY NURSERY PERSONNEL HAPPY AND PRODUCTIVE

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Good, happy, properly-trained and motivated people in the right positions are the key to company growth and success. Measuring and reporting work results is important both to the company and to individuals working singly and in teams. Considerate personnel management practices should allow employers and employees to have excellent satisfying careers in the best business in America.

Following is an outline of what we consider the key elements in a management program that will give these results.

STEP-BY-STEP PROCEDURE

I. **Selection process:** Choosing the proper person to fill a clearly defined need.
   A. Have an effective selection process in place with many steps to be carried out with diligence, patience, and thoroughness.
   B. Develop a job description.
   C. Review r ésume and match requirements with qualifications.
   D. Conduct a structured interview with individual superiors and group peers, demonstrate skills needed, have an informal social.
      1) Ask how the applicant would solve problems.
      2) Ask for self-evaluation.
         a) Good qualifications.
         b) Need improvement.
      3) Use open-ended questions that cannot be answered yes or no.
   E. Rank candidates; hire best to fill job.

II. **Orientation**
   A. First day.
      1) Introduce to peers and reports required.
      2) Go through company handbook.
      3) Show company video tape if you have one.
      4) Talk about company history and culture.
      5) Tell employee what is expected of him.
         a) Give him another copy and review his job description.

b) Inform employee on important points of job.

B. Follow-up periodically.
   1) Have "I want to help you" attitude.
   2) Display open-door policy.
   3) Pat on back; boost morale.
   4) Be friendly: inquire as to family, school, and housing, particularly if employee was relocated from another area.

III. **Evaluation and feedback**

A. Give all employees evaluations both formally and informally.

B. Praise them for excellent performance.
   Pats on back and "attaboys" will improve morale and productivity.

C. For "areas needing improvement" begin on a positive note, then:
   1) Discuss the area of needed improvement.
   2) Suggest a way to correct or improve.
   3) Set time-frames for achieving improvement.
   4) End on positive note.
   5) Do not ignore "areas needing improvement" in evaluations.

IV. Competitive pay and benefits.

A. Ability to attract better people is increased with competitive pay and benefits.
   1) Paying below market salaries will keep your employees on edge and keep them receptive to any offer at any time.
   2) Beware of hiring an employee for far less than they received from their prior job. They won't be satisfied, and you may be hiring a lemon.
   3) Offer incentives.
      a) Bonus, equity positions, a key results plan, other . . .
      b) Base on quantifiable things such as profits, cost reductions, low unit costs, less accidents, marketing, unit sales, or production plans.
      c) Give plans in writing.
      d) Make sure they are fair and designed to motivate employees to high sustained performance.
   4) Provide a competitive health care plan.
   5) Provide any other benefits that your competitive situation demands or that you can justify.

Check through your Chamber of Commerce' Existing Industry Committee to compare area businesses' benefit plans. They vary

widely by area, industry, and position of employee. Example: Benefits may include paid holidays and vacations, insurance, relocation expenses, autos for personal use, appreciation dinners, awards night, special recognition, pay during jury duty, and military reserve duty.

V. Promote team concept.

A. Many major companies are surviving because they have adopted a team management approach.
   1) Sense of belonging is just about as important as dollars to employees.
   2) Encourage team members to participate in problem solving; their ideas are excellent; many heads are better than one or two.
   3) Make employees feel their thoughts as well as their work are greatly appreciated.
   4) Integrated Quality Management (IQM) can be the basis of a company mission statement. Employees working together, and with management, are essential to the success of such a program.

B. Promote team concept continuously and strive for continuous improvement at every level of operations.

VI. Training

A. Convince your employees of your sincere desire to see them grow on job.

B. Plan training for employees both on job site and away that will broaden them. Give them the opportunity to
   1) Attend IPPS meetings.
   2) Attend seminars sponsored by groups such as:
      a) American Nursery Association
      b) Cooperative Extension Service
      c) Other University personnel or units

C. Training increases effectiveness, gives job satisfaction, and improves morale.

EFFICACY OF CHLORINATED IRRIGATION WATER FOR CONTROLLING ROOT ROT ORGANISMS

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Abstract. Five months of irrigation with 0 2 ppm free chlorine did not result in reduced root isolations of *Pythium, Phytophthora,* or *Rhizoctonia*, or number of propagules in the growth medium of *Juniperus conferta* 'Blue Pacific' Number of propagules in the growth medium of *Elaeagnus pungens* (silver thorn) was generally less for chlorinated than nonchlorinated plants

INTRODUCTION

The chlorination of potable water has been a common practice for many years (4). Recently, irrigation water for nursery crops has been chlorinated for the purpose of suppressing fungal organisms. Daughtry (1) reported that chlorination of nursery irrigation water resulted in a 30% reduction in fungicide use.

Water restrictions in Florida necessitate that plant producers minimize water use and reclaim surface water. Reclaimed or recirculated water has been thought of as a potential source of pathogens. Consequently, chlorination of runoff water may be beneficial when water is reused. Even though nursery irrigation water has been chlorinated and disease suppression appeared successful, the efficacy of chlorination has not been documented under nursery conditions. The following study was conducted to document the efficacy of chlorinating reclaimed runoff water.

MATERIALS AND METHODS

The study was conducted at Gramling Nursery, Inc., Plant City, Florida (latitude 28° 00'N, longitude 82° 07'W). Gramling Nursery collects runoff from a 17 acre area in a ⅓ acre pond that is about 15 ft deep. A gas chlorine system (Advance Chlorinator Model 480 (481C1/VR428C) Capital Controls Co., Colmar, Pennsylvania 18915) was installed near the irrigation pump, and a Lovibond® 2000

Comparator TK 100 (The Tintometer Company, Williamsburg, Virginia 23185) was used to monitor free chlorine in the irrigation water using N,N-diethyl-p-phenylenediamine (DPD) reagent. Reclaimed water was chlorinated (0.2 ppm free chlorine) during each irrigation applied to half the nursery acreage while the other half received reclaimed water without chlorination. Plants were irrigated with about 1 in. of water every other day, or as needed.

At the initiation of the study (March, 1989), 200 plants of *Elaeagnus pungens* (silver thorn) and *Juniperus conferta* 'Blue Pacific' were placed in the chlorinated and 200 of each in the nonchlorinated area. 'Blue Pacific' was chosen based on previous observations that it was very susceptible to the root-rot pathogens, *Pythium, Phytophthora,* and *Rhizoctonia* and that *Elaeagnus* was less susceptible than 'Blue Pacific' juniper. The 'Blue Pacific' juniper plants were potted December 28, 1988 and the silver thorn were potted January 24, 1989. The container medium was a 50% sedge peat: 25% pine bark: 15% cypress sawdust, and 10% builder's sand (by volume). The medium was amended with dolomitic limestone to adjust pH to between 6.0 and 7.0, and with 3 lb/yd^3 of Step (trademarked micronutrient fertilizer of O. M. Scott and Sons Co., Marysville, Ohio 43041). Lesco 20-6-12 (a trademarked fertilizer of Lakeshore Equipment & Supply, Co., Elyria, Ohio, 44036) was surface-applied at potting (17.3 g/container or 2 tsp. to each trade 1-gal. container), and repeated about every 4 months.

Water samples for pathogen analysis were taken prior to chlorination (March) from the pond and irrigation nozzles during irrigation, and sampling was repeated in July. The water was centrifuged and propagules counted. Each month (April to August), 5 plants of each species were randomly removed from the chlorinated and nonchlorinated areas. Root pieces from each plant were treated and stained according to the procedures of the University of Florida Extension Plant Disease Clinic. *Pythium, Phytophthora,* and *Rhizoctonia* counts were made for roots, and *Pythium* and *Phytophthora* counts made for the growth medium. Growth medium and root samples were also taken in March prior to chlorination. Propagule numbers for the growth medium were obtained using growth medium particles less than 1.19 mm or 14 mesh (U. S. Standard Sieve #16).

Twenty 3-gal. *Gardenia jasminoides, Ilex cornuta* 'Dwarf Burford', *Juniperus chinensis* 'Parsonii', and *Podocarpus macrophyllus* plants were placed in both the chlorinated and nonchlorinated areas at the initiation of the study. Twenty 1-gal. *Hibiscus rosa-sinensis* (green and variegated) plants were also placed in each area. Tissue samples were taken from the uppermost mature leaves of each species in March before chlorination, and

again in July. Three composite samples were taken from each species except *Hibiscus*. One composite sample was taken from nonvariegated *Hibiscus* and one composite sample was taken from variegated *Hibiscus* plants. Tissue was dried for 24 hr. at 160 °F and chloride percentages determined by Soil and Plant Lab, Santa Clara, California 95050.

During July, August, and September, leachates were collected (6) prior to root isolation and growth medium propagule determinations were made for the 5 chlorinated and 5 nonchlorinated *Elaeagnus* plants. Leachate chloride levels were determined according to procedures of the University of Florida Extension Soil Testing Laboratory (5).

RESULTS AND DISSCUSSION

Data for the roots and growth medium indicate that *Elaeagnus* roots and growth medium had a smaller percentage of isolations and number of propagules, respectively, than did juniper (Tables 1 and 2). Root isolation percentages and growth medium propagule numbers were generally smaller for the chlorinated than for the nonchlorinated *Elaeagnus*. Root and growth medium data for both species varied considerably, but propagule numbers were higher for chlorinated than for nonchlorinated juniper plants during April, May, and June. Shoot chlorosis, typically associated with root rot, was exhibited after June by many of the juniper plants in both the chlorinated and nonchlorinated areas. This chlorosis concurs with large numbers of propagules in the growth medium and roots in May and June. However, the irrigation water sampled in March and July did not contain recoverable propagules (data not shown). *Elaeagnus* did not exhibit chlorosis.

Table 1. Root isolation percentages for *Elaeagnus pungens* (silver thorn) and *Juniperus conferta* 'Blue Pacific' that received chlorinated (C) or nonchlorintated (N) irrigation water.

Species and time	*Pythium*		*Phytophthora*		*Rhizoctonia*	
	C	N	C	N	C	N
Elaeagnus						
March	12%	16%	9%	11%	64%	8%
April	15	13	1	3	13	37
May	7	20	1	—	6	25
June	16	5	1	5	2	3
July	15	5	14	15	—	—
August	9	—	0	50	0	17
Juniperus						
March	34	39	17	15	20	46
April	43	4	17	65	9	27
May	20	42	48	35	38	34
June	79	31	62	43	14	24
July	71	26	33	77	2	4
August	25	65	63	67	23	26

C = Chlorinated; N = Nonchlorinated
Chlorination began after the March sampling

Table 2. Number of propagules (*Pythium* and *Phytophthora*) in the growth medium of *Elaeagnus pungens* (silver thorn) and *Juniperus conferta* 'Blue Pacific'.

Time	*Elaeagnus*		*Juniperus*	
	C	N	C	N
March	284	101	280	235
April	1[illegible]	169	363	129
May	—	—	359	340
June	14	61	258	78
July	52	145	78	147
August	67	105	128	233

Growth medium samples were less than 1 19 mm
C = Chlorinated, N = Nonchlorinated
Chlorination began after the March sampling.

Leachate chloride levels for *Elaeagnus* in July, August, and September were 9.4, 9.2, and 6.0 ppm, respectively, for the chlorinated plants, and 10.2, 7.4, and 9.4, respectively, for the nonchlorinated plants. Leachate levels were presumed to be similar for 'Blue Pacific' juniper since plants were treated similarly. These leachate levels were probably not excessive in view of the research of Frink and Bugbee (3) in which a solution containing 18 ppm chloride did not result in a reduction in shoot dry weight for

16 of 23 species tested. Tissue chloride levels were generally similar for the chlorinated and nonchlorinated plants (Table 3) and no visual damage was noted.

Table 3. Leaf tissue chloride percentages for *Gardenia jasminoides, Hibiscus rosa-sinensis, Ilex cornuta* 'Dwarf Burford', *Juniperus chinensis* 'Parsonii' and *Podocarpus macrophyllus* that received chlorinated or nonchlorinated irrigation water Chlorination began after the March sampling.

Species	Chlorinated		Nonchlorinated	
	March	July	March	July
Gardenia	0 13%	0.12%	0 14%	0 14%
Hibiscus (green)	0.39	0 43	0.34	0.46
Hibiscus (variegated)	0 30	0 92	0.27	0.81
Ilex	0 12	0.17	0.12	0 17
Juniperus	0 16	0 17	0 19	0 21
Podocarpus	0 41	0.49	0 49	0 48

Our study indicated that 0.2 ppm free chlorine in reclaimed irrigation water did not effectively suppress root rot pathogens in the growth medium or roots of 'Blue Pacific' juniper. Although the efficacy is questionable based on data for *Elaeagnus*, higher rates of chlorine may be advantageous when disease pressure is high as was the case in the beginning of this study.

In another study conducted with greenhouse-grown *G. jasminoides* and *P. macrophyllus*, 1 and 10 ppm chloride applied weekly to the foliage resulted in minimal leaf chlorosis of *G. jasminoides*, with more chlorosis evident at 100 and 1000 ppm chloride. *P. macrophyllus* did not exhibit chlorosis. The pH of the 100 and 1000 ppm solutions was 9.5 and 10.5, respectively. A pH above 9.0 may suppress the biocidal activity of chlorine (2) and may have attributed to the chlorosis. The pH of pond and chlorinated irrigation water at Gramling Nursery was 7.0 and 6.8, respectively, in September.

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TECHNICAL SESSIONS

EASTERN REGION

Thirty-Ninth Annual Meeting

December 4-8, 1989

TORONTO, CANADA

TECHNICAL SESSIONS
Tuesday Morning, December 5, 1989

The thirty-ninth annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:00 a.m. in the Concert Hall of the Royal York Hotel, Toronto, Canada.

PRESIDENT GRAHAM: On behalf of the Eastern Region and the Local Site Committee I wish you a very warm welcome to Toronto. Your Program Chairman, Peter Orum, this year has put together what I can only describe as an excellent program for our 39th annual meeting. The Local Site Committee under the able leadership of Joerg Leiss has worked hard to put together interesting tours. If you have any questions during the meeting please ask us for assistance. To start our meeting this morning we have Chris Andrews, Executive Director of the CNTA (Canadian Nursery Trade Association) to welcome us.

CHRIS ANDREWS: Ed. Note Mr. Andrews welcomed all in attendance on behalf of the CTNA and discussed the exciting things that are occuring in the nursery industry in Canada.

PRESIDENT GRAHAM: I will now turn the program over to Peter Orum, our Program Chairman.

PETER ORUM: It is indeed great to be back in Toronto even though it is a little on the cool side, however, I think it was that way 11 years ago. First of all, I would like to say thank you to those people who have made it possible for me to do my job this year, to speakers and moderators, and everyone else who have been very willing and cooperative in getting everything together for the meeting. We have tried this year to get everything divided into sections of somewhat similar things. The first section this morning will be on grafting and cuttings. Our moderator is Joerg Leiss.

IPPS BACKGROUND

RALPH SHUGERT

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As a member of the IPPS International Board—serving as International Historian—welcome to the 39th Annual Eastern Region Conference.

It is fitting that Program Chairman, Peter Orum, has asked me to say a few words as to the background of our beloved Society, since it was 21 years ago I had the honor of serving as Eastern Region President during our Conference held in this marvelous hotel. That 1968 meeting was our initial Canadian visit and was truly successful.

As we commence our Conference I would like to review, with you, the history of our Society since the inaugural meeting held at the Statler Hotel, Cleveland, Ohio, November, 1951. The Society, at that time named the Plant Propagators' Society, was the dream of a few far-sighted individuals who felt such a society would be of great benefit to the professional nurseryman, the nursery community, and the academic facet of the nursery profession. The first officers elected in 1951, were President, Jim Wells; Vice-President, L. C. Chadwick; and Secretary/Treasurer, Ed Scanlon.

In July, 1951, in conjunction with the AAN Annual Meeting at Detroit, Michigan, an organizational committee of ten gentlemen: Jim Wells, L. C. Chadwick, Ed Scanlon, Dick Filmore, Bill Snyder, Jim Ilgenfritz, Pieter Zorg, John Siebenthaler, and Roy Nordine (Steve O'Rourke was out of the country doing research in Trinidad and unable to attend) worked hard to form the framework of the Society we know today. On December 11 and 12, 1952 the Society convened in Cleveland, Ohio, at the Wade Park Manor Hotel. This establishment would be the site of the next six meetings. The year 1959 found us meeting in Philadelphia with a record attendance of 227! I can still hear echoes of members complaining about, "too many people", "getting too big", "people are here that I don't know", etc. . .

As the decade of the 1950s came to a close, the Society added the word International to its title and the Western Region was created at its inaugural meeting in 1960. The Eastern Region voted in 1962 at Cincinnati on an amendment to delete the word International from our Constitution. The amendment failed, fortunately, and several members (including a charter member) left the Conference, never to return again.

In September, 1970 the first, and only, joint meeting of the Western and Eastern Regions was held. We had excellent weather, an outstanding program and site, but the attendance was very disappointing! Members simply did not turn out! As International Vice-President in 1970 I had the honor of serving as Conference Program Chairman, and one of the finest papers presented at that St. Paul, Minnesota meeting was by George Oki. The next time you are pursuing back issues of our Proceedings, pick up Volume 20 and marvel at the words of Past International President Oki.

I am writing a history of our beloved Society, as requested in 1985 by then International President Byers. I have titled chapter III "A Decade of Growth" which covers the Society's activities from 1970 to 1979. In the early years of the decade, I had the highest honor I have ever received, that of being elected International President for the year 1971. As of January 1, 1973, the Society appointed a Historian to the International Board and I have had the privilege to serve in that position since its inception. The Board now has three members—Editor, SecretaryTreasurer, and Historian—who can assist new officers in understanding the ideology of previous boards, since those three positions are reasonably permanent.

The development of the three overseas regions was the result of much unselfish missionary work of a great gentleman, James S. Wells. This dedicated Society member spent many hours, and some of his personal income, to realize his dream of a truly International Society. Jim had the thrill of giving the keynote papers on September 18, 1968, the Inaugural meeting of G.B.&I. (Great Britain and Ireland); September 26, 1972 in New Zealand; and October 28, 1973 in Australia. Our latest Region, the Southern, had their first meeting December 7, 1976, moderated by John Machen. They officially established their Region in 1977 with the dynamic Charlie Parkerson serving as President. He would later serve as International President when the Board met in Aberdeen, Scotland.

We start the decade of the 1990's under the competent leadership of our own Elton Smith. The 1989 International Board charged Elton and all Regions, to vigorously pursue recruitment (our Society total membership has been almost stagnate in the past five years) and the pursuit of new Regions. Preliminary dialogue in the countries of Poland, Israel, and France have commenced and the Board has created a budget line item for Regional expansion.

As of August 15, 1989, the Society has a total of 2,433 members world-wide, of which 670 members belong to our Eastern Region. Our motto, "TO SEEK AND TO SHARE", which was contributed by Peter Vermeulen, is being practiced world-wide. We are all fortunate to be members. We are all marching to the same drummer!

APICAL GRAFTING OF *ACER PALMATUM* AND OTHER DECIDUOUS PLANTS

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WHY DO WE GRAFT *ACER?*

For brevity in this presentation we will use *Acer* for *A. palmatum*, or Japanese maple. Until 1980 we had been importing *Acer* from the North American West Coast and from Europe. These were well-grown plants but sometimes there was some difficulty in acclimatization to our harsher Ontario, Canadian winters. The root washing requirement for imports from Europe was also a negative factor. In addition, the great transport distances substantially increased the cost. Hence, the decision to propagate *Acer* at our nursery.

As to grafting versus growing from cuttings, we had observed that in some species, notably *Viburnum* and *Cornus*, plants from cuttings were more difficult to overwinter in the first years and also were slower growing than grafted types. Our conviction regarding Japanese maple was confirmed after hearing a report by William Flemer III of Princeton Nurseries at the IPPS Annual Meeting in Grand Rapids, Michigan, citing a recent experience with grafted and rooted *Acer* of the same cultivar, age, and size. He observed in the spring after overwintering that plants grown from grafts were all alive while plants grown from cuttings were all dead. While realizing that such drastic contrast would not necessarily always occur, our colder climate would increase the possibility of disappointment in overwintering. We resolved to graft all our Japanese maples and the results have been consistently satisfactory.

EFFICIENCY IN GRAFTING

Our topic is focusing on the economic efficiency of grafting, suggesting modification and simplification of traditional methods.

After seeing grafting in The Netherlands, where this art had been an important technique in ornamental arboriculture for centuries when skilled grafters were relatively plentiful and affordable, the question naturally came up whether all of the traditional elaborate steps were necessary. We share the view of an experienced nurseryman quoted by Bruce Macdonald in his book, *Practical Woody Plant Propagation*, that success in grafting depends 45% on preparation, 10% on the carpentry work, and 45% on aftercare. These three stages as handled in our nursery, are described below.

PREPARATION

We grow the seedlings, preferably from locally collected seeds for climatic reasons. The seeds are sown in November in unheated polyhouses, and covered with 10 mm (3/8 in.) of sand. Seedlings are dug the following October, graded, headed back to 15 cm (6 in.), and the roots are washed and shortened to pot depth. The seedlings are potted high, with the upper part of the root system protruding well above the pot rim, in 55 x 75 mm (2.5 in.) round clay grafting pots or square plastic pots of corresponding volume. The shallow potting places the tip of the hypocotyl about 50 mm (2 in.) above the pot rim, enabling the grafter to carry out the grafting operation. The potted understock is then placed in the bottom-heated raised benches at 13 to 16 °C (55 to 60 °F). Pots are covered with 25 mm (1 in.) of moist peat moss or perlite. No plastic tent is installed at this stage. Seedlings established in pots for one year are preferred over newly potted understock.

GRAFTING TECHNIQUES

Grafting is done at a table during January and February as soon as white roots appear along the perimeter of potballs.

Grafting is done apically (splice grafting) instead of by the traditional side veneer method. We cut the understock off immediately below the first node above the root neck. The scion is inserted on this top or apex. This method was experimentally implemented on a gradual scale over three years, 10% the first year, 50% the second year, and 100% the third year.

We use a modification of cleft or splice grafting. After three years, the results showed that elimination of the ''sap drawer'' part of the understock was a safe step, providing the other elements of care, such as air humidity, temperature, light, and water management are strictly applied. Some incidences of sap bleeding were occasionally observed, without harmful result. Note that the exact place of decapitating the seedling prior to grafting is immediately below the first (lowest) pair of buds, originally located in the axils of the cotyledons, which is at the upper end of the hypocotyl. In *Acer*, the hypocotyl is only approximately 25 mm (1 in.) long, contains no buds and will not sucker. Unlike some species such as *Malus, Prunus, Populus,* and *Rubus, Acer* appears not to produce suckers from any adventitious buds on the roots.

A vertical cut is made in the understock, approximately 20 mm (3/4 in) deep, at the diameter, or middle line of the understock, or at such a distance from the center and parallel with the diameter as will accommodate the thickness of the scion.

The scion is cut on both sides at approximately a 15 degree angle and slightly blunted on the outside bottom to avoid a dead point (without cambium) at the bottom tip. The outside cut is started slightly lower to ensure that the lip top matches the top of the scion cut. This way a ''church window'' is created on the inside cut of the scion.

Rubber ties are used, wrapped preferably only 4 to 5 times around, tight at top and bottom, forgoing the cosmetics of parallel and untwisted ties. Waxing of all grafts going under a plastic tent is eliminated as no desiccation occurs.

As soon as possible, the grafts are placed in the bench on a 10 cm (4 in.) layer of moist peat moss or perlite and the pots are covered 10 mm (1/2 in.) with the same material and covered with a 2 mil clear plastic tent, 20 cm (8 in.) to 45 cm (18 in.) high, supported by a ''duro-wall'' frame. At this time the heat under the benches is raised to 21 °C (70 °F). The grafts are not removed or handled in any way until April, when the plants are moved to polyhouses where the rubber grafting strips are taken off immediately before potting.

ADVANTAGES OF THIS METHOD

The graft carpentry is less time consuming than with the side veneer; and it is easier to hold the scion in place and apply the wrapping. The operation can be done successfully with a lesser degree of skill. Much greater is the advantage during the after-care period, as the grafts are left untouched until planting time.

In the side veneer method, the sap drawer part of the understock begins producing rapid growth much earlier than the scion. By the time scion growth begins, extensive understock growth takes so much light away from the tender new scion growth that they become flimsy, misshapen, and subject to decay, especially after dark days. Attempts had been made to remove the sap drawers while leaving the grafts in the bench. With the approach of pruning shears from the top, the angle was such that a close cut could not be made and much damage was done to the light-deprived, fragile stems and foliage of the scions. We found a proper cutting of the sap drawer only feasible after removal of the grafts from the bench. Even then the plants suffered considerably from being moved and handled at this tender stage. The removal of sap drawers was also time consuming at a very busy time in the spring when every skilled person was needed for activities of a more immediate urgency.

With splice grafting, the need for heading back and for sucker removal during the growing season the next two years is eliminated. A saving of 40 to 50% in after-care time (before potting in container growing pots a month later) and the lack of damage to the fragile plants by handling and moving are also obtained.

We have used the same splice grafting technique for the grafting of *Betula, Alnus, Amelanchier, Carpinus, Cornus, Corylus, Fagus, Ginkgo, Hamamelis, Quercus, Ulmus,* and *Viburnum*. In all our experiences the results were equal to or better than with more traditional methods and less costly.

CHARLES HILDEBRANT: By what method are you maintaining the humidity? What mechanism are you using to control fungus invasion?

TOM INTVEN: The poly tent keeps humidity high. It is sealed tightly and creates a sweat box. The peatmoss is moist and supplies the moisture. We keep it sealed for about 2 weeks.

We have no problems because of the lack of foliage and never have used a fungicide.

HENDRIK CLARK: When do you bring the rootstocks into the house for grafting?

TOM INTVEN: Late October or November and then keep them on the bench through December at 50 to 55 °F. The understocks are brought in after one or two good, hard frosts which cause leaf drop. We graft in January and February.

HOW RECORDS CAN IMPROVE GRAFTING

EDWARD L. CARPENTER

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At Midwest Groundcovers we custom graft *Pinus, Picea,* and *Juniperus*. This discussion revolves around the side veneer and the side graft used on these plants. However, these ideas can be used in other forms of grafting and budding. The object of record keeping is to repeat a successful crop of grafts, or to improve upon a poor crop of grafts by identifying any actual or potential problems.

This paper is divided into two parts. The first is record keeping on the grafter and the second is record keeping on the plant material. Before starting, an action plan is given to all those involved with the grafting process. The plan explains the grafting schedules, how to prepare understocks, how to take a scion, how to make a graft, the cultural care of the graft, spray program, and how the "takes" will be measured. This eliminates any confusion and problems that might arise.

RECORDS ON THE GRAFTERS

The primary reason to keep records on the grafters is to see who can graft well. By recording the facts, personal feelings are eliminated. The idea that the best grafter is the person who has been with the nursery the longest, or who is the fastest, is no longer a valid point. It is important to determine the successful grafters because they should be the ones responsible for the grafting operation and instructing new employees on correct procedures.

Records the supervisor should keep include whether the grafter keeps a sharp and clean knife, how quickly the graft is actually made, and the handling of plant material during the grafting process. A person can make textbook perfect grafts, but have a low percentage live because of the amount of time involved to make the grafts. For example, an employee who cuts and recuts the understock, puts the scion in the understock, takes it out and fits it in again, while trying to get a perfect looking graft is allowing the cambial layers to dry out and die. The supervisor should observe how the employee handles the plant material during the grafting operation. Things to watch for include leaving the scions on the work table for extended periods of time, placing the finished grafts in the greenhouse properly, and if the heeling-in crew handled the plants with proper care to avoid jarring the scion loose.

Each grafter keeps a daily record (see Form #1). This consists of the cultivar, quantity grafted, and comments. In the comments section the employee makes notes, such as dry scions, understocks in poor shape, poor root development, and that the size of the scions and understocks do not match. This is used as a reference if problems are encountered.

A year ago, Midwest Groundcovers experienced a drop in percentage of good grafts made in the afternoon. This was determined by numbering the flats and then placing them on the bench in that order. With this information other work, such as scion collection or understock preparation, can be planned in the afternoon to avoid this poor production time.

RECORDS ON THE PLANT MATERIAL

The reason for keeping records on the plant material is to use this information to have the best possible material available for the grafting process. Types of records that are kept during scion collection include: when the scion was taken, whether an extremely cold or windy front was passing through, and if the air temperature was sufficiently warm to prevent damage when the scion was collected. Records that should be kept after the scion is collected include: aftercare, and length of time in cold storage. Each bag should have a label in it with the cultivar name, and the date collected so the scions are used in proper order.

The records on the understocks should include whether they are straight or curved, the diameter, presence of good color, when they were placed on bottom heat, and stage of root development at time of grafting. Comments are also made if something unusual happens, such as the heat going off in the greenhouse or the cooler not working.

Records are also made on the cultural care of the graft after it is placed on the bench and heeled in. Special notes are made if the heat fluctuated during the heeling-in process, or whether there was adequate moisture present, and at what temperature was the bench maintained. The exact heeling-in process should be recorded, in order to be aware of conditions as the graft heels.

By keeping records such as these if there should be a crop failure then the reason can be better determined or an outstanding crop can be duplicated. The successful grafters are identified so they can be responsible for the grafting process, and provide the best cultural care to the plant while it is heeling-in.

Record keeping should not take all day, but a few seconds at a time throughout the day can lead to improvements, save time and effort and increase your success.

FORM # 1 DAILY GRAFTING RECORD

NAME: _____

DATE	CULTIVAR	QUANTITY	COMMENTS

RALPH SHUGERT: With conifer scions, are you storing or using them quickly?

EDWARD CARPENTER: We try to use them quickly except if we see a real cold weather front is coming through. We try to use them within a week, but this is not always possible in the Chicago area.

RALPH SHUGERT: Thirty years ago a question was raised on frozen scion wood. How do you handle freshly-cut frozen scion or cutting wood.

EDWARD CARPENTER: If it is frozen we handle it as carefully as possible. We bring it into the cooler and gradually thaw it out.

RALPH SHUGERT: I notice that you are not using bottom heat with juniper grafts. Is that expedient or desirable?

EDWARD CARPENTER: We are using bottom heat and it seems to help.

JOERG LEISS: Do you cover the spruce grafts right up to the needles? I see a problem with that.

EDWARD CARPENTER: We cover both pine and spruce grafts.

SEASON, GENOTYPE, AND APPLICATION METHODS AS THEY AFFECT PACLOBUTRAZOL-INDUCED ROOTING OF CUTTINGS OF SEVERAL HARDWOOD SPECIES

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Abstract. Paclobutrazol was effective in increasing the percentage rooting, or root numbers, for some species but not others The effectiveness of paclobutrazol was greater in the spring and summer and less in the fall Paclobutrazol-treated *Euonymus kiautschovica* cuttings grew only slightly less than control plants in early- and mid-summer; however, late summer paclobutrazol-treated *Prunus serrulata* 'Kwanzan' and *Forsythia* × *intermedia* propagules did not elongate. At least one hour of paclobutrazol immersion of leafy cuttings is necessary to observe plant growth regulator effects.

REVIEW OF LITERATURE

Paclobutrazol, a gibberellin synthesis inhibitor, has many effects on plant growth including reduction of shoot elongation and leaf size, and altering flower production and leaf water loss (2, 4). Paclobutrazol has also increased the number of roots and percentage rooting of herbaceous and hardwood cuttings (1, 3). In these experiments, the basal ends of the plants were dipped in solutions of paclobutrazol for at least 36 hours. This method of application would be too costly to be feasible unless large differences in success were demonstrated. In addition, the seasonal effect of paclobutrazol on rooting has not been fully investigated. Theoretically, the effectiveness of paclobutrazol should be minimal when gibberellins are at lower concentrations, e.g. in the late summer and fall. The information presented in this report was designed to address these questions and expand the information available on the effect of paclobutrazol on rooting of a wider range of woody species.

MATERIAL AND METHODS

All cuttings were taken from outdoor-grown plants, trimmed to 15 cm length (except *Chionanthus*, 6 cm), stripped of excess leaves or leaf surface, treated, then placed in perlite-peat (3:1, v/v) in plastic nursery tubes (4 cm dia x 9 cm depth; 67 per tray). The cuttings were then placed in an outdoor plastic-covered

intermittent mist chamber supplied with bottom heat (25°C). Except for *Chionanthus virginicus* and *Cornus kousa*, where 24 cuttings were used per treatment; all root data represent more than 60 cuttings per treatment level. Other species tested included: *Acer palmatum* 'Bloodgood', *Euonymus kiautschovica, Prunus serrulata* 'Kwansan', *Syringa reticulata, Rhododendron* sp. and *Forsythia* × *intermedia*.

Paclobutrazol and control (water and Tween 20) treatments were applied for 40 min. to an hour, unless otherwise noted, by immersing the leafy cuttings in the test solution (immersed) or by immersing only the basal end of the cutting in the test solution (basal dip). Cuttings were allowed to dry for 5 min. after treatment. Paclobutrazol 50WP was used as supplied by ICI Americas Inc. (Goldsboro, NC). Initial experiments inadvertently used concentrations above the normal solubility of paclobutrazol in water (35 mg/liter); thereafter, saturated solutions were used by adding >50 mg/l paclobutrazol to water and mixing. Wood's formulation of auxin (1.03% IBA and 0.51% NAA; Wood's Nursery, Portland, OR) was used (1/4 for *Euonymus*, or 1/20 strength for other species) on all cuttings except as specified. The cuttings were basal-dipped in the Wood's solution for 30 sec. and allowed to dry for 2 min.

The number of roots per cutting and root length were counted after 1 to 2 months in the propagation chamber. For *Euonymus*, rooting was also scored using the following general scale: 1 = no roots; 2 = 1 root per plant; 3 = 2 to 5 roots per plant; 4 = >5 roots per plant, but only a loose root ball; 5 = >5 roots per plant but with a firm root ball. Chi-square analysis was performed on these data at the 1% level.

Twenty *Euonymus* plants per treatment from a March experiment were allowed to grow in 15 cm clay pots in the greenhouse until October, when shoot length was recorded. August-treated *Prunus* and *Forsythia* cuttings were also potted and shoot growth was observed in October.

RESULTS AND DISCUSSION

In the initial experiments, both auxin and paclobutrazol enhanced the percentage of *Euonymus* cuttings that rooted, from near 40% to near 70%, as well as the number of roots per rooted cutting (Table 1). A mid- to late- summer 1-hr immersion application of paclobutrazol to leafy cuttings also enhanced rooting in four of six species; however, their percentage rooting was increased by an average of only 12% (Table 2). Except for *Prunus*, the number of roots per cutting was not enhanced.

Table 1. The effect of paclobutrazol on the number of roots per rooted cutting of *Euonymus kiautschovica*. Two experiments were conducted, each using a 10-min. saturated paclobutrazol (paclo) immersion. Auxin treatment was a quarter-strength Wood's formulation (ANOVA P=5% for auxin and paclobutrazol effects)

Treatment	Number of roots		Mean
	Expt. 1	Expt. 2	
Control	8.8	12.4	10 6
Control + auxin	8.7	30.9	19.8
Paclo	25.2	39.4	32.3
Paclo + auxin	26.7	33.8	30.5
LSD P=5%	11 0	9.6	

The results from previous experiments indicated differences in uptake from basal cuttings may have caused genotypic variation in response to paclobutrazol (3); however, after five to ten minutes, leaves of immersed cuttings of some species became waterlogged. A positive rooting response to paclobutrazol of *Euonymus* cuttings was obtained after a 1-hour immersion (Table 3).

Table 2. Effect of a 1-hour June-August immersion application of paclobutrazol (paclo) on the percentage rooting and number of roots per rooted cutting (in parentheses) of six species of woody plants.

Genera	Control (%)	Paclo (%)
Syringa	58 (9)	53 (8)
Chionanthus	16 (3)	27 (2)
Acer	23 (2)	40 (3)
Prunus	47 (11)	58 (17)
Cornus	8 (2)	18 (3)
Rhododendron	95 (4)	87 (4)

Applications of paclobutrazol by basal dips were less effective when treated for up to 24 hours. Pre-spraying the stock plant with a saturated solution of paclobutrazol four days before cuttings were taken was effective (Table 3). The enhancement of rooting in these experiments was generally less than previously reported for herbaceous plants using a >36 hr basal dip (1, 3); however, immersion for one hour, or pre-spraying source plants, requires much less work.

Table 3. The effect of various application methods on the root score of *Euonymus kiautschovica* cuttings treated with saturated paclobutrazol (paclo) solutions Significances are from chi-square comparisons of proportions of paclobutrazol-treated root scores with the control

Application treatment	Control	Paclo	Significance
10 sec immersion	3 7	3 5	NS
1 hr immersion	2 7	4.1	1%
6 hr basal dip	2 4	2.8	5%
24 hr basal dip	3 1	3 2	NS
Spray source plants	3 3	4 0	1%

NS = not significant

Unless there were variations in plant absorption of paclobutrazol, there may be other reasons for the observed genotypic variation (Table 2). When *Euonymus* cuttings were treated with paclobutrazol throughout the growing season, the amount and direction of the response varied (Table 4). Later season applications were less effective; theoretically, gibberellin activity is reduced and/or endogenous inhibitor concentrations would be greater at this time. If paclobutrazol enhances rooting because it inhibits gibberellin synthesis, this reduced late season effectiveness would be expected.

Table 4. The effectiveness of paclobutrazol on the root score of *Euonymus* cuttings treated by immersion during various months. Numbers given are (root score of paclobutrazol treatment/control treatment root score) × 100%. All values of paclobutrazol treatments are significantly different (P = 1%) from controls using a chi-square analysis of root score data for each experiment.

Month of treatment	Effectiveness
February	150
March	117
June	154
August	113
September	79

There is an additional caution regarding the use of paclobutrazol in August or September. Early season application of paclobutrazol to *Euonymus* did not significantly reduce total growth, although flowering occurred in the fall on 29% of the treated plants (Table 5). Most of the (mathematical) difference in growth occurred early (data not shown). Some early growth inhibition was found in some species in a previous early season experiment (3); but most recovered within weeks. In contrast, mid- to late- season application of paclobutrazol resulted in reduced growth of *Forsythia* (Table 6) and a 75% reduction in bud break of *Prunus* (data not shown).

Table 5. The effect of spring application of paclobutrazol on the subsequent growth of *Euonymus kiautschovica* cuttings after 7 months Shoot length differences were not significantly different.

Application	Shoot length (cm)	Plants with flowers (%)
Control	31 6	0
Paclobutrazol, 10 sec immersion	28 8	0
Paclobutrazol, 1 hr immersion	25.6	29

In summary, early season application of paclobutrazol can enhance rooting with little reduction in plant growth, although in some species it may not be worth the extra expense. Late season application may not enhance rooting but the effect on shoot elongation may be substantial. An immersion of one hour, or prespraying stock plants, are effective methods for application of paclobutrazol to enhance rooting in some species

Table 6. The effect of paclobutrazol (paclo) immersion time on the percentage rooting and shoot elongation in cm (in parentheses) of *Forsythia* cuttings taken in August.

	Treatment time		
Treatment	10 min	1 hr	6 hr
Control	73 (24)	93 (27)	69 (17)
Paclo	82 (20)	73 (12)	74 (4)

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BILL INTVEN: When soaking plant material in liquid, the humidity of the air may have an influence on the amount of auxin taken up. I base this on experience in Holland and Canada. I had seen all kinds of success rooting with auxins in Holland. When I moved to Canada the first year I almost failed and had tip burn. I came to the conclusion that the amount of liquid and chemicals absorbed by cuttings depends on how much water the cuttings absorb. The air was more humid in Holland and they absorbed much less while the tips burned in Canada. I assumed they absorbed more chemical in Canada.

HARRY SWARTZ: I agree with you that you can concentrate more material by moving more water through the cuttings. The basal dip was done in the summer when temperatures were around 100 °F so there was a lot of transpiration. We had to replace the water on the 24 hour soaks. The 24 to 36 hour periods are just too long for use and the one hour dip was the easiest for me.

BRUCE BRIGGS: What was the concentration of spray on stock plants?

HARRY SWARTZ: A saturated solution of 30 ppm.

BRUCE BRIGGS: Did time of day for spraying have any effect? I ask this question because we know hormone actions are influenced by temperature.

HARRY SWARTZ: We did not repeat it at different temperatures but hope to study that point.

MIKE ANDERSON: What is the toxicity of the product?

HARRY SWARTZ: It is relatively nontoxic. It is a fungicide, and we handle it with gloves. It does not act as a fungicide because much higher concentrations are needed for such action. It's a triazole with very low acute dermal, toxicity (LD) of > 1000 mg/kg on rats.

PETER VERMEULEN: What is the residual effect?

HARRY SWARTZ: On most of the species the effect lasts less than 6 weeks. In my treatment I have noticed effects up to 18 months. Therefore you need to be careful with stock plants. In tissue-cultured plants I have noticed that it decreases stomatal water loss. Also it has been reported to increase waxiness of the tissue culture plants.

STORAGE OF CUTTING WOOD PRIOR TO STICKING

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This topic has been reported in many of our *Proceedings* as well as *The Plant Propagator*. In addition, many published papers allude to cutting storage, relative humidity, temperature, and duration. I will discuss Zelenka Nursery's experience regarding the storage of *Juniperus, Taxus,* and *Thuja* cutting wood. I will also comment on some of the published data that enabled our nursery to warrant R&D testing and eventually establish an accepted production practice.

The phrase "carbohydrate-reserves" was capably explained by Sid Waxman (12) at our 1962 meeting in Cincinnati. He was discussing the taking of *Taxus* wood prior to the rest (dormancy) in the buds being completely broken. At this same meeting, Ray Halward (6) advised us to store dormant scionwood at 2 to 5 °C (35 to 40 °F) with high humidity. He commented that without sufficient humidity this technique will not be successful. At our Newport, Rhode Island meeting in 1966, Jim Law read Darrell Holmes' (7) paper discussing storing *Juniperus* wood for "several days", and dormant deciduous wood from October to April. The following year in Mobile, Alabama, during a question period, Vince Bailey (1) discussed refrigeration of conifer cutting wood over-winter, and sticking the cuttings in April. This fine nursery has been using this practice since the mid-1950s.

The one paper that I can so vividly recall was the one presented by Dick Cross from Minnesota (4) in 1971 at Norfolk. I can still hear his words stating that never again will he go to the field with brooms to sweep the snow away from stock plants. He would collect about 30 bushels of cutting/scion wood and place them in his root cellar. He cautioned all of us to have the wood dry to avoid mold. This was a great paper and those of us who have waded in snow up to our knees were very sympathetic to this great propagator's words.

A dynamic paper relative to this topic was presented in 1977 by D. H. Simons (10) from the Australian Region. He stressed that the major function of storage is to avoid change or to slow down cell deterioration. Since cutting wood has no root system, it is extremely susceptible to water loss. This paper helped me to understand, somewhat, the conversion of starch to sugar at low storage temperatures as in the case of Irish potato and the complete reverse of this phenomenon with sweet potato. When I asked him how

much time is required for the conversion, he surmised, "slowly over prolonged storage periods". I want to believe that this conversion contributes to higher rooting percentages when we stick properly stored cutting wood.

When we met for the second time in Toronto in 1978, the Graduate Student Award paper presented by Barry Eisenberg (5) covered this topic. Granted, he discussed the merits of LP (low pressure) and RF (refrigerated storage), but I am certain that Sid Waxman would agree that the physiology is comparable. The following year, in St. Louis (1979), my good friend Dave Bakker (2) discussed freezing bareroot liners, cautioning all of us to maintain high humidity or we would have serious storage problems. This comment was repeated in 1980 by my mentor, Hugh Steavenson (11), who commented how important the Bahnson humidifier was in his storage facility. This humidity factor was mentioned by Shugert (9) in 1982 and by Richey (8) in 1986.

A 1984 paper presented by Volker Behrens (3) from West Germany, discussed the storing of ten coniferous species/cultivars at four temperature regimes and, at 2°C (34°F), had a high reduction of sugars. Strangely this paper did not reference humidity.

I would be remiss not mentioning jacketed storage often used by our G.B. & I. members. Many of us saw this for the first time in August, 1973, when we followed Jim Wells on our pilgrimage to the United Kingdom. Some of us in the room this morning also saw the jacketed cold store at Nick Dunn's nursery in August of this year on the G.B. & I. tour. This storage tool holds the temperature at a constant 0 to 1°C, and is used for cutting wood and understocks. I suspect a few people in the room this morning have had jacketed cold store experience.

I shall now explain the Zelenka Nursery practice for the storage of unrooted cuttings of *Juniperus*, *Taxus*, and *Thuja*.

As I earlier commented, at our nursery we mandate that an R&D project must proceed for three years before we can change an accepted Zelenka Nursery practice. I serve as the R&D Department, and some of my projects were such dismal failures they didn't require the second and third year test. Happily, R&D No. 86-2—"Storage of *Taxus* cutting wood" was successful.

The large quantity of wood needed is predicated on our nursery's production plan. Wood is required for our contract grower for sales, and for "insurance cuttings". Due to the above cutting wood requirements, in 1989 we collected wood for one million *Juniperus*, 1-1/2 million *Thuja*, and 5 million *Taxus*. Of the above total, half will be stuck by our contract grower and half by Zelenka's head propagator.

Timing of taking the cuttings is not a major concern of mine. I was taught, over two score years ago, that coniferous evergreens must have several hard frosts prior to taking cuttings. This is wrong! In 1955, Hugh Steavenson and I, in Elsberry, Missouri, took *Taxus* cuttings in September, stuck them in ground beds and transplanted the following September. I am glad that Hugh and I did not read the book! A charter member of our Society, Dick Filmore, guided us on this procedure since none of us had any asexual propagation experience. Therefore, frost "hardening-off", etc. is not a primary concern. We start with *Juniperus* in late September, with a completion date of mid-October. This cutting wood comes entirely from container-grown plants, so there is close communication between the Propagator, the Container Cultural Manager, and the Quality Inventory Control Department. These folks exchange pleasantries often during this three-week period. The *Taxus* and *Thuja* wood is harvested from field-grown plants and *Thuja* windbreaks, beginning in mid-October and is completed by mid-November. We were about a week late this year (1989), due to an unseasonable winter blizzard bringing snow, ice, and high winds.

We handle all wood from the three genera the same. Harvest is with hand shears, and on occasion some *Taxus* are harvested with a modified combine. The cutting wood is loosely placed in slotted pallet boxes to allow air circulation, and the pallets go into refrigerated storage (34 to 36 °F) with 90% humidity provided by the Bahnson humidifier. In my opinion, humidity is the key to this storage technique. I say this since several years we rented storage space from a perennial grower neighbor who carries his humidity about 40%, and we had desiccated cutting wood. Another fascinating feature of this storage, which possibly goes back to starch/sugar conversion, is that if you take *Taxus* 'Hunnewelliana' cutting wood, showing some brown winter needle color, after about three weeks the foliage is green again! The humidity factor also enters the picture when we recall earlier research, Simons (10), reminding us that cutting wood is susceptible to water loss since the root system is absent.

I have been asked how long wood can be held under these conditions—we have stored for seven months. The earlier mention of "insurance cutting wood" enters into the picture at this point. Assume, heaven forbid, that a catastrophe occurred such as a thermostat malfunctioning and a bench of cuttings burns up in February. With wood in the humidified refrigeration, you would have time to restick that bench and not lose one year of production time. Any "insurance" *Taxus* wood remaining is utilized by sticking one ground bed polyhouse in mid-March, and the balance in mid- to late- April. This technique has been used for many years by

propagators in Lake County, Ohio. You will hear the phrase "twelve month" *Taxus* used with this practice.

In review, and contrary to propagation textbooks of another decade, *Juniperus, Taxus* and *Thuja* wood CAN be harvested prior to hard frosts, CAN be stuck without stripping basal foliage, and CAN be stored for a considerable amount of time. Obviously, any wood under stress, water related/nutritional problems/disease, is going to present problems. I firmly believe that the key is humidity, and if you try this practice at your nursery try to maintain humidity levels of 90%.

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CHARLES HILDEBRANT: Have you done any work with an anti-desiccant in your storage?

RALPH SHUGERT: No. I have had many years of anti-desiccant use in field studies and none of them have been satisfactory.

WAYNE LOVELACE: My question is in reference to your stated lack of a cold period on taxus. At Forrest Kealing Nursery we use basically the same technique, except we feel we are getting the cold period in the cold house. Do you feel that you are getting that cold treatment in storage?

RALPH SHUGERT: I think the key for the grower is that it eliminates the need to collect frozen wood. I do not know the answer to your question but there may be a starch-sugar conversion at the cold temperature. I think there is a need for a cold period but there may also be a different effect.

GARY RITCHIE: We root a lot of Douglas fir cuttings out west. When we experimented with different temperatures we found that -1 °C extended our storage life dramatically. Mold colonization is also prevented. Cold storage may be satisfying the chilling requirement for bud dormancy and therefore satisfying the need for a cold requirement present before taking the cutting. We have found that with early winter cuttings the longer the storage the better they root, up to a point.

RALPH SHUGERT: Did you have the same humidity at the various temperatures?

GARY RITCHIE: Yes, it was probably close to 100% because we placed the cuttings into clear plastic bags and each contained a large block of saturated Oasis material.

PROPYLENE GLYCOL QUICK-DIPS: PRACTICAL APPLICATIONS

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INTRODUCTION

Liquid quick-dips have steadily gained popularity as a means of treating cuttings with auxin. Traditionally, alcohols have been the primary solvents for synthetic auxins (4, 5, 6, 7, 9, 10). However, in some cases alcohols in combination with auxins have proven to be deleterious to cuttings. Alcohols have been implicated with basal necrosis, premature leaf drop, and abnormal root development (1, 3, 4, 6, 7, 8, 9, 12). Alternatives to alcohols do exist and have been used on a limited scale, (5, 6). Barnes (2) and McCrachen (9) have both done research with propylene glycol with positive results. McCrachen (9) showed that propylene glycol reduces the oxidation rate of IBA in solution and that the activity of propylene glycol-IBA solutions remains stable after one year. His work also showed that dips of IBA in propylene glycol at concentrations of 1000, 3000, and 5000 ppm were slightly superior to equal concentrations in ethyl alcohol. In some cases the positive correlation was as much as a 10% improvement. Dirr (6) lists *Berberis thunbergii* 'Crimson Pygmy' as being highly sensitive to ethanol quick-dips. McCrachen showed that with this species, root quality was superior with propylene glycol dips as compared to ethanol dips.

Research by Barnes (2) over the past two years has shown propylene glycol to be an effective auxin solvent. Several points of use and application are presented here.

LIQUID DIPS

Liquid quick-dips from auxin and propylene glycol can be made in two ways:

1. Pure auxin crystals can be dissolved in either 50 or 100% propylene glycol to make up a concentrated stock solution. Normally, these solutions are prepared with a concentration of 10,000 ppm (1%). These solutions can then be used as any other quick-dip preparation. Dirr and Heuser (6) give an excellent review of quick-dips. It is important to note that auxins (IBA and NAA) do not readily dissolve in (50%) propylene glycol unless the solvent is heated to around 160°F, although upon cooling, auxins will not precipitate out. The new auxin, phenyl-indole thiolobutyrate, will dissolve in propylene glycol (50%) to about 2000 ppm when heated.

2. Liquid quick dips can be made from auxin-talc powders. In this case a given amount of talc preparation, (commercial rooting powders) is put in a kitchen blender and blended with 50% propylene glycol to give a workable solution. The ratio of powder to the solvent can be adjusted to make any concentration up to around 5000 ppm. (Note, if the solvent is heated, greater concentrations can be achieved). It is convenient to make such solutions in a ratio of one part powder to nine parts solvent. A 4% IBA talc powder, when mixed with glycol, will result in a solution of approximately 4000 ppm IBA. Machen (11) gives an excellent paper on the making and blending of hormone formulations. By using the blender method, constituents such as boron, rooting co-factors, and fungicides can conveniently be included (2).

For the average nurseryman, auxin solutions made from talc powders are the easiest to prepare and use. A survey of Dirr and Heuser (6) indicates that the majority of plants can be rooted with an auxin concentration of 1000 to 3000 ppm. Solutions of these types can be easily prepared with a kitchen blender, a kitchen scale, measuring spoons, and some measuring cups. Any commercial rooting powder is suitable for these solutions and the 50% propylene glycol can be obtained from many recreational vehicle centers as a water system antifreeze.

While these solutions can be used like any other quick-dip, it is important to make some basic considerations. The cuttings must be wounded, and the drying time for treated cuttings is longer than what would be with an alcohol quick-dip. However, this is offset by more auxin being made available to the cutting.

We have used glycol-auxin solutions for the following types of cuttings: hardwood conifer, soft and hardened springwood cuttings, and ripened one year growth of broadleaf evergreens (Table 1).

Table 1. General production with propylene glycol quick-dips.

Deciduous	IBA conc. (ppm)	Rooting (%)
Franklinia alatamaha	1000	100
Hamamelis vernalis	1000	90
Prunus serrulata 'Kwanzan'	1000	100
Viburnum 'Alleghany'	1500	85
Viburnum carlesii	1500	95
Evergreens, conifers		
Calocedrus decurrens	2000	80
Cedrus deodora	2000	85
Chamaecyparis obtusa cv.	2000	90
Cryptomeria japonica 'Sekan-sugi'	2000	100
Juniperus chinensis 'Hetzii'	1000	100
Taxus cuspidata 'Densiformis'	1000	95

Evergreens, Broadleaf		
Camellia sinensis	2000	88
Ilex glabra 'Shamrock'	1000	100
Ilex opaca 'Old Heavy Berry'	1000	100
Skimmia reevesiana	1000	100
Ericaceous		
Leucothoe axillaris	1000	90
Pieris japonica	3000	80
Rhododendron 'Delaware Valley White'	1000	100

The use of any new technology should be followed with prudence. In some cases, glycol solutions are not superior to alcohol quickdips; however, this seems to be offset by some rather startling results with difficult-to-root plants (Table 2).

Table 2. Difficult to root plants response to glycol quick-dips.

Species	IBA conc. (ppm)	Rooting (%)
Betula spp.	1500	80
Cercidiphyllum magnificum 'Pendulum'	1500	60
Calycanthus floridus	1500	80
Chionanthus virginicus[1]	4000	77
C. virginicus[2]	4000	35
Elliottia racemosa[3]	4000	50
Fraxinus chinensis[3]	2000	80
Osmanthus americanus	2000	100
Pinus roxburghii[3]	2000	80

[1] [2] One and 10 year old mother plants respectively
[3] Cutting rooting in samples of (10) or less

Table 3. Propylene glycol solutions· pros and cons.

Advantages	Disadvantages
Less basal burning	Cuttings should be wounded
Leaf drop negligible	Longer drying time[1]
Non-toxic solvent	Solvent must be heated
Less volatile solvent.	

[1] This is off-set by auxin remaining in solution longer and is more available to the cutting.

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DAN STUDEBAKER: How long do you let the cuttings dry?

BILL BARNES: About 15 min., so it is not a serious impediment.

DAN STUDEBAKER: Is it fairly stable after it is on the cutting?

BILL BARNES: Yes, it is. One thing we like about the glycol formulations is that we can add food dye to the dips. Therefore, I can tell the workers to dip the cuttings in a specific colored solution; it solves a great deal of problems.

RICK LEWANDOWSKI: What about the presence of fungicides in the solution?

BILL BARNES: We have found no effect from thiram. But Benlate has worked with *Prunus subhirtella* ''Plena Rosea''. It did help the rooting.

RICK LEWANDOWSKI: You mentioned storage for 21 days. Is that related to flocculation of the IBA out of solution?

BILL BARNES: We have found no effect from thiram. But Benlate has worked with *Prunus subhirtella* 'Plena Rosea'. It did help the rooting.

RICK LEWANDOWSKI: You mentioned storage for 21 days. Is that related to flocculation of the IBA out of solution?

BILL BARNES: When we use a blender mix, we use large quantities of glycol and water, make a gallon, for example, and microbial action may occur.

RICK LEWANDOWSKI: With difficult-to-root species, is timing still critical?

BILL BARNES: On difficult-to-root species timing is very critical. In our area late May and June is the most important time. Very soft tissue is best for rooting.

MAJORIE HANCOCK: Have you used this material with lilacs and Japanese maples?

BILL BARNES: Yes, with the Japanese maples, particularly dissected types and with 'Bloodgood'. On French hybrid lilacs we have had variable results. Much clonal differences in rooting of French lilacs exist and this shows up in our rooting.

JOERG LEISS: Do you use powders to make your solutions?

BILL BARNES: We use crystals for the concentrated auxin solutions. To make large volumes of solution we use talc powders because all you need is a measuring spoon and blender, and that saves time.

VOICE: Have you used this method with herbaceous material?

BILL BARNES: Yes, it works well.

VOICE: Can you cite any examples?

BILL BARNES: *Chrysanthemum pacificum* and some phlox. We use about 1000 ppm concentration.

TOM McCLOUD: Were the solutions stored in the dark?

BILL BARNES: No, in the light in a clear glass bottle to test storage under adverse conditions.

VARIABILITY AMONG WITCHES'-BROOM SEEDLINGS

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One very productive method of developing new forms of dwarf conifers is by the germination of seeds collected from witches'brooms. These mutations which occur on many conifer species are far more common than I thought they were when I first started looking for them 25 years ago. At that time I would drive hundreds of miles to see them. Now, after all this time I have come to realize that they are not so rare. On my property, consisting of ten acres, I have found two white pine witches'-brooms, one of them no further than two feet from my deck.

Grafts made from a witches'-broom will of course, result in a group of dwarf plants all genetically identical. Propagation of seeds from a broom, however, will result in a group of diverse seedlings, each having its own genetic makeup. Witches'-broom progenies usually consist of seedlings in which half are dwarf and half are normal. The normal seedlings are either discarded or used for rootstocks. It is among the former group of seedlings that we may discover dwarf forms that are unusual. Such variability occurs not only among seedlings within a progeny, but also between different witches'-broom progenies (Figure 1).

Figure 1. Witches'-broom plantings at the University of Connecticut

Variation among different seedlings may be observed in: foliage color, needle length, needle density, stem diameter, branch density, branch rigidity, branch orientation, annual rate of growth, and plant form. In addition there are differences among seedlings in their ability to be propagated by cuttings.

An example of variation in rooting among seedlings within a progeny is shown in Table 1, where percentage rooting ranged from 0 to 100%. The cuttings were taken August 15, 1989 and rooted by November 15, 1989. Terminal shoots were treated with Hormodin -3, placed in flats of peat and perlite (1:1, v/v) then placed under mist.

Table 1. Variability in the rooting of six *Larix laricina* witches'-broom clones September 1, 1989, to November 15, 1989.

Clone number	Percent of cuttings rooted	Average number of roots per rooted cutting
62	0[1]	0.0
15	100	4.75
60	40	3.50
45	95	8 00
50	70	3.90
61	80	4.70

[1] 20 cuttings per treatment

We have grown, over the past 25 years, several hundred thousand witches'-broom seedlings. These seedlings were obtained from brooms found on:

Larix laricina	eastern larch
Picea abies	Norway spruce
Pinus banksiana	jack pine
P. densiflora	Japanese red pine
P. resinosa	red pine
P. rigida	pitch pine
P. strobus	eastern white pine
P. sylvestris	Scotch pine
Tsuga canadensis	Canada hemlock

My objectives are to constantly evaluate and eventually select those plants that are slow growing, aesthetically pleasing, and different from other dwarf forms currently available. I am very selective and usually wait until the plants are at least seven years old before naming and introducing them to the trade. During the past 25 years I named only 19 plants, most of which were over 10 years old before being named.

Once a plant is named and published, scions or cuttings are distributed to nurserymen who then propagate them and list them in their catalogs.

The characteristics of the various seedlings raised could be described as miniature, dwarf, semi-dwarf, upright, spreading, weeping and prostrate. Several species exhibited seedlings having dark-green, golden-yellow or variegated needles. Variation in needle length, shoot length, and annual growth were dramatic (Table 2). Shape also varies widely among witches'-broom seedlings.

Table 2. A comparison of the dimensions of the largest and smallest witches'-broom seedlings.

	Species and age			
	Pinus sylvestris (5 years)	*Pinus strobus* (25 years)	*Picea abies* (10 years)	*Tsuga canadensis* (18 years)
Smallest seedling				
Height (cm)	21 0	40 6	20.0	90 0
Width (cm)	25 0	60 0	30 0	2 8
Shoot length (cm)	3.0	4.0	3.0	22.0
Needle length (cm)	1 4	2.5	0 7	0.9
Largest seedling				
Height (cm)	28 0	3400.0	2600.0	4200 0
Width (cm)	27 0	3200 0	2900 0	2900 0
Shoot length (cm)	18 0	15 0	14.0	15.0
Needle length (cm)	3.7	7 0	2 0	0 6

Although seedlings within a single broom progeny show considerable variation from one another, an exception occurs in *Pinus resinosa* (red pine) and *Larix laricina* (eastern larch). Here, all seedlings are generally similar in needle length and form. Differences arise however when comparing one broom's progeny with another. In one red pine progeny the needles were very long, the branches loosely arranged and horizontal. In the other, the plants were upright with short needles and very dense stiff branching. *Larix laricina* (eastern larch) also showed minor differences among seedlings within a progeny but showed major differences among broom progenies. In the first progeny all seedlings were conical with a much greater rate of growth than those in the second progeny which were low mounds with a very low rate of growth.

Seedlings from one *Picea abies* (Norway spruce) broom were extremely variable in form and in rate of development. In this progeny were plants that were ovate, circular, broadly ovate,

obovate, and triangular. In another progeny were plants that were mainly broadly ovate and slow growing. In both progenies branching was very dense.

Pinus densiflora (Japanese red pine), *P. sylvestris* (Scots pine) and *P. strobus* (eastern white pine) showed extreme variation in needle length, growth rate, branch density and form.

Tsuga canadensis (Canada hemlock) differed from the other species by exhibiting two degrees of dwarfness within a progeny.

In one progeny some of the seedlings, after 16 years, were taller than wide (4.2 meters high x 2.9 meters wide), while others were wider than tall (1.8 meters wide and 0.9 meters high).

In the final analysis, witches'-broom seedlings are unusual. They are aesthetically pleasing, and functionally valuable. Their wide variation in form and in rate of growth should make them excellent sources of new plant introductions.

VOICE: How long do you evaluate the cultures before introduction? I am particularly interested in height and width.

SIDNEY WAXMAN: As far as my introductions go, I usually wait more than 10 years.

ELWIN ORTON: I understand that you sell your excess plants to generate funds. With so many of them similar, don't you think that some of them are going to get into the trade?

SIDNEY WAXMAN: We sell them to landscapers and ask them not to propagate them.

Tuesday Afternoon, December 5, 1989

The Tuesday afternoon session convened at 1:30 p.m. with Charles Hildebrant serving as Moderator.

NEW FRONTIERS WITH DAYLILIES: FROM A HYBRIDIZER'S PERSPECTIVE

DARREL APPS

Woodside Gardens
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Next year, 1990, marks the 100th anniversary of *Hemerocallis* (daylily) hybridizing. In circa 1890, George Yeld, an English school teacher, made crosses of *Hemerocallis lilioasphodelus* with *Hemerocallis middendorffii* (5). Two years later in 1892 he officially announced the first daylily cultivar, 'Apricot'.

Today there are over 30,000 registered cultivars and nearly 200 active hybridizers. Last year alone 189 different breeders named 1116 new daylilies. Although marketing statistics are not available, daylilies are thought by many to be the number one perennial plant sold in the United States. One of the reasons for their recent popularity is the color diversity in new cultivars; this is especially surprising since the original 23 species were primarily yellow and orange. Today the only color missing is true blue. The fact that daylilies are not native to the North American continent makes their recent widespread acceptance even more intriguing!

DAYLILY MILESTONES

There are several milestones in the advancement of this genus:

1. The first hybrid cross in 1890 by George Yeld (5).

2. The importation of species from Asian countries to the United States. Dr. Albert Newton Steward, living in China, sent more than 50 importations to Dr. A. B. Stout at the New York Botanical Garden from 1924 to 1942 (6).

3. Dr. A. B. Stout published the book *Daylilies* in 1934 (7). This is primarily a record of hemerocallis species and early species hybrids.

4. The American Hemerocallis Society was formed in 1946 and focused special attention on this genus (9).

5. Several individuals began hybridizing daylilies in the United States. Dr. Ezra Krause, a native of Michigan was one of the most prominent (3).

6. A University of Minnesota student Robert Schreiner flowered several colchicine-induced tetraploids in 1947 (8).

7. Dr. Charles Heuser and this author published their work on tissue culturing the first hybrid daylily in the Canadian Journal of Botany in 1974 (4).

8. Dr. Michael Kasha from Florida State University, and his graduate student, Kathryn Bisset, published a paper on the color chemistry of modern daylilies in 1976 (2).

9. This author proposed a system for Selecting Daylilies with Commercial Value that was published in the 1984 IPPS Combined Proceedings (1).

The potential for new cultivar development and the subsequent replacement of inferior named forms is particularly rapid within this genus. Each decade the top 100 listed on the popularity poll is virtually replaced with another 100. Tissue culture propagation has further speeded up the process (at this point in time tissue culture isolation is estimated to be only 50% successful). Because there is a large number of breeders, improvements are rapid with both diploid and tetraploid forms. Individual breeders work intensively with many different forms: dormants, semievergreens, evergreens, *large flowers* (4½ *in.* >), *small flowers* (3-4½ *in.*), *miniatures flowers* (<3 in.), heights from 9 to 48 in., hardy forms, tender forms, all colors, single flowers, and double flowers.

Briefly here are the steps I take from hybridizing to the introduction of new cultivars:

1. **Hybridizing.** Crosses are made from 9 to 11 a.m. each day. In the mid-Atlantic states daylilies can be crossed from May to September. I work with both diploids and tetraploids and successfully store frozen pollen from one season to the next. Pollen sterility and incompatibility limit ''takes'', often to 30% or less. All crosses are tagged with a permanent marking pen.

2. **Collecting seeds.** Seeds mature in approximately 60 days. Seed pods are harvested when the pod cracks. Seeds are usually shiny black—a very few cultivars produce tan seeds. I do not allow seeds to dry or to shrink. They are stored in sealed containers and refrigerated until they are planted.

3. **Planting seeds.** Because of the difficulty with weeds all of my seedlings are now grown in pots until the ramets are ¾ in. across. Seeds are started in 4x4x4½ in. deep plastic pots (Nupot 12),

usually no more than 30 seeds per pot. Each pot is separately labeled with the cross. All seeds are planted in the winter such that the seeds will receive stratification of at least 6 weeks (seeds from evergreen parents do not need to be stratified), usually at temperatures just above freezing. Seeds are sown 2 to 3 times their thickness. Germination occurs in 10 to 14 days at temperatures above 70°F. Weed-free soilless media are used (either Promix or Sunshine Mix depending on the availability and cost).

4. **Transplanting.** Six to eight weeks after sowing the seedlings are pricked off and planted individually into 3x3x3¼ in. deep plastic pots (Nupot 16) using the same media as above. Seedlings are irrigated regularly and fertilized with Peter's 20-20-20 every 2 weeks. I produce 3000 to 5000 transplants each year.

5. **Lining out.** When the individual seedlings reach a ramet width of ¾ in. or greater they are large enough to be lined out in the field. When they are taken out of the pot most roots are found in the bottom portion. This is important because after they are planted the roots will be 3 to 4 in. below the surface and free of injury from pre-emergent herbicides. Rows are spaced 12 in. apart and seedlings are planted 6 in. apart in the row. Aisle spaces 2 to 3 ft. wide are left every few feet so that seedlings are easily reached for hybridizing. Plants are then watered in and Surflan applied at ½ the recommended rate. Generally seedlings from seeds sown during the winter are ready to line out by August 1 of the same year. I try to have all seedlings in place by September 15 so that they have time to "root in" before winter.

6. **Growing.** About one-half of the seedlings lined out will bloom the following summer. All are kept two full growing seasons for final evaluation. All of my soil has been amended with 4 to 6 in. of mushroom compost that is rototilled into the top layer. Each bed receives 3 pounds of 10-10-10 fertilizer per 100 sq ft about May 1. Earlier fertilizing tends to push soft growth and makes plants susceptible to late spring frosts. Plants are irrigated whenever moisture is inadequate. During the second growing season slugs are often problems. They are controlled with baits of metaldehyde and Sevin. Some years thrips need to be controlled. I use three different chemicals, Diazinon WP on May 1, Orthene WP on June 1 and Maverik WP on July 1.

7. **Selecting new cultivars.** Basically I look for new flower color breaks, wide petalled forms and flowers with heavy substance. I do not like to select a daylily for naming unless it flowers for 4 or more weeks and has 20 or more buds per scape. I am especially interested in vigorous, disease-free plants that increase rapidly (2 to 3 new ramets each year). Often I reject a beautiful flowering plant if the

foliage is not a deep green color and attractive all season. I can anticipate 1 to 5 introduceable seedlings per 1000 seedlings.

8. **Marketing.** There are many potential markets available to hybridizers. An obvious one is the 5000 members of the American Hemerocallis Society. Breeders can usually sell 30 to 50 plants of each introduction for $50 to $200 during the first year of introduction. The market preference is currently for large-flowered yellows, pinks, and pastels shades. Miniatures are more difficult to sell.

Recently wholesale nurseries are beginning to purchase exclusive rights for unintroduced seedlings. The amount charged is usually based on the number of plants available. The bottom price is usually $1,000 and can be considerably higher for seedlings with rebloom.

Mailorder nurseries have had good success in selling these highly photogenic plants. Cover shots can generate 3000 to 5000 sales of a new cultivar. In order to get that number tissue culture techniques are usually necessary. Once a daylily is on the cover of a major mailorder catalog its sales potential is greatly increased in all of the other markets.

Landscape contractors usually do not purchase new introductions. Several do buy seedling discards. There is considerable controversy over this practice. Many hybridizers feel that 40 to 60 percent of their seedlings are better than those older cultivars presently being sold. Since all seedlings have to be dug this helps pay for removing them.

Garden centers are more likely to purchase named cultivars that have been introduced for a few years. Several garden centers in the eastern United States market will pay $2.00 to $10.00 per fan. Many hybridizers purchase many new cultivars each year to maintain an up-to-date gene pool. Each year they discard a number of older introductions by selling them to garden centers.

Large tissue culture laboratories are beginning to purchase exclusive new daylily cultivars for their own markets. Because there are many new daylilies to choose from, they usually try to purchase from established, well known breeders.

Not unlike the "you pick" market for fruits and vegetables are "daylily digs". During bloom season customers are allowed in seedling daylily fields to choose the daylily they want a staff member to dig. Some are sold bareroot and others with soil.

The Chicago Botanical Garden is an example of a public institution that has started a plant introduction program called Chicagoland Grows. Daylilies will be one of their new offerings. Daylilies are also being sought internationally: West Germany, Australia, New

Zealand, Japan and England are examples of countries that are beginning to import new introductions.

SOME NEWER DAYLILIES WITH GOOD POTENTIAL

Because of the large number of new plants introduced each year it is difficult for nurserymen to have the knowledge to select the most outstanding new hybrids. Here are just a few cultivars that perform well in many regions of the United States:

'Atlanta Full House'—single, yellow, tetraploid
'Beauty to Behold'—single, yellow, diploid
'Condilla'—double, gold, diploid
'Barbara Mitchell'—single. lavender-pink. diploid
'Siloam Show Girl'—single, red, diploid
'Super Purple'—single, red-purple, diploid
'Window Dressing'—single, white, diploid

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GROWING BETTER MOUNTAIN LAUREL IN CONTAINERS

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INTRODUCTION

For the past decade a group has formed in the corners, halls, restaurants, and elsewhere at the Eastern Region IPPS meetings to discuss mountain laurel (*Kalmia latifolia*) propagation and production. Some of the finest nurserymen and researchers from North America and Europe have participated in these conversations. Therefore, when asked to assemble something coherent on the current state of knowledge concerning mountain laurel production for the 1989 meeting, we expected that all we would have to do was visit some of the better nurseries and we would know how to grow excellent mountain laurel. We were wrong.

During the past year we have visited nurseries growing mountain laurel in eight eastern states (hardiness Zones 5 to 8) and talked with growers throughout the country by phone. Only two nurseries were consistently producing excellent mountain laurel in containers. Nearly all of the nurserymen we visited were growing good, but less than excellent, mountain laurels in containers. By contrast, given enough time and patience, nearly all nurserymen growing mountain laurel in the field were able to produce top quality plants. All of these nurserymen have our thanks. We promised not to tell who is doing what, just share overall findings.

This paper is a selective review of container grower practices. In addition, we have referred heavily to unpublished or about to be published research by Dr. Hummel at Washington State University, Dr. Johnson, University of Georgia, and a group at N. C. State University that includes Dr. Bilderback, Dr. Shelton, Dr. Warren, and Dick Bir. We aren't even close to having all the answers for growing excellent mountain laurel consistently, but with nurserymen and researchers working together we are making progress. Mountain laurel is worth the effort.

By observing mountain laurel in the wild as well as in our gardens, we have discovered certain things. Among these are that mountain laurel does not thrive in wet or poorly drained soils, grows best in acid soils, and does not do well if heavily fertilized. If you transplant an otherwise healthy mountain laurel to the edge of a loamy, fertile

vegetable garden, it seems to slowly look worse and worse until it reaches the point where you may wish it would die. However, it usually lingers reminding you of your mistake

What does this mean when nurserymen want to grow mountain laurels in containers? Since the conditions described, other than soil fertility, are those under which we grow azaleas, it seems logical that an ''azalea mix'' should grow terrific mountain laurel For two nurserymen and some researchers it is.

GROWING MEDIA

Drs. Hummel and Johnson found that they could grow mountain laurel equally well in a medium of 1:1 or 4·1 pine bark.peat in Georgia or 1.1 or 4 1 fir bark:peat in Washington. A particle size analysis of the bark used in both locations showed it to be remarkably similar. However, the fir bark contained significantly more fine particles which could result in a greater water holding capacity Plants in Griffin, Georgia, were grown under 50% lath shade while those grown in Puyallup, Washington were grown in full sun. 'Elf' and 'Freckles' produced good plants in both locations while 'Goodrich' did not produce good plants in either location.

Media components encountered in our nursery survey included hardwood bark, pine bark, fir bark, redwood sawdust, composted hardwood leaves, composted brewery sludge, composted municipal sludge, sand, granite tailings, loamy soil, peat (at least three grades), perlite, styrofoam, and vermiculite. Samples were collected from many eastern U. S. nurseries and analyzed by the Horticultural Substrates Laboratory at N. C. State University

The most consistently excellent plants were being grown in a pine bark·peat mix. Two nurseries growing in peat:styrofoam or pine bark hardwood bark·peat:sand produced plants nearly as good. When the two media in which the best plants were being produced were compared to the two media in which the worst, but still quite good quality mountain laurel, were being grown, we found that the best plants were being grown in significantly lighter (lower bulk density) media that was more porous and had more water available to plants under normal, non-moisture stressed growing conditions (Figure 1).

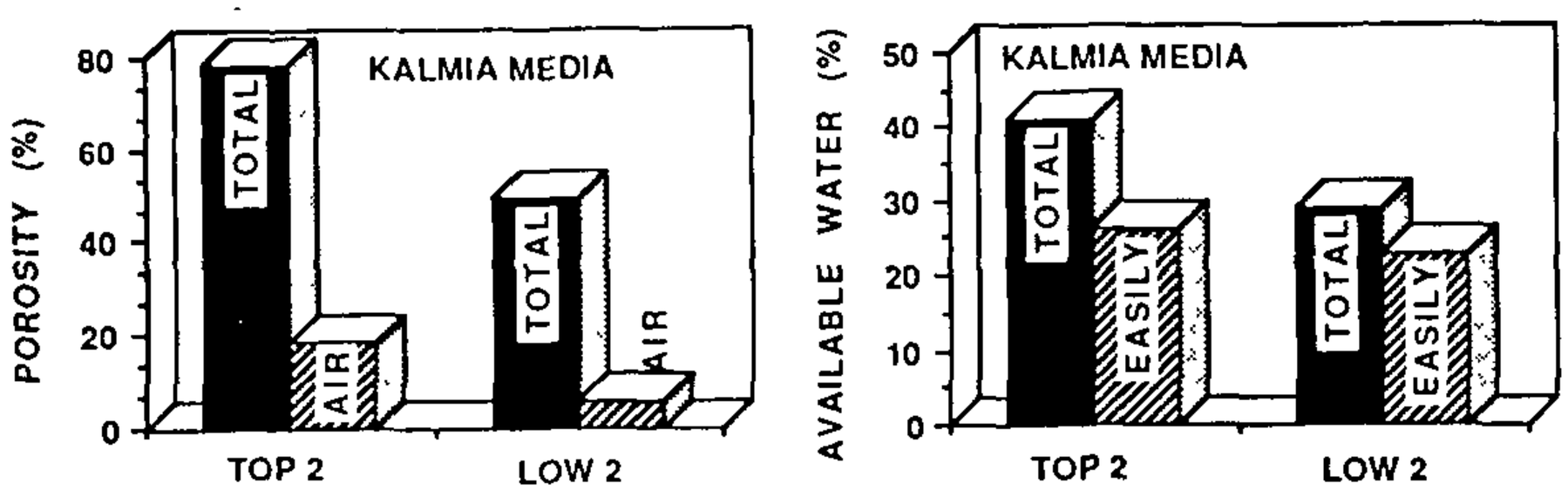

Figure 1. Porosity (left) and available water (right) from survey nurseries growing the best (top) and the poorest (low) *Kalmia latifolia*

What does this mean? Media with more pore space grew the best plants. However, plants need to have both air around the roots and water easily available. It also suggests that unless you are growing mountain laurels tall enough to blow over, sand and other mineral matter are probably costing you growth as well as money in shipping.

IRRIGATION

Two very small nurseries growing mostly seedlings were consistently producing very good plants in poorly drained mixes. We found very good plants grown in media that was neither very porous nor retained much water. Drs. Hummel and Johnson grew statistically equal plants in media that was 50% bark or 80% bark. How? They all irrigate containers only when they need it.

Irrigation management seems to be more important in producing top quality container-grown mountain laurel than having a porous media. Nurseries that were irrigating blocks of azaleas and mountain laurel equally had excellent azaleas but lesser quality mountain laurels. Mountain laurel appears to need less water, i.e., grow them drier than azaleas. Nurseries that grow mountain laurel drier than azaleas also had roots all the way to the bottom of the pot while most other nurseries did not. One grower referred to growing drier as "teasing the roots to the bottom," while those with roots only half way to the bottom of the container after a full growing season said, "it's the nature of the plant to be shallow-rooted." Whatever you call it, mountain laurel can tolerate drier conditions in the wild than some other ericaceous plants and seem to respond positively to watering less often than other plants in container nurseries. Frequency of watering, not how much water was applied was the key. When plants were irrigated, they were irrigated thoroughly.

SHADE

In the northeast or in southern mountains no shade was needed to grow good mountain laurel. However, much better container-grown mountain laurel were produced in the shade than in full sun in the Piedmont of the southeastern U.S. These plants are grown under high pine shade, 50% lath, or fabric shade. The grower with the best container mountain laurel in the southeast grows under both black and white shade cloth. Although he grows fine mountain laurel under both types of shade, those produced under white shade were more visually appealing. Part of this may be due to light quality, but some is probably due to a temperature difference. During the summer, it's cooler under white shade.

FERTILIZATION

One of the real benefits to the research done by Drs. Hummel and Johnson is that similar conditions and the same treatments were applied at opposite ends of the U.S. They found that a combination of 60% nitrate/40% ammonia nitrogen at a medium rate (80 mg N/gallon pot applied as a liquid every two weeks) gave the best growth at both locations.

Soon to be published research on container-grown mountain laurel seedlings by Dr. Warren showed that significantly more growth occurred at 100 ppm N with weekly liquid fertilization than at 50 ppm. However, 200 ppm N did not result in additional growth nor did it visibly injure these plants which were grown in 50% lath shade while those grown in Puyallup, Washington were grown in full sun. 'Elf' and 'Freckles' produced good plants in both locations while 'Goodrich' did not produce good plants in either location. this level during the heart of the growing season.

How does this translate when compared to the various production systems encountered in the survey? In 1988, the best plants I saw were grown using Scott's SREF. In 1989, the best mountain laurels I saw were grown using Scott's ProKote, at the same nursery. The next best plants were grown using Osmocote 18-6-12 or a liquid feed program, feeding weekly with about 100 ppm N. All of the best plants were being grown at levels that should result in at least 100 ppm N. The source of fertilizer doesn't appear to be as important as the rate and management.

Top quality mountain laurels can be grown whether you use a liquid-feed or slow-release fertilizer program. However, attention must also be paid to providing the plants with calcium, magnesium, and minor elements. The best plants were being grown in a pine bark:peat mix to which 5 to 7 pounds per cubic yard of dolomitic limestone was added pre-plant. Commercial minor element sources

at suggested rates seemed to last a full season except in Dr. Johnson's test where a minor element supplement had to be applied mid-season. Since it is hotter longer in Griffin, Georgia than many other places mountain laurel is grown, more irrigation water may have been used He was also using pine bark as a primary medium component, which resulted in a pH of 4.2. Both high water use and low pH media may account for his need for additional minor elements. A medium pH range of 4.3 to 5.5 seemed to produce good mountain laurel otherwise

CULTIVARS AND PRUNING

One question asked each nurseryman concerned which cultivar they liked best in containers and which they liked worst. Every cultivar listed on the "worst" list (except 'Goodrich') also appeared on the "best" list. I attribute these differences to the growers—not to the cultivars. 'Elf' and 'Carol' were most often listed as the "best" with 'Olympic Fire' not far behind. All of the "best" chosen by growers have excellent clean, crisp foliage characteristics when grown in containers. After these three there was a list of nine, all suggested once The new cultivars that seems to be pleasing growers most in 1989 is 'Minuet', which has leaves and habit similar to 'Elf,' but has banded flowers and is slightly less abruptly upright than 'Elf.'

'Sarah' appeared in both "best" and "worst" lists. Whenever it was in a "worst" list, the nursery seemed to fertilize more heavily than those listing it as "best". When Dr. Jaynes was asked about his cultivar, he said 'Sarah' is fertilizer-sensitive and burns easily. When not fertilized heavily, it is a beautiful foliage as well as flowering plant in full sun in the mountains of North Carolina. By contrast, 'Stillwood' drops at least half its leaves each fall regardless of the nutritional program. Much more cultivar evaluation needs to be done under widely varying environmental conditions before we can make firm landscape suggestions in different climates.

The most consistent complaint I heard from growers was related to "floppy" growth. In 1988 and 1989, this characteristic seems due to a number of factors regardless of whether the plants were tissue-culture in origin. Strange growth forms from tissue-culture plants have been discussed at IPPS, in *American Nurseryman*, and elsewhere. I can add nothing to that discussion.

Floppy growth may be due to genetics. Mountain laurels with banded flowers tend to flop more often than whites, pinks, or redbuds Floppy growth may also be related to media. I saw a lot more flopping in pure pine bark than where peat was added to the mix. I suspect it can be caused by nutrient imbalances and growing

in too much shade as well. However, the most consistent reason for floppy plants in eastern U.S. nurseries is failure to prune plants hard when they are small. A soft pinch isn't enough. An unpruned plant 3 to 4 in. tall needs to have at least half of it's height removed to get a good branching response in containers. Unfortunately, sometimes pruning doesn't work either.

CONCLUSIONS

Progress is being made in research to unlock the mysteries of mountain laurel culture. With proper management, it should be possible to provide good to excellent container-grown plants to the landscape market now. As we learn more about mountain laurel growth and the idiosyncracies of cultivar characteristics, even better plants should be available in the future.

BILL FLEMER: Is there any preference to using web bottom pots over cans with holes in the side?

RICHARD BIR: It does not make any difference as long as there is adequate drainage on the side.

PETER VERMEULEN: I have a question on the use of white versus black shade. Was there a comparison between the two?

RICHARD BIR: The best plants were under the white shade from my perception.

CHARLES HILDEBRANT: What is the white shade made from?

RICHARD BIR: A woven plastic material.

THE MARRIAGE OF OBSERVATION AND RESEARCH FOR THE IMPROVEMENT OF WOODY PLANT INTRODUCTIONS

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How many new plants pass muster in the marketplace over the long haul? Forty percent, you say. I venture to estimate less than 5% withstand the test of time. In the fourth edition of the Dirr *Manual* 50 new *Malus* cultivars, 15 new *Spiraea* cultivars, and 10 new *Acer rubrum* selections are included. The question has been asked many times relative to what is known about the new plant's performance capabilities? In most instances, absolutely nothing. Let's take one of Father Fiala's 33 new *Malus* introductions and examine its attributes (2).

'Ballerina' is described as "small, upright rounded, heavily flowering tree to 15 ft high; leaves dark green, disease resistant; white buds opening to large, very cupped, white, single but showy blossoms; fruits, 2/5 to 1/2 in., bright yellow, persistent to hard frosts. Excellent tree for narrow places."

Does this information really tell one *anything* about geographical and cultural adaptability? Certainly not! In Athens, Georgia will this crabapple receive sufficient chilling hours to overcome bud rest? Although touted as disease-resistant, will this attribute hold true in the heat and humidity of Washington, D. C.? Will the plant be cold-hardy in Fargo, North Dakota, or heat-tolerant in Orlando, Florida? Actually, none of these questions can be answered.

Most new woody plant introductions have been discovered through casual or focused observation. Even the progeny from controlled breeding programs were selected more for aesthetics than any other characteristic. Dr. Donald Egolf, Dr. Elwin Orton, and Dr. Harold Pellett's programs have focused on beauty, but also disease-resistance and cold-hardiness.

No individual or program can determine all the desirable traits of a potential introduction; however, many important characteristics can be predetermined. The following are a few that might be applied to any new introduction:

- Cold tolerance (including acclimation, midwinter hardiness, and deacclimation).
- Heat tolerance.
- Drought tolerance.
- Salt tolerance.
- Air pollution tolerance.
- Wet soil tolerance.
- Acid and alkaline soil tolerances.
- Chilling hours—(Hours below 45 °F necessary to overcome bud rest; important for introductions selected from northern seed provenances that will be sold in southern markets).
- Insect and disease resistances.
- Propagability—(Dr. Egolf's latest crape myrtle introduction's include 'Wichita', a cultivar almost impossible to root in commercial quantities).
- Adaptability to container and/or field production systems.
- If field-grown, ease of transplanting.
- Branch flexuosity—(Sufficient so branches are not easily broken in shipping and handling).
- Rate of growth—(Ability to fill a container in an economic time frame, or produce larger caliper).
- Density of crown at a young age—(This is one reason for Bradford pear's salability as a young tree).
- Wound healing capacity.
- Thickness of bark.

The possible criteria are endless but the above examples stress the importance of asking questions about a new introduction's performance capabilities. In our program, we have several potential introductions that may be superior to anything on the market. Most were selected from established plants growing under Zone 8 (USDA) conditions (+10 to +20 °F). The lowest recorded temperature in Athens, Georgia was -3 °F and all plants discussed herein survived without injury. Our goal was to utilize laboratory techniques to determine the acclimation, midwinter hardiness, and deacclimation of the potential introductions. Previous work (1) indicated that laboratory data corresponded with the field cold hardiness of known *Acer rubrum* cultivars. All potential introductions will be laboratory tested. We believe the data will provide an early barometer of the northern geographical adaptability.

POTENTIAL INTRODUCTIONS

***Acer rubrum* 'Edna Davis', Edna Davis red maple.** A 30-year-old tree in Athens offers consistent orange-red to red fall color. This is a seedling of var. *drummondii*, the southern type. The dark

green leaves are smaller than 'October Glory' and 'Red Sunset'. The habit is medium pyramidal with branches uniformly and densely spaced throughout the canopy. Parent is 35 ft high and 25 ft wide. This selection may require less chilling hours than 'October Glory' which cannot be grown successfully in south Georgia. Cuttings root readily when treated with 5000 ppm K-IBA quick dip, and placed in perlite:peat (2:1 v/v) and mist. Cold hardiness tests will be conducted during 1989-1990.

***Nyssa sylvatica*, black tupelo.** As yet an unnamed clone with superb scarlet fall color. The leaves are larger than typical, more leathery, lustrous, and dark green. Habit is typical for the species. The parent female tree is 25 ft tall and 15 ft wide. Dr. J. C. Raulston has successfully March-grafted it on seedling understock.

***Ulmus parvifolia*, Chinese or lacebark elm (four selections).** **'Emerald Isle'** is a broad-spreading elm with a rounded crown resulting in a pleasing globe-shaped outline. It measured 30 ft high and 54 ft wide. At 3 ft from the soil line, the mature tree has a 30 in. diameter trunk and an 88 in. circumference.

The bark exfoliates 2 ft from the ground in a puzzle-like pattern, exposing light gray and gray-green to orangish brown colors. The bark is flecked with orangy brown, corky lenticels. The trunk's base develops a rough, blocky, gray-black bark.

The leathery, lustrous dark green (almost black) foliage is densely borne at the ends of the fine branches, creating a dense canopy. The leaves are more leathery and darker green than the typical phenotype. Fall coloration is bronze-brown and not really effective.

'Emerald Isle' showed no symptoms of leaf scorch during the 1986-88 summers, which have been the driest on record in the Southeast. The tree is also highly resistant to Dutch elm disease and elm leaf beetle.

The leaves are alternate and simple, 1 to 2 in. long and 1/2 to 7/8 in. wide. They are ovate to slightly obovate and lustrous dark green, almost black-green on the top and grey-green on the bottom. Leathery to touch, the leaves can be acute or obtuse. They are oblique and have simple rounded serrations. They are glabrous on both sides and exhibit 10 to 16 vein pairs. The petioles are 1/8 to 1/4 in. long, light green and pubescent. The cultivar's chestnut brown buds are ovoid, imbricate, slightly pubescent, 1/8 in. long and slightly divergent.

In the first year, the stems are fine-textured, terete, brown, and pubescent. By the second year, the stems turn gray-brown and glabrous with small orangy brown lenticels. The pith is small, solid, and brown.

'Emerald Vase' is an upright-spreading tree (Figure 1) with an outline similar to that of American elm. It measures 70 ft high and

59 ft wide. At 4 ft from the soil line, the mature tree has a 35 in. diameter trunk and a 110 in. circumference.

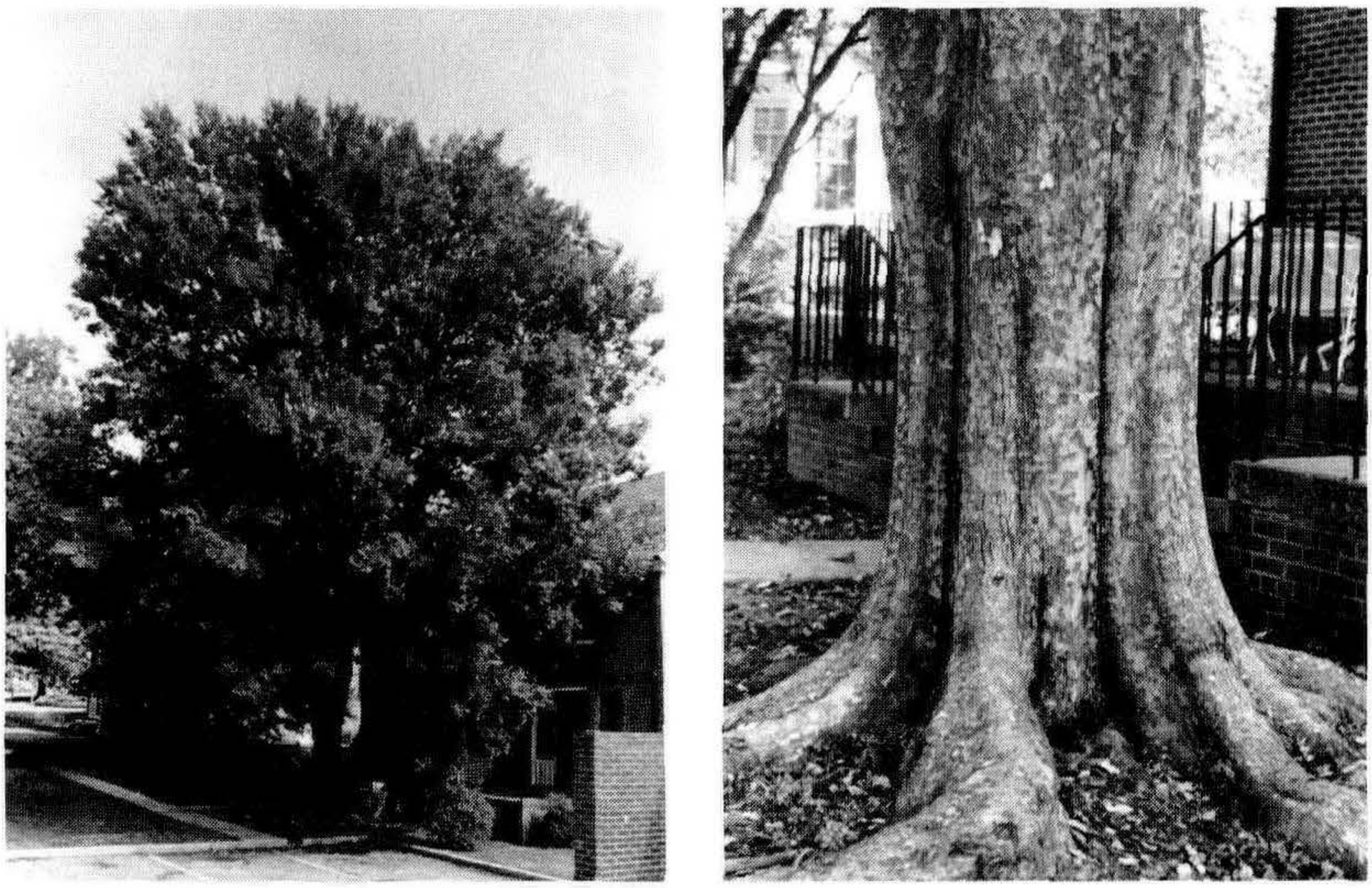

Figure 1. *Ulmus parvifolia* 'Emerald Vase'. *Left.* Note vase-shape of tree. *Right.* Bark exfoliates in a puzzle-like pattern.

The bark exfoliates in a puzzle-like pattern (Figure 1) exposing light gray, slate gray, gray-green, and orangy brown colors; it is flecked with burnt orange corkish lenticels. The exfoliation begins at the base of the trunk and continues upward to include upper branches 1 to 2 in. in diameter. Surface roots also exfoliate. Unlike the typically rounded trunk of the species, the trunk is irregularly fluted.

The lustrous rich green foliage is densely borne at the ends of the fine branches, creating a dense canopy. Leaf color and texture are typical of the species. Fall color is a subdued yellow. Despite the record drought conditions, no leaf scorch or dieback symptoms are evident. In addition, the parent tree is thriving in an 18 ft by 18 ft area surrounded by concrete. 'Emerald Vase' is also highly resistant to Dutch elm disease and elm leaf beetle. The leaves are alternate and simple, ¾ to 2 in. long and ⅜ to ¾ in. wide. They are ovate to slightly obovate, lustrous bright green on the top and gray-green on the bottom. They can be acute or obtuse, oblique, with simple serrations that are slightly more pointed than those on 'Emerald Isle'. The leaves are glabrous on both sides and show 11 to 16 vein pairs. The petioles are 1/8 or 1/4 in. long, light-green, and

pubescent. The chestnut brown buds are ovoid, imbricate, slightly pubescent, 1/8 in. long and slightly divergent.

During the first year, the stems are fine textured, terete, brown, and pubescent. In the second year they turn glabrous and gray-brown, with small orangy lenticels. The pith is small, solid, and brown.

Table 1 presents a cold hardiness profile for the two Emerald introductions. Although maximum cold hardiness of 'Emerald Isle' in December, 1988 and January, 1989 was -11 °F, both introductions acclimate (harden) early in fall, and deacclimate (deharden) late in spring. They are the first of the introductions to drop leaves in fall and the latest to leaf out in spring.

Table 1. Lowest survival temperature in degrees F (LST)[1] of *Ulmus parvifolia* 'Emerald Isle' and 'Emerald Vase', collected from August 31, 1988 to May 16, 1989.

08-31-88	10-04-88	11-16-88	12-01-88	01-19-89	03-15-89	04-12-89	05-16-89
'Emerald Isle'							
16	16	10	-11	-11	-6	10	21
'Emerald Vase'							
16	16	16	-6	-6	0	16	16

[1] LST refers to the lowest temperature at which the plants were not injured; i e., on 12-1-88, 'Emerald Isle' survived -11 °F but was killed at the next low temperature increment.

'Burgundy' is vigorous with a rounded outline and leathery, lustrous, dark-green leaves that turn wine-red in November. Parent tree is estimated at 7 to 8-years-old. Leaves persist into December in Athens, Georgia, and we suspect it will be less cold hardy than 'Emerald Isle' and 'Emerald Vase'. The bark is exfoliating with orange-brown inner bark. The mosaic, jigsaw-puzzle bark is not yet evident. Of all the selections this is the easiest to root, with 90/or greater success using June and July softwoods and a 5000 ppm K-IBA quick-dip.

The fourth, an unnamed clone from South Carolina is a splendid oval-rounded, billowy, cloud-like, rich green foliaged form with handsome exfoliating bark. Bark shows the exfoliating, jigsaw puzzle pattern in colors of gray, brown, and orange-brown on the mature trunk to 1 to 2 in. diameter branches. This is, perhaps, the handsomest form in an open-grown situation and offers a distinguished and refined canopy. Parent tree is 50 ft high and 40 ft wide. To date, it has been the most difficult to propagate.

***Magnolia grandiflora*, southern magnolia (three selections).** The devastating cold winters of 1976-77, 1977-78, and 1983-1985 provided a great screening for the southern magnolias in

Cincinnati's Spring Grove Cemetery and Arboretum. Several plants survived in fine form. Temperatures were -25 °F or lower on two separate occasions. We are currently testing the survivors and are hopeful that observed field survival corresponds to laboratory values. Thomas Smith, Leonard Thomas, and Matthew Vehr of Spring Grove are cooperating on this project.

Spring Grove #16. This is the smallest (4 to 5 in. by 2 to 3 in.) and most handsome foliage form. Currently 25 ft high and 39 ft wide, 20 in. diameter at 5 ft; densely branched and foliaged. The leaves are the most lustrous dark green of the three selections with a brown indumentum (pubescence) on their undersides. The indumentum is the heaviest of the three selections.

Spring Grove #19. A dense broad pyramidal form with larger (6 to 7 in. by 3 to 4 in.) leaves than #16. The lustrous green leaves are moderately pubescent on the underside. Will be a better plant for restricted space. Parent plant is 32 ft high and 27 ft wide with a 16 in. truck diameter at 6 in.

Spring Grove #43. Slightly smaller than #19 with a similar habit and perhaps a darker green leaf with the least pubescence on the underside. From a distance too similar to #19 to be distinguishable. Currently, 22 ft high and 19 ft wide with two trunks joined at ground level; one 7.4 in., the other 8.3 in.

All selections have been propagated from August firm-wood cuttings using a 10,000 ppm NAA-50% alcohol 5-sec dip, perlite, and mist. Rooting takes 6 to 10 weeks. [Fortunately the best form (#16) is the easiest to root.]

***Hydrangea quercifolia*, oakleaf hydrangea.**

'Alice' is a large flowered form with 14 in. long inflorescences and sterile florets covering the fertile flowers creating a dense inflorescence. Parent plant is 10 ft high. The leaves are larger than typical but the plant is growing in a shady environment. Fall color is a pleasing wine-red.

'Alison' is a cultivar that initially we did not believe was as good as 'Alice' but the flowers are held upright and the sterile florets are dense and cover the bulk of the fertile flowers. Inflorescences range from 6 to 8 in. long. Fall color is wine-red. The habit is broad-mounded and the parent plant about 8 to 10 ft high and 12 to 15 ft wide.

June to August cuttings are successfully rooted with 3000 to 5000 ppm K-IBA-quick-dip, perlite, or perlite:peat (2:1, v/v), mist. Plants, when transplanted to a one-gallon container, will be full and dense by September-October of the same propagating season, especially those rooted early in the season.

Cornus mas. An unnamed clone of this species was selected by the Spring Grove Cemetery Arboretum and horticulturists for its tree-like habit, non-suckering nature, and more leathery lustrous

dark-green foliage. Parent tree is 15½ ft high and 23½ ft wide with a 7.4 in. trunk diameter at 6 in. The species is adaptable to extremes of soil and climate. This new selection might be a good small street or container tree. Currently being cold hardiness tested.

The plants discussed may prove exceptional, or fall in the vast wasteland now occupied by former promising introductions. Numerous factors contribute to the success of a particular introduction. The bonding of observation and research permits a much earlier assessment of a plant's potential than the traditional trial and error method. In the future, we estimate that laboratory research tests will have a profound impact on whether a plant is released.

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VARIATION IN TISSUE CULTURE PROPAGATED PLANTS

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Variant or off-type plants resulting from tissue culture propagation are a concern of growers interested in using micropropagated plants (1, 2). This variation resulting from tissue culture has been reviewed comprehensively recently by several authors (4, 7). To determine how serious a problem such variant plants might be, it is useful to review the methods available for micropropagation and the sources of potential variation.

Propagation methods. Micropropagated plants can be produced from axillary or adventitious shoots or from somatic embryos. Production from axillary shoots is the most common method used and involves using plant growth regulators called cytokinins to prematurely stimulate the growth of buds in the axils of leaves on shoots growing in tissue-culture. Shoots produced from axillary buds are most likely to maintain genotypic and phenotypic fidelity. This method is used for a wide range of plants, such as *Dieffenbachia, Syngonium, Rhododendron, Acer*, and *Rubus*, for example.

Adventitious shoots can be produced either from pre-existing tissues (e.g. epidermis) or organs (e.g. leaves) or from callus (undifferentiated cells). Since adventitious shoots normally arise from single cells (7), chimeral forms of plants (e.g. leaf variegation, flower color) will not be phenotypically true-to-type. For this reason and for other concerns about genotypic and phenotypic fidelity, use of adventitious shoots for micropropagation is not common. However, such shoots are used for certain plants, for example African violet (*Saintpaulia*).

Somatic embryos develop from vegetative cells and thus should have a genotype identical to the plant from which they are derived. These embryos can be grown into plants just as are the zygotic embryos in normal seeds. Methods of using somatic embryos in artificial seeds are under development. Somatic embryos are not used yet for commercial micropropagation, but propagation systems based on somatic embryogenesis are being developed for a number of crops, e.g. daylily (*Hemerocallis*) (5). A major advantage of somatic embryos is the low unit cost so that they could be used both for crops that are normally seed-propagated because of cost considerations as well as for other crops. Thus, use of

somatic embyros is anticipated for vegetables, annual flowers, agronomic crops, and forest trees. Other crops will also have the potential for propagation from somatic embryos. For example, Preil (6) has worked extensively with poinsettias grown from somatic embryos. These plants grown are uniform, but differ somewhat from the parent cultivar in certain characteristics.

Types of variation. Variation resulting from tissue culture can be classified as genetic, epigenetic, or physiological. Genetic variation is that which arises as the result of a change in the genes of a plant, i.e. a mutation (3). Genetically different plants originating in tissue culture from somatic cells are called somaclonal variants. Such changes may be expressed as a difference in growth habit (dwarfing), variegation in leaves, difference in flower color, etc. The variation will persist through vegetative propagation and the variant characteristic will be transmitted to seedling progeny.

Epigenetic variation does not involve a change in the genetic makeup of the plant, but is the result of a change in expression of a gene or genes (3). Different morphological forms representing juvenile and mature states, e.g. in *Hedera helix*, are an example of epigenetic changes in plant development. Such changes are stable through vegetative propagation, although the stability will vary depending upon the species or cultivar, but are not transmitted through seed.

In micropropagated plants, an additional type of variation, physiological, can occur that tends to be transient in nature (3). Typically these changes, e.g. increased branching and vigor, disappear with time or following another cycle of conventional vegetative propagation. The basis for these changes is still unknown, but they may be epigenetic.

Control of variation. Several steps can be taken to reduce the amount of variation occurring in tissue culture. The first is to micropropagate only those cultivars that are genetically stable. Thus, many chimeral forms are not suitable for micropropagation, but the decision on whether a chimeral form is suitable must be made on a case by case basis. Some other genotypes will also be found through testing to be more likely to produce variants after micropropagation and should be cultured and evaluated with care. For example, highly polyploid types are usually unstable.

Since variation can increase with increasing time in culture, it is advisable to establish fresh material of a given cultivar in culture at regular intervals. These intervals probably should not be longer than three years and should be less for some crops.

The micropropagation system least likely to produce variants should be used. Thus, axillary shoot proliferation is preferable to adventitious shoot proliferation unless extensive trials have shown that plants growing from adventitious shoots are uniform, stable,

and phenotypically identical to the source cultivar. Use of plants produced by somatic embryogenesis will require extensive testing and is unlikely to be of importance for the nursery industry for some years to come.

Selection of the appropriate explants when subculturing clumps of shoots is significant, because callus tissue often develops at the base of a shoot clump. Adventitious shoots may arise from this callus so that it is safer to transfer only the upper portions of each shoot. This method reduces the rate of proliferation, however.

Composition of the medium used to grow the cultures *in vitro* must also be evaluated carefully, especially the type and concentration of growth regulators used. Cytokinins are of special concern because supra-optimal concentrations can stimulate adventitious bud formation and may contribute to some of the epigenetic variation seen in micropropagated plants.

An essential feature of any well-designed micropropagation program is the long-term evaluation of micropropagated plants. Naturally, with woody plants, this will involve considerable time, effort and expense, but ultimately it must be done to confirm that the micropropagated plants are phenotypically identical to the original clone. When this step is slighted or skipped, expensive problems can develop, as has been demonstrated already with several crops.

Furthermore, a testing program ensures that the identity of the micropropagated plants can be checked to ensure that no mislabeling occurred at any stage of the culture procedures.

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VARIATION WITHIN A CLONE DURING TISSUE CULTURE PROPAGATION

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Commercial plant propagators use vegetative propagation to increase the number of individuals of a superior clone. Traditionally, cuttings and grafts have been used to maintain and increase the numbers of individuals in a clone. More recently, tissue culture propagation has become economically feasible for some species. In either case, the integrity of the clone—its being ''true-to-type''—is a major objective for the propagator.

A clone is described by the International Code of Nomenclature for Cultivated Plants as a ''genetically uniform assemblage of individuals derived from a single individual.'' However, being ''genetically uniform'' does not necessarily mean that variation cannot occur within a clone. Tissue culture propagation represents a new challenge to the propagator to maintain the integrity of the individual clone. New challenges, but challenges from the same influences that induce clonal variation during standard vegetative propagation. Variation within a clone occurs by genetic, non-genetic, or epigenetic mechanisms (1). However, the frequency of clonal variation can be higher during tissue culture propagation compared to other types of vegetative propagation, requiring the propagator to be particularly aware of the appearance of ''off types''.

Understanding the mechanisms underlying clonal variation during tissue culture requires an understanding of the patterns of shoot formation found *in vitro*. Shoots form *in vitro* from axillary meristems or from newly-formed adventitious meristems. In general, the lowest frequency of variation is found in shoots formed from axillary meristems. Adventitious meristems can form directly from pre-existing cells in the stem, petiole, and leaf or indirectly from newly-formed callus cells. Indirect adventitious meristem formation from callus cells exhibits the highest frequency of variation.

Genetic variation in tissue culture (usually termed somaclonal variation) has been frequently documented and the subject has been recently reviewed (5). This type of variation is most commonly derived from meristems formed from callus cultures, but can occur during any adventitious shoot formation. Somaclonal variation is undesirable for clonal propagation, but it has recently been

exploited for the production of novel mutants. Generally, the frequency of mutation increases with an increasing number of subcultures. Variant individuals developed from callus cultures have been selected for increased disease resistance, tolerance to stress (salt, herbicides, etc.) and novel growth habit. Several new clones have been developed through somaclonal variation, particularly in vegetatively-propagated plants, including potato, sugar cane, and scented geranium (5). Besides the natural mutations that can be found during adventitious shoot formation, induced mutations using radiation or chemicals have also been used to introduce novel genetic variation into plants during tissue culture. More recently, foreign DNA has been introduced into somatic cells using *Agrobacterium* or a variety of physical means. As more desirable single gene traits are identified, DNA transfer will become an increasingly important source of genetic variation through tissue culture.

Non-genetic forms of variation are represented by chimeras, disease infected clones, and physiological variants. A chimera can be viewed as a genetic mosaic with the shoot meristem composed of a mixed population of genetically different cells. A shoot meristem has three distinct layers termed the L I, L II, and L III layers. A chimera occurs when one of these layers or a portion of a single layer contains cells with a different genetic makeup compared to the parent plant.

Chimeras, especially chimeras responsible for variegation, present a significant problem for propagators using tissue culture. Chimeral separation in tissue culture is very common and can be anticipated in any tissue culture system that utilizes adventitious meristem formation. The practical implications to the plant propagator are illustrated by the results from the tissue culture propagation of a variegated hosta (*Hosta sieboldiana* 'Francis Williams') (7). During tissue culture, chimeral separation occurred either due to the new meristem forming from a single histogen cell layer or from an unstable chimeral rearrangement of cells between histogen layers. The result was a chimeral rearrangement resulting in propagules that were all green, all gold, or plants with a green and gold chimeral makeup similar to the original clone. The best chance to maintain the integrity of a variegated clone during tissue culture is to use shoots derived from axillary meristems that maintain the chimeral histogen arrangement.

Disease infection usually creates a disease problem that is commonly detrimental and easily observable. However, pathogen infection can be masked, where the only visible symptoms are a reduction in growth rate or vigor. A viral infection can also induce a desirable variegation of leaves and flower petals very similar to

chimeras. Common examples are represented by tulip flower "breaks" and the variegated foliage form of flowering maple (*Abutilon pictum* 'Thompsonii'). Disease infection causes a change in the phenotype of the infected individual, but the genetic makeup of the plant has not been permanently altered and will revert to the original phenotype after the elimination of the pathogen. Disease infected clones propagate "true-to-type" from cuttings as long as the disease organism is present.

In variegated geraniums, Cassells and Minas (2) have shown that individuals behave differently in tissue culture depending whether the variegation is the result of a chimera or a virus infection. Chimeral geraniums responded as anticipated in tissue culture forming variegated plants from axillary meristems and undergoing chimeral separation from adventitious meristems forming both variegated and solid color individuals. With virus infected geraniums, the exact opposite was observed. Axillary meristems, which did not contain the virus, were all solid-colored. Shoots formed from adventitious meristems all contained the virus and were variegated. Obviously, the propagator must be aware of the source of variegation to determine an appropriate tissue culture protocol for the production scheme of variegated clones.

Physiological or phenotypic variation is a common form of non-genetic variation. There are numerous examples where plant growth and development (growth habit, flower size, flower color, etc.) are influenced by the environment. However, this type of variation is not a persistent change and the variant will revert to a "true-to-type" individual under a similar growing environment to other members of the clone.

In contrast to physiological variation, epigenetic variation represents a relatively stable change in the appearance of an individual in a clone regardless of the environment. Epigenetic variation is a stable change in the gene expression of an individual, not a change or mutation in existing genes. Epigenetic variants conform to the International Code of Nomenclature's definition of a clone by being "genetically uniform". However, these individuals can be extremely different in their appearance and this difference remains "true-to-type" during vegetative propagation. The most familiar form of epigenetic variation is represented by the juvenility phenomenon (3). Juvenile plants most commonly differ from the mature phase of the clone by growth habit, leaf shape, ease of root initiation from cuttings, and the ability to flower under normally inductive conditions.

Differences in the growth and development of tissue culture versus conventionally propagated individuals have been observed in the field (4). It is difficult to determine if these differences are

examples of physiological or epigenetic variation. The situation with blueberry tissue culture is a good illustration. Tissue-cultured blueberry plants showed a reduction in apical dominance and increased basal branching compared to conventionally propagated plants (8). It was suggested that there was a possible cytokinin carryover from the tissue culture environment. It is well-documented that applied cytokinin can increase basal branching in many woody plants, but these characteristics could also suggest a juvenile growth habit. Lyrene (6), using ease of root formation as an indicator of juvenility, observed that stem cuttings were easier to root from field-grown tissue culture propagated plants compared to conventionally propagated individuals of blueberry. He proposed that an epigenetic phase change was induced during tissue culture. It will remain difficult to ascribe these changes observed in growth and development in tissue culture to either a physiological or epigenetic variation until a more direct biochemical or molecular marker becomes available to describe epigenetic variants. Regardless, it remains for the plant propagator to determine if this change in growth and development significantly alters the clonal phenotype of the tissue culture plants making them an unmarketable product.

Tissue culture is another tool the plant propagator has to vegetatively propagate clonal plant material. Tissue culture is very useful for slow-to-multiply or difficult-to-propagate plants. However, it may not be appropriate in all situations. As with other methods of vegetative propagation, the burden of propagating "true-to-type" individuals remains with the propagator. Care should be taken to select a proper source plant and vigilant observations must be made both in the lab and in the field to prevent clonal variation of the propagated product.

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PLANT TISSUE CULTURE—WHERE IS IT GOING?

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INTRODUCTION

The last ten years have established micropropagation as a commercial production technique for horticultural crops. Zimmerman estimates that approximately half the production has been in foliage crops, a quarter in woody ornamental plants and shade trees, and the remaining quarter shared by fruits and non-woody flowering plants (7). The first part of the 1980s recorded a huge increase in both capacity and production of micropropagules. In the second half of the decade overall U.S. production has probably increased only slightly, with the largest gains in the micropropagation of woody ornamentals, shade trees, and fruit crops. The micropropagation industry appears to be in a maturation phase, experiencing consolidation and market development. Market development has focused on maintaining or improving quality, dependability, and position.

Micropropagation is usually considered a part of the biotechnology industry. Like micropropagation, the other components of the biotechnology industry such as companies specializing in genetic engineering are also in a maturation and consolidation phase. Now is an appropriate time to consider what will be necessary for stimulating future growth in micropropagation. In this paper, we will discuss possible scenarios.

PATHWAYS FOR EXPANSION

Reducing the Cost per Unit. Tissue culture is a labor intensive industry and thus has had to rely on a high $/unit return to make a profit. The recent expansion of the woody ornamental segment of the market continues this trend as the value of a shade tree micropropagule is much higher than a foliage plant micropropagule. If techniques existed to reduce the $/unit costs, then other markets could be accessed, e.g. annuals, vegetables, and forest crops. Some

attempts have been made to automate medium preparation and handling of culture vessels. This is only a small step in the right direction. The primary requirement is a fusion of biology with engineering to utilize robotics and bioreactors. Unfortunately, the current standard biological system used in commercial micropropagation is not readily adaptable to engineering solutions for labor cost reduction. The cutting of shoots in the cultures and transferring explants to fresh medium is an important phase of quality control. The growth variation in culture across the many crops currently micropropagated makes the development of an inexpensive and universal robotic system difficult. Additionally, most bioreactors are not adapted to plants; rather they have been designed for microorganisms like yeast and bacteria. Thus, large-scale commercial automation without creation of new biological technologies seems remote.

Creation of New Biological Technologies. At least four systems are being investigated; if they can be successfully applied, huge new markets could be accessed. For example, conifers, especially temperate pine, spruce, and fir, have not proven adaptable to shoot culture methods. Both the ornamental and forestry markets would welcome reliable clonal propagation techniques for these genera. A second feature is that these new biological techniques appear much more amenable to automation than standard shoot culture.

Four techniques being explored by research laboratories are:

1) *Somatic Embryogenesis*—this is the adventitious development, in sterile culture, of true (seed-like) embryos (Figure 1). Unlike zygotic embryos from seed, these would be clonal and thus exact duplicates of each other (2). A somatic embryogenic system was developed for carrots in the 1950's but the first report of an embryogenic system for conifers (pine) occurred in 1985, a recent breakthrough (6). Examples of current research are spruce, pine, monocots (corn and other grains), and vegetables (celery).

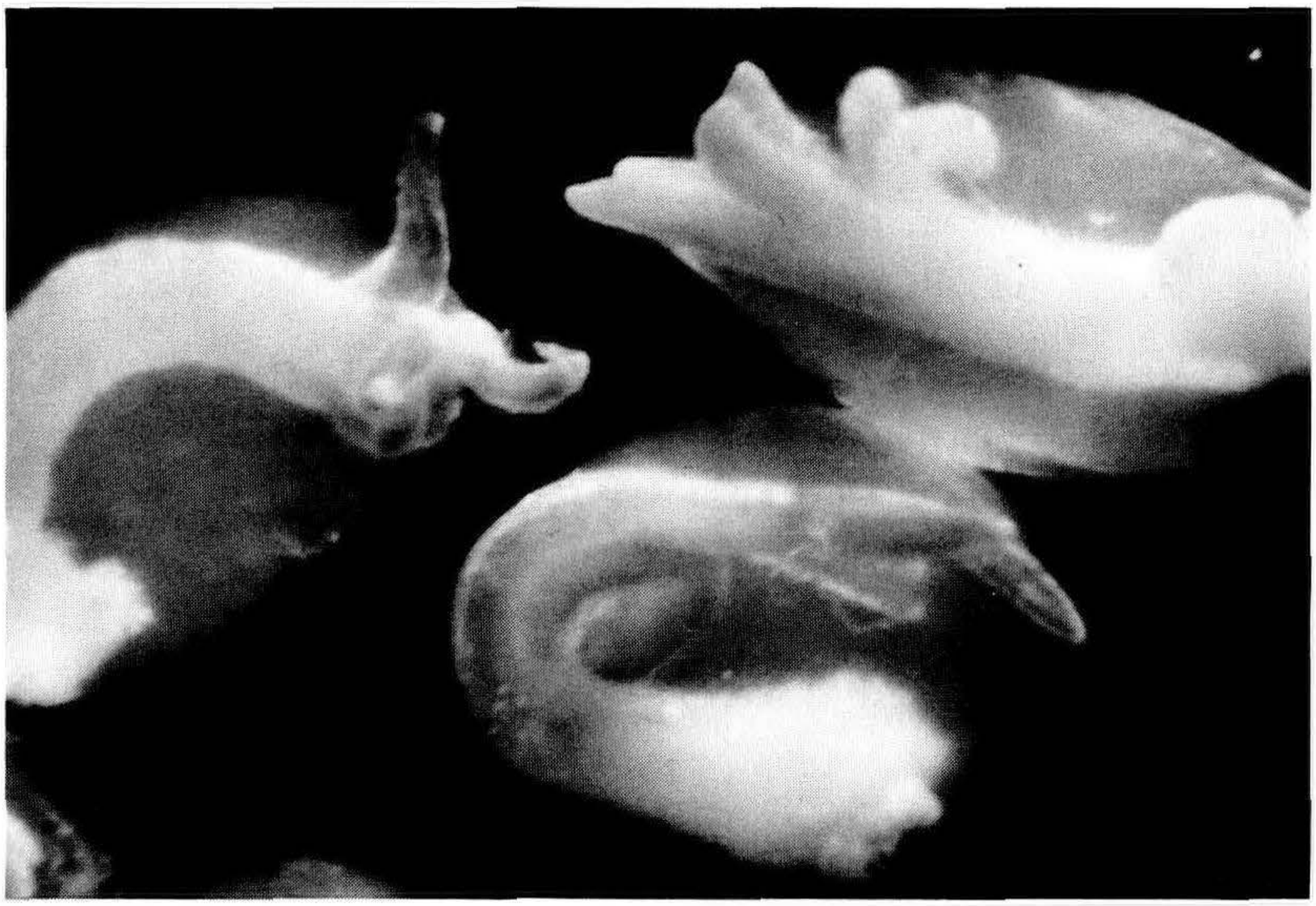

Figure 1. Spruce somatic embryos encapsulated in a gel-like substance (alginate) to prevent desiccation until plantlets are established. The hope is these could be handled much like true seed.

2) *Nodules*—this is an organogenic system where adventitious buds are developed from self-replicating, cell formations exhibiting a high degree of cellular organization (vascularization) (4). Examples of current work on nodules (Figure 2) include poplar, spruce, and some perennials.

Figure 2. A culture of nodules showing all the phases of shoot differentiation. These nodules were differentiated in a bioreactor. The most developed shoot has also formed an adventitious root. Reprinted from Plenum Publishing Corp., Lit. Cite 4.

3) *Meristemoids*—these are dense meristematic masses that can be divided into individual meristems (1). Radiata pine is an example of current research.

4) *Specialized Structures*—these take a variety of forms, potato microtubers would be an example (Figure 3). Other work is being done on bulbs and corms.

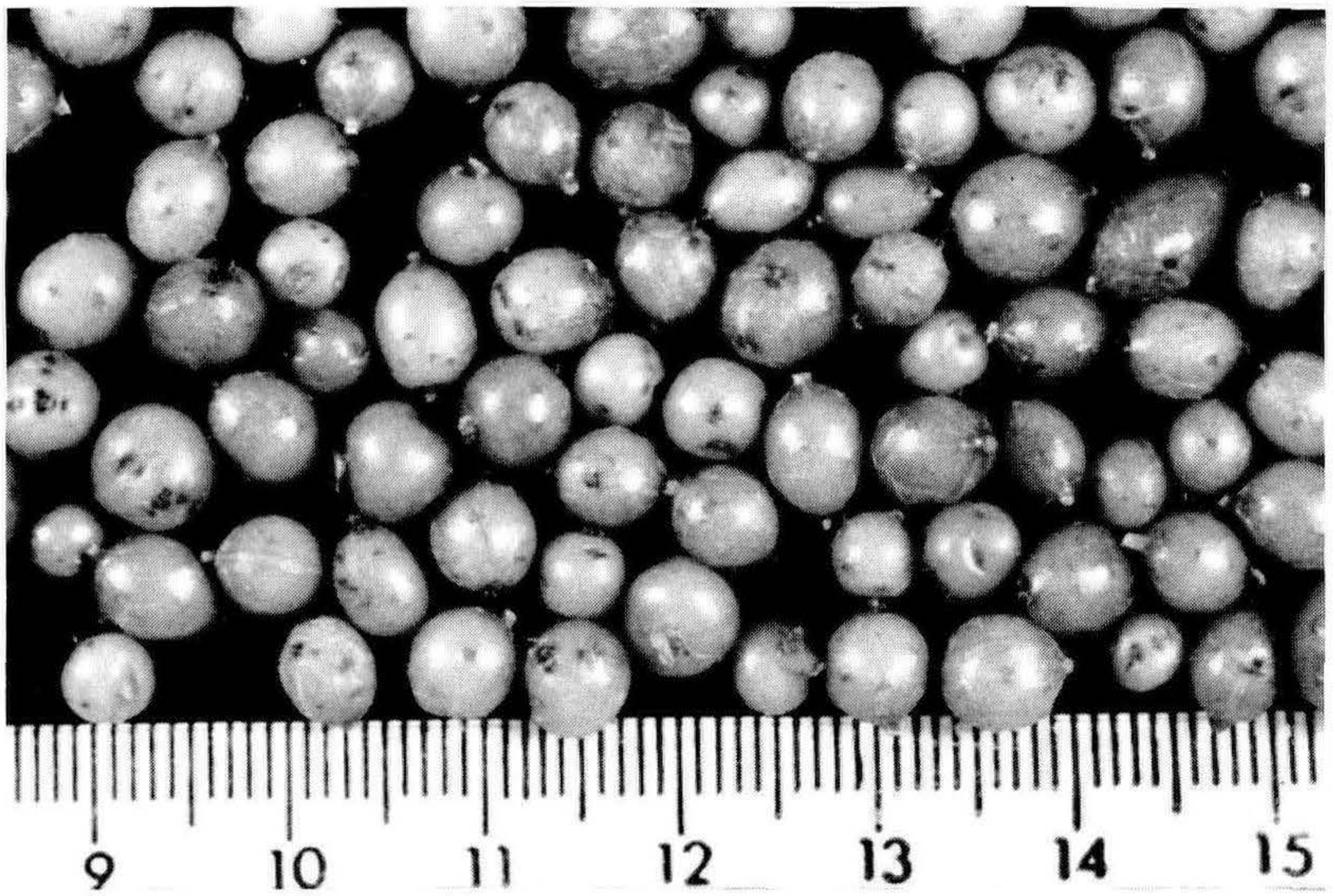

Figure 3. Potato microtubers produced in a bioreactor culture system.

All four of these biological technologies have parallel technical problems that must be understood before they become commercially viable.

1) *Difficulty in Establishing the Starting Cultures.* With embryogenesis, starting explants are often limited to embryonic material. This can be complicated by the narrow period of time in which a developing zygotic embryo is able to be induced to form somatic embryos. In spruce, for example, the time window for optimum embryogenic induction may be less than 2 weeks. Unfortunately, with woody perennials it is important to be able to work with mature material where desirable characteristics can be identified. The other three systems have been similarly recalcitrant to establish self-generating and sustaining cultures using a variety of crops.

2) *Uniform Development.* For commercial purposes, on the order of 90% of a culture must be at a uniform stage of maturity. Such uniformity has not been easily obtained.

3) *Conversion to Plants*. Regenerating uniform and vigorous plantlets has been difficult and rates low or variable. In part, the difficulty is due to a poor understanding of cellular differentiation and controlling mechanisms (4, 6).

New Products. The third and perhaps most widely publicized method for micropropagation to enter a major expansion mode is the creation of new products. This is already an important mechanism in the ornamental plant micropropagation industry where laboratories work closely with plant breeders and can assist in the rapid introduction of new clones. Genetic engineering of new plants could lead to the domination of existing markets as well as creation of new markets. Woody plants, especially trees, make ideal candidates for genetic engineering when you consider the immense obstacles facing traditional breeders; long juvenile periods, large size, complex genetics, lack of basic inheritance information, and species diversity. Two questions have to be answered: 1) Do the techniques exist to biologically engineer new woody plants, and 2) Have genes been identified for important characteristics?

Plant tissue culture is the supporting sister of this new thrust in biotechnology since most gene transfers have relied on sterile cultures as the starting material. Further, once the genetic transformation has occurred, plant regeneration, multiplication, and ex vitro establishment are required by techniques familiar to individuals involved in micropropagation (3). The feature that makes the genetic transformation approach so attractive with trees is the ability to add individual and unique characteristics to our best specimens without altering the desirable traits for which that specimen was originally selected. This would provide a tremendous advantage in plant improvement programs.

The techniques to genetically modify trees involve an assortment of laboratory procedures, mostly transferred from work with herbaceous plants. The most elegant technique is genetic transformation involving the insertion and expression of isolated genes. This has been done using biological vectors like *Agrobacterium tumefaciens* (crown gall disease) or mechanically.

The most sophisticated and successful technique currently available involves bombardment with gold or tungsten pellets. The pellets are coated with the desired genetic information and ''shot'' into the plant cells, where the genetic information is incorporated into the plant genome.

The second question, the identification and isolation of specific genes, is a greater obstacle. The positive aspect is that genes can be borrowed from organisms throughout the biological kingdom—bacteria, algae, animals, other plants. The negative aspect is that

characteristics determined by many genes (e.g. hardiness) are not yet readily manipulated.

It is now apparent that genetic engineering of woody plants can benefit several areas in crop improvement. We would like to briefly describe a few of the general areas we envision as beneficial:

1) *Resistance to Chemical Agents*. A number of traits are known to be controlled by specific genes, some of which have already been isolated from plant and non-plant sources. Resistance to herbicides (e.g. glyphosate) is one of these and while this may not be of special significance to ornamental growers, it may be important in the forestry and vegetable industries. Other genes, for example—tolerance to salt or heavy metals, have yet to be identified but are not outside the realm of possibility.

2) *Resistance to Biological Pests*. This is of enormous interest to the nursery community and insect resistance genes have and are continuing to be identified. In particular, the endotoxin gene in *Bacillis thuringiensis* (Bt) that conveys resistance to lepidopteran pests is available. Resistance to disease appears to be much more difficult. The use of genes encoding viral coat protein RNA was shown to limit damage caused by viruses in transformed cucumber, tomato, alfalfa, and potato. This approach could be of value with trees that are subject to viral epidemics (6). In all cases, the target pest must be chosen very carefully so that the chances of promoting the development of resistance is minimized. This is a crucial consideration with long-lived perennial plants.

3) *Change in Plant Form*. Traits like dwarfness, branch scaffold structure, and flower color all seem potential candidates for genetic engineering via genes controlling hormone or enzyme production. Compact forms of some ornamental shrubs (*Rhododendron*) have already been isolated using somaclonal techniques. Genetic manipulation of hormonal status without altering critical growth patterns will be a necessary goal.

4) *Sexual Characteristics*. At present genes to control plant fertility or sterility are not well understood but identification and isolation of these genes is a possibility. Sterile plants would eliminate the drain of the plant reserves into reproduction and in others would eliminate aesthetic problems (messy fruits) or hazards (acorn on sidewalks). Indeed, sterility may be a regulatory requirement of many genetically engineered woody plants.

5) *Environmental Stress Resistance*. Field testing of transformed strawberry plants with increased frost tolerance has already occurred. Very recent work on cotton and drought stress has pinpointed some controlling factors such as fibrous root structure.

Other possibilities for genetic modification of trees include a variety of techniques such as haploid culture, somatic hybridization

through protoplast fusion, and stimulation of mutations through callus (somaclones). These techniques will be less predictable and will require more evaluation than genetic transformants, yet can be useful adjuncts to conventional woody plant improvement programs. For example, disease resistance appears to be much more approachable using somaclonal variation.

SUMMARY

While the micropropagation industry may have given the impression of stagnation for the last few years, we believe it has, in fact, been a period of maturation. The maturation has been expressed as an improvement of quality, dependability, and market service. With the introduction of automation tooled for biological systems, new plant culture techniques, and new bio-engineered plants, the micropropagation industry is expected to be invigorated. Individuals working in the field of micropropagation are excited about the potential advances we have discussed and are waiting impatiently for these techniques to be applied commercially, especially to the field of ornamental horticulture.

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KALMIA LATIFOLIA—TISSUE CULTURE VS. CUTTINGS

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At Knuttel Nursery, we produce *Kalmia latifolia* (mountain laurel) for the nursery industry three ways. (1) From stem cuttings taken from existing stock. (2) We buy micropropagated plantlets that are grown in an accelerated growth program. (3) We take small stem cuttings from the growing micropropagated plants.

We have had good results from each method, and each method has merit in our program.

To propagate *Kalmia latifolia* from stem cuttings, we implemented a program inspired by the research presented by Alfred J. Fordham of Weston Nurseries Inc., Hopkinton, Massachusetts, at the 1977 meeting of the Eastern Region, International Plant Propagators' Society (1).

Kalmia latifolia cuttings are taken the first week in December from the current year's growth. We generally take cuttings from 2 to 4 in. in length. The cutting is wounded on one side. The wound is approximately one inch long and treated with a hormone. The hormone powder is a 2.2% IBA mixture (5 tbsp 4.4% IBA, 3 tbsp 0.1% IBA, 1 tbsp Dithane M-45 [Mancozeb], 1 tbsp. Benlate [benomyl], and a pinch of boric acid).

The cuttings are placed in beds filled with horticultural grade sphagnum peat moss and southern pine bark (6:1, v/v). The benches are tented with clear plastic. Bottom heat is maintained from 72 to 75 °F.

Roots begin to appear in three months. The plastic tents are then removed. Root growth continues and the plants are well-rooted in five months. We achieve from 92 to 95% rooting.

These rooted cuttings are planted into one-gallon containers, where they remain for two years. The first year the plants make substantial root growth, but very little vegetative growth. The following year the plants make vigorous top growth. The third year these plants are potted into two-gallon pots to grow to salable landscape size.

Five years ago we began to purchase tissue-cultured mountain laurel and grow them in a winter accelerated growth program (2). We purchase small rooted microcuttings in late fall to parallel our traditional cutting propagation program.

We pot the small plants into trays filled with a soil mix containing 2 yd^3 softwood bark, and one yd^3 each of vermiculite, peat, and hardwood bark. Dolomitic limestone, triple superphosphate, and

Osmocote 18-6-12 (8-9 month formulation) are also included in this soil mix.

The trays are placed on benches at a height of 3 ft. in a greenhouse heated to between 65 and 67 °F. The natural daylength is extended by night lighting five minutes every ½ hr. Standard greenhouse management practices are followed. Special care is taken to regularly prune the plantlets so that they become full, multibranched plants.

By June, we have well-established liners that we pot into 1½ gal. containers. At the end of the second growing season, we have full, 12 to 15 in. budded mountain laurel plants for garden center sales.

An additional method, cutting amplification, was suggested by Dr. Richard Jaynes. The tiny tips of the juvenile growing tissue-cultured plants are pruned and stuck unwounded into our tented propagation beds. Within three to four weeks, 97% of these small cuttings will have rooted, producing a large rootball in two months. These cuttings are taken from December to April, whenever the tissue-cultured plants need pruning. These rooted cuttings are then put in our one-gallon production cycle.

In conclusion, we feel that the various methods of mountain laurel propagation described can yield equal benefit for the commercial nursery.

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Thursday Morning, December 7, 1989

The Thursday morning session convened at 8:00 a.m. with Leonard P. Stoltz serving as Moderator.

IMPLICATIONS OF WATER RECYCLING

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During the decade of the 1990's water recycling may no longer be an option due to a public attitude that is developing on environmental issues. The implications of *not* recycling irrigation water may become the more important issue. Water recycling in a primitive form began when the first creatures on earth started swimming in and drinking from the many streams and rivers that crisscross the continents. As civilization developed along the waterways, the amount of waste materials dumped into the water became sufficient to cause pollution. In many parts of the world society is gradually learning how to deal with this pollution in order to maintain reasonable standards of water quality.

Environmental issues are expected to become extremely important during the next 10 year period. Agriculture will receive special attention due to at least in part the large quantities of chemical fertilizers, herbicides, and other pesticides that are applied to agricultural land. The nursery and greenhouse industry is closely aligned with general agriculture and will come under the same, if not greater scrutiny, as general agriculture, due to the physical location of the operations. Unfortunately, farmers are now only a small percentage of the population of industrialized countries and consequently they are losing their political clout. It is now more important than ever for people involved in agriculture to be aware of the legislation that affects their industry and to question public comments that are being voiced on the agricultural issues.

Most nursery and greenhouse operations represent very intense agricultural systems. The crop value per acre is much higher than general agriculture and the use of agricultural chemicals is also much greater. This has resulted in some operations being identified

as point source polluters. This potential will become increasingly great as new legislation is passed and enforcement of existing legislation is intensified.

The latest concept that has worldwide attention is the idea of sustainable systems. These are defined as systems that can be continued for extended periods of time without having a detectable effect on the environment. Systems of this type will need to become the goal of every grower.

Ground water contamination is presently of great interest. With the present analytical equipment, it is possible to detect extremely small quantities of contaminants present in the water taken from test wells. Nitrates in the ground water have been a concern for many years but now measurable amounts of herbicides and insecticides are also being found in some areas. In California this has led to restrictions on the use of these chemicals in the areas where they are showing up in the ground water.

In nursery and greenhouse operations the waste water from irrigation and fertilization programs represents the major source for potential ground water contamination. This water may also pick up other agricultural chemicals applied to the soil or the crops. In many operations the runoff water may exceed 50% of the volume of water applied to the crop. Since it is not practical at this time to completely eliminate the use of chemicals on the horticultural crops, the potential for a contamination of the ground water must be minimized by more prudent use of the irrigation water. This will involve more efficient irrigation programs including recycling systems.

Recycling can be accomplished in a variety of ways with one of the more popular at this time being the ebb & flow system which is currently widely used throughout Europe. With this system, the potted plants are placed in a water tight tray and sub-irrigated with a fertilizer solution. All of the water that is not taken up by the plants during the irrigation is drained back into a holding tank where the conductivity of the solution is monitored and then adjusted to provide the crop with a consistent fertilizer program. These systems can be completely automated and are becoming more popular in areas where it is necessary to conserve water or to control runoff.

With a system of this type considerable saving in both water and fertilizer use is realized and where no water is applied to the leaf surface of the plant fewer chemicals are needed to control foliar disease problems. The salinity buildup that occurs with sub-irrigation has not been a problem on short term crops and there does not seem to be any unusual increase in root disease problems with the system. Initially the runoff water needs to be analyzed to

evaluate changes in the chemical composition that occur as the water is recycled. These changes will vary depending upon the starting chemistry of the water, the fertilizer additions, and the dimensions of the system.

Greenhouse growers now have the capability of nearly eliminating runoff with systems such as the ebb & flow method of irrigation. More widespread use of systems of this type is inevitable as the environmental emphasis forces the grower to become more responsible for the waste generated by his business. At this time, it is important for all growers to take an active part in both waste management and developing the environmental legislation that will control the horticultural industry in the future. Without this involvement, legislation which will cripple production, is inevitable.

RICHARD BOSLEY: Does your firm design these systems?

JOHN RODEBAUGH: No, just monitor them.

WATER RECYCLING AT MONROVIA NURSERY COMPANY, AZUSA, CALIFORNIA, AND DAYTON, OREGON —AN OVERVIEW

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During the early seventies, Monrovia Nursery Company, seeing the writing on the wall, began investigating the possibilities of controlling water runoff to conserve water, protect the environment, reduce regulatory constraints, and save money.

In 1969, the California legislature, upon recommendation from the State Water Resources Control Board, passed the Porter-Cologne Water Quality Control Act, and in 1972 Congress amended the Federal Water Pollution Control Act (which was originally drafted in 1956). The U.S. Environmental Protection Agency had delegated to the regional Boards the responsibility of setting water standards for their areas. The Los Angeles Water Quality Control Board set certain parameters for discharge water (Table 1), and in 1975 we were asked to monitor our discharges.

Table 1. Limits set by the Los Angeles Water Quality Control Board for constituents in discharge waters

Constituent	mg liter^{-1}
Suspended solids	75
Biological oxygen demand (BOD)	30
Oil and grease	15
Total dissolved solids	750
Nitrate N	10
Chloride	175
Chloride and sulfate	500
Total chromium	0 01
Surfactants	0 5
Total identifiable chlorinated hydrocarbons	0 004
Turbidity	75 ntu
Settleable solids	0 2 ml liter^{-1}

The Los Angeles Water Quality Control Board, following Federal clean water standards, set a limit of 45 ppm nitrate (10 ppm nitrogen) for waste water. Any nursery using a liquid constant feed system utilizing ammonium nitrate, feeding at a rate of 200 ppm nitrogen, would have 100 ppm nitrate in their runoff. Preliminary tests with a minor system of filtration of water for reuse proved to be unsatisfactory. For one thing, overhead irrigation with dirty

water resulted in dirty, unsalable plants. Our research department undertook a study of all the possible ways of meeting these new standards including: diluting runoff enough with clean water to allow discharge into sewers, denitrification, collecting runoff and reusing on alternative field crops or acreage, and a complete water treatment and blending process which would allow reuse.

We already knew that irrigation runoff could not simply be filtered and reused. Conrad Skimina, our research director, conducted extensive research to study: the effects of water treatment chemicals on plants, disinfection of water (including chlorine and chloramine phytotoxicity), the effectiveness of flocculation chemicals and polymers on water clarification, salinity build-up, disposal or reuse of sludge, efficacy of sedimentation , design of the systems, runoff and water consumption, changes in the elemental constituents of the water, effects of herbicides, and costs of treatment.

A decision was made to recycle based on our concern for conservation of water and energy and was intended to reduce pollution and regulatory constraints. Recycling resulted in zero discharge and consequently did not require a discharge permit. Prior tests with plant growth response to treated/blended recycled water was generally favorable.

The culmination of all our studies and concerns was the construction of a water treatment plant in 1979 at a cost of 1.3 million dollars. The plant consists of seven sedimentation pits, an equalization reservoir, upflow clarifier, filter, blending pit, and storage reservoir. The water drains from irrigated beds into open ditches and canals which culminate in sedimentation pits. The sedimentation pits are actually small reservoirs where sand and silt are settled out and floating debris is baffled. The water, still laden with clay and some silt, overflows into pump pits where it is pumped to the equalization basin to allow further settling of silt. From this point, the water is pumped into a treatment building where the pH is adjusted prior to the addition of flocculation and coagulant aids. Clarification follows as a result of the settling of the flocculated clay. The water spills over the top of the upflow clarifier and is then disinfected with monochloramine. Next, the water is polished by a filtration process using gravel, sand, and anthracite coal. It is then blended at a ratio of one to one with fresh, fortified water to make up the losses due to percolation, evaporation, and plant use. The finished water flows into a 1.3 million gallon reservoir for reuse. The plant is capable of processing 2.3 million gallons of runoff per day (Figure 1).

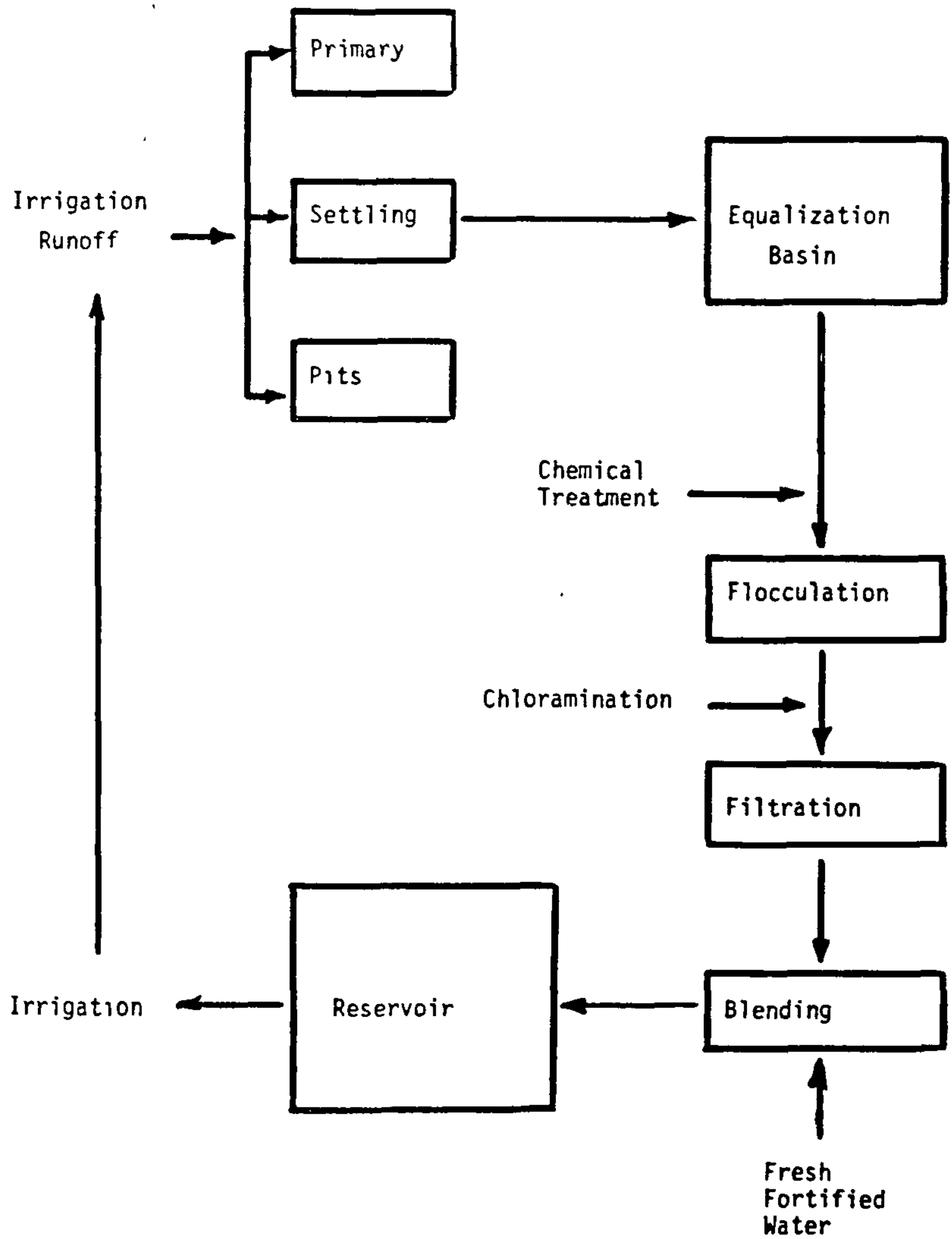

Figure 1. Schematic of water recycling and treatment (Azusa, California).

In 1984, Monrovia Nursery Company undertook a careful expansion program by opening a new production facility in the Willamette Valley of northern Oregon. We knew from the start, despite water being plentiful and of excellent quality, that water management would be a primary concern. From day one, all development in Oregon was done with the plan of recycling 100 percent of our runoff. Only recently have the regulatory agencies (namely the Department of Environmental Quality and the Oregon Department of Agriculture) initiated an effort to address waste water discharge. They are now in the final stages of setting the parameters (which will need to be met by 1993) for many of the river basins. In addition to nitrogen, phosphorus (which is not listed on Los Angeles' parameters) is of concern because it is thought by some to be a contributing factor driving algae growth on rivers and lakes during the summer.

Because of the Oregon environment, there are a couple of additional alternatives to recycling which could be considered. They are: to allow for soil buffer strips around nurseries (especially small growers) to permit soil attentuation and absorption of potential runoff, use of artifical wetlands to filter nutrients from the runoff (natural denitrification), or the use of "pulse" irrigation (increased frequency and decreased duration of applications). The idea of "pulse" irrigation is now also being tried by many Southern California growers.

Our nursery in Oregon is situated on fairly flat land (2 to 3 percent slope) which necessitated the need for grading, graveling (6 in. thick), and tiling the growing beds. All canals and ditches are also graveled with "rip-rap" (a 6 in. diameter rock) to minimize erosion. All of this gravel acts as a crude filter and decreases the turbidity of the slow-moving water on its way back to the sedimentation or settling pit. At the settling pit, any remaining silt is settled out and floating debris is collected. In Oregon, the settling pit may be a formed concrete structure or an informal pit preceding a collection pond. The collection ponds are large (up to 30 acre-feet) and quiescent, allowing natural clarification to occur. The water is introduced and chlorinated at one end of the pond and pumped out of the other end. We try to maintain a residual of 3 to 5 ppm chlorine at this point. From the collection pond, the water is pumped to a reservoir where it is blended with fresh water; after blending, the chlorine residual will be 1 to 1½ ppm. The water is monitored and refortified prior to reuse (Figure 2).

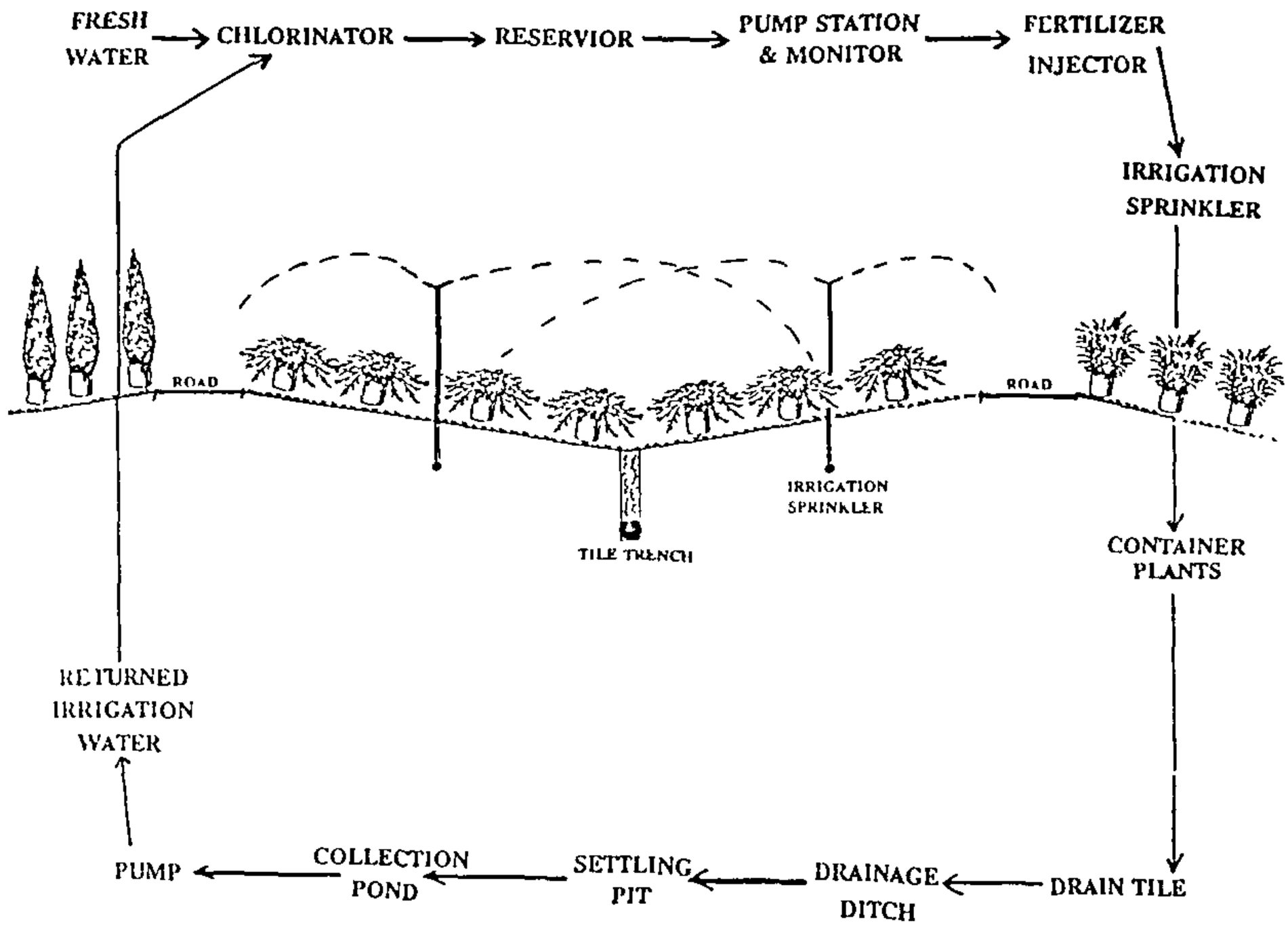

Figure 2. Schemetic of water recycling and treatment. (Dayton, Oregon)

In California, recycled water is used on everything except cuttings, liners, azaleas, and camellias. In Oregon, it is used on the entire nursery with the exception of cutting propagation. When we began recycling, we studied 106 cultivars to compare their growth and color under actual recycled water to that of fresh fortified water. A random sample of 31 of these cultivars were tested in depth and showed an overall mean growth of 106% compared with 100% for the fresh fortified water. Some cultivars did show plant response decreases which may have been due to phytotoxicity to specific compounds found in leachates or to traces of herbicides (Table 2).

Table 2. Plant response to recycled[z] vs non-cycled water[y]

Plant	% Relative growth[x], recycled water
Actinidia deliciosa (syn *A. chinensis*)	159[w]
Araucaria heterophylla	96
Arbutus unedo 'Compacta'	95
Berberis thunbergii 'Atropurpurea'	171
Brunfelsia pauciflora 'Floribunda'	85
Buxus microphylla var *japonica*	100
Cedrus deodara	104
Cinnamomum camphora	94
Crassula argentea	120
Cryptomeria japonica 'Nana'	100
Cupressus sempervirens 'Glauca'	100
C macrocarpa 'Donard Gold'	90
Ensete ventricosum	111
Gelsemium sempervirens	73
Hibiscus mutabilis 'Rubrus'	91
H rosa-sinensis 'Ross Estey'	85
Juniperus chinensis 'Keteleeri	120
J chinensis 'Robusta Green'	92
J sabina 'Broadmoor'	100
J scopulorum 'Pathfinder'	110
J virginiana 'Cupressifolia'	100
Magnolia grandiflora	102
Mahonia aquifolium 'Compacta'	102
Nerium oleander 'Cherry Ripe'	95
Osmanthus heterophyllus 'Variegatus'	110
Pinerus canariensis	95
P thunbergiana	95
Platycladus orientalis 'Aureus Nanus'	84
Prunus caroliniana 'Bright 'n Tight'	160
Raphiolepis indica 'Enchantress'	94
Syzygium paniculatum	73

[z] 50% processed runoff and 50% fresh fortified make-up water
[y] Fresh, fortified water
[x] Compared with 100% for non-cycled water
[w] Means of 14 replicates

Recycling results in 50% water conservation which, with a constant fertilization system, also translates to a 50% savings of most nutrients. Our research department found that all nutrient elements increased in recycled water with the exception of nitrogen and iron. Nitrogen remains relatively constant and iron decreases (Table 3). This negates the need to add many of these nutrients to the fresh makeup water.

Table 3. Percent change in constituents in processed runoff water

Compared with fortified fresh water (blend water)	Constituent	Compared with reservoir water[z] (irrigation water)
140	H	100
-0 4	pH	-0.3
11	EC	7
-45	NH_4N	-20
38	No_3N	8
0 6	Total N	-0.6
0	P	25
17	K	2
184	Ca	54
189	Mg	44
14	Fe	14
50	Cu	0
150	Zn	67
360	Mn	92
113	Na	55
3	B	-6
6	NTU[y]	-3

[z] 50% processed runoff + 50% fresh fortified water
[y] Nephelometric turbidity units

Another added benefit that our research department has documented is an 82% reduction in *Poa annua* seed germination. This is due to a slight residual of the herbicides we use in our system.

Of primary concern with any system designed to reuse water for plant irrigation is the possible build up of unwanted salts. Fortunately, our fresh water supply is of excellent quality, being low in salinity, sodium, and boron. Even with the additional fortification of the water, all elements fall into satisfactory levels for good water quality. Salinity in the system increases on the average of 18% per cycle. This increase, however, is at a decreasing rate since it is blended with lower salinity, fresh, fortified water. Theoretically, the system will reach equilibrium by the seventh cycle (Table 4). The increase in salinity may range from 0% in the winter to 28% per cycle occasionally in the summer.

Table 4. Theoretical conductivity trends of re-cycled water

Recycling sequence	Run-off + 18% / cycle	MHO'S x 10^5 make-up water	Mean of 50/50 blend applied water
0	—	120	120
1	142	120	131
2	155	120	137
3	162	120	141
4	166	120	143
5	169	120	144
6	170	120	145
7	171	120	146[z]
8	171	120	146

[z] Equilibrium

Allocation of costs for operating the treatment plant in California is: energy, 47.8%; chemicals, 38.4%; equipment maintenance, 5.1%; and labor, 8.7%. It presently costs $417.00 to process one million gallons of water or $135.00 per acre foot. Oregon costs are, of course, much lower.

If the water regulatory agencies in your area have not addressed waste water management practices or set parameters to meet clean water standards, rest assured they will soon. But why wait? Our industry does more to beautify and cleanse the environment than any other. We, the producers of living, green plants, want always to be perceived as the "good guys".

Finally, I would like to thank Conrad Skimina, Research Director for Monrovia Nursery Company, for his help in preparing this paper.

CLAYTON FULLER: In pond areas not plastic lined, will settling of pollutants occur and will this be a problem in 20 to 25 years if core samples are taken? Will we (nursery businesses) be in the same situation as the gas station operator with a leak?

RICK WELLS: That is a good question. In California all reservoirs are concrete lined and all the sludge is used in our soil mix and disposed of that way. In Oregon we are placing pilot wells around the perimeter to look for contaminants. It may be necessary to line the ponds in the future.

BIOLOGICAL CONTROL OF INSECTS AND MITES IN GREENHOUSE CROPS

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INTRODUCTION

Biological control is the use of beneficial organisms to keep pest organisms under control. In the context of the greenhouse and nursery, such beneficial organisms include beneficial bacteria, beneficial fungi, beneficial nematodes, beneficial insects, and beneficial mites (1, 2). Beneficial insects and mites are used extensively throughout European glasshouse vegetables for control of greenhouse whiteflies and spider mites (4, 6) and are seeing increased use in interior landscapes (5).

This paper describes a demonstration project using beneficial insects and mites for control of greenhouse pests in Arthur H. Steffen's clematis in Rochester, New York. Steffen's, the largest propagator of clematis worldwide, first experimented with biological controls in 1977 (3). They see innovation toward biological controls as one of the answers to public and worker concerns with chemical pesticides.

The project was originally intended to be a demonstration of biological control of spider mites, but after we carefully set up the trial, no spider mites appeared anywhere in any of the greenhouses all season. However, we faced infestations of whiteflies, thrips, cyclamen mites, and aphids with biological and least toxic solutions. This paper describes the preparations and season-long controls undertaken in the demonstration greenhouse and compares it to treatments in an adjacent, conventionally managed greenhouse.

PROJECT SETUP

Steffen's dedicated one 2000 sq ft greenhouse of clematis to the biological control project and an adjacent identical greenhouse to serve as a comparison under conventional control. To ensure pest levels as low as possible, all plants were removed and all weeds eradicated from the biological control house by late February. The house stood completely empty for nine weeks, ensuring cleanup of any pests by starvation and unfavorable temperatures.

Next we set up a pest monitoring and record-keeping system to ensure early detection of pests and early introduction of beneficial insects and mites. A Steffen's grower was responsible for daily monitoring of plants during watering and weekly counts of pests

on four 3 in. x 5 in. yellow sticky cards placed at canopy level throughout each house. In addition, records of pest levels were kept in map form on a grid outline of the greenhouse with different colors and symbols designating different pests and density levels.

A third precaution prior to starting this program was to determine which pesticides would be compatible with biological controls in case some pests should require pesticide treatment. Published and unpublished research shows that Safer's Soap, Vendex, and Avid are all relatively permissive to survival of beneficials (5, Sanderson, personal comm., see acknowledgements). Steffen's tested these three pesticides on several cultivars of clematis with no adverse effects.

BIOLOGICAL CONTROL APPLICATION

Releases of the whitefy parasite, *Encarsia formosa* began soon after the plants were placed in the greenhouse, as we knew that a small number of whiteflies came in on the plants. Sticky card catches averaged about 3.7 adult whiteflies per card per week (a very low catch). We released 1000 wasps at each of the first three releases (Table 1), and 2000 in the June releases (increased numbers due only to extras being available). Since these tiny, beneficial wasps have a generation time of 25 days at 70 °F, multiple releases are necessary to quickly create overlapping generations of the whitefly parasites and get constant whitefly parasitization.

Table 1 summarizes the biological control releases.

Table 1. Biological control treatements 1989.

Beneficial	Release dates
Thrips predators, 50T (*Amblyseius barkeri*)	7/12
Aphid lions, 2T (*Chrysoperla rufilabris*)	7/7, 8/2, 8/26
Whitefly parasites (*Encarsia formosa*)	5/11, 5/18, 5/26, 6/2, 6/8, 8/12, 8/17, 9/6

With the transfer of a small number of whitefly-infested plants into the biocontrol house in late July, whiteflies once more threatened, so we resumed *Encarsia* releases. We released 2000 on the first day and 1000 on each of two subsequent days.

Thrips first appeared on yellow sticky cards near the intake vent in mid-June, and per card catches had doubled by mid-July from 7 to 14. Cyclamen mites were of concern elsewhere in the complex.

Fifty thousand predacious mites, *Amblyseius barkeri*, were released on July 12 to contain both these pests. Suspended in wheat bran, they were sprinkled throughout the house and concentrated near the intake vent.

Patches of aphids began to threaten in early July and were controlled with spot treatments of Safer's Soap (2.5 oz/gal water) on the worst areas, and releases of 2000 lacewing immatures (*Chrysoperla rufilabris*) throughout the aphid infestation. Lacewings eat aphids only while immature over a period of about 2 weeks, so multiple releases are also important for prolonged control. The July 20 Safer's treatment was repeated on July 30 because a substitute applicator apparently did not get adequate covereage, resulting in negligible control on July 20.

RESULTS AND DISCUSSION

When the spider mites did not appear by August 24, we ceased formal observations except to do a final pest map on October 31. Pesticide treatments in the biocontrol and conventional houses are summarized in Table 2. All treatments in the conventional house were whole-house treatments, whereas the Safer's treatments in the biological control house were spot treatments. The conventional Kelthane treatments were for cyclamen mites, while the Orthene and Diazinon were directed against whiteflies and thrips.

Table 2. Pesticide treatments 1989

Conventional control house		Biological control house	
Date	Pesticide	Date	Pesticide
7/13	Kelthane	7/13	Safer's soap
7/20	Kelthane	7/20	Safer's soap
8/10	Orthene	7/30	Safer's soap
8/16	Diazinon	9/7	Benlate drench
8/23	Benlate drench		

Average whitefly and thrip populations detected on the sticky cards through the season are shown in Figures 1 and 2, respectively. Since sticky cards lure whiteflies from a distance, a catch of 3 per week represents a situation where the whiteflies can barely be detected during a prolonged search of many plants. The late-season whitefly outbreak highlighted the pest management tenet about cleaning up new stock before introducing it into a clean house. Between August 24 and October 31, whitefly numbers in the biocontrol house jumped to considerably more than 14 per square foot in some infested locales, but these whiteflies became heavily

parasitized and were not considered a problem. Thrips levels in the biocontrol house closely tracked those in the conventional house. Aphid numbers remained spotty and light throughout August, and then disappeared.

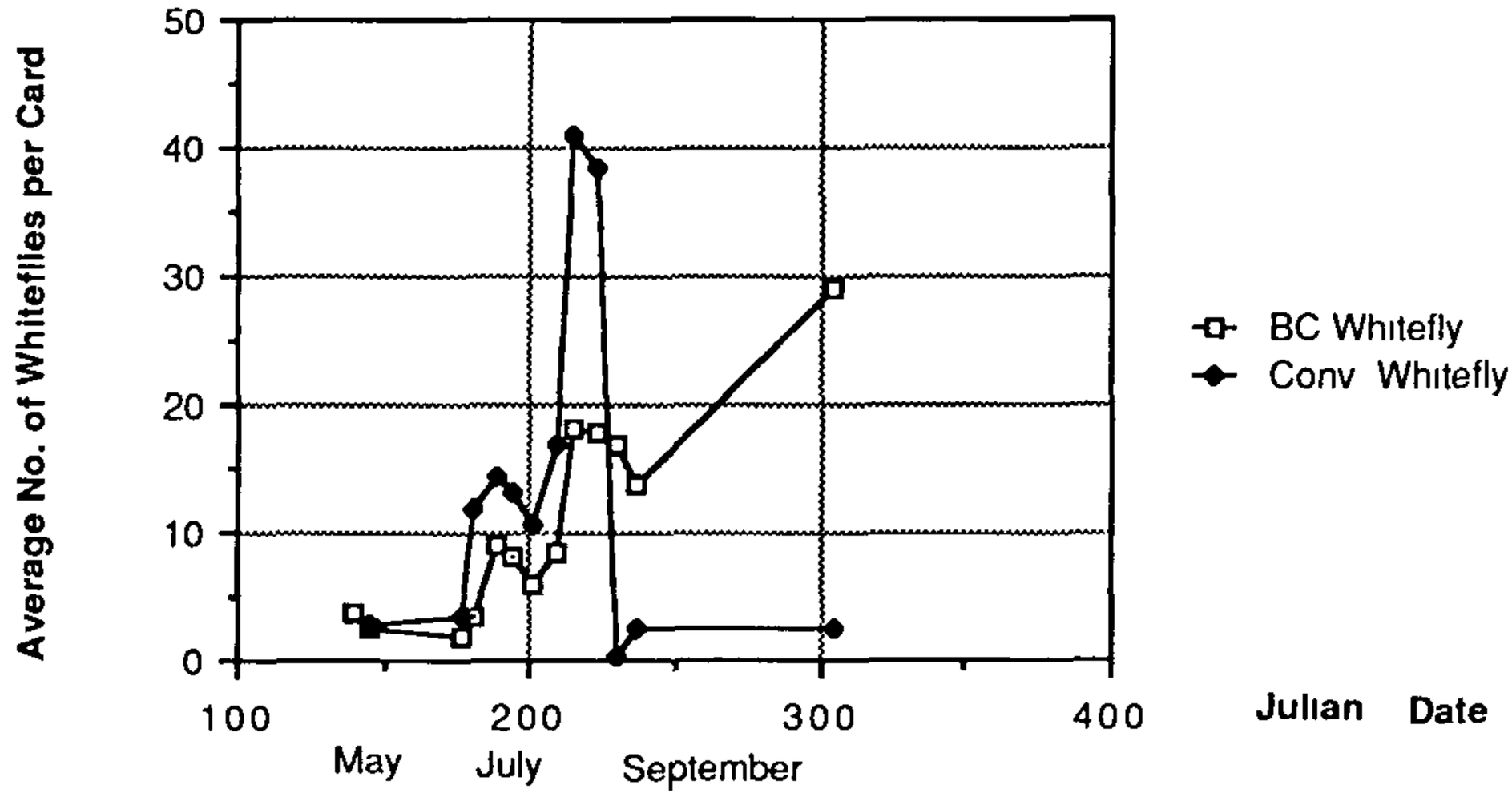

Figure 1. Weekly sticky card counts of whiteflies.

This trial emphasizes the different schedules used by biocontrol and conventional pesticide programs. The first biological control for whiteflies was applied May 11 when whiteflies were barely detectable on sticky cards. In contrast, the first pesticide control for whiteflies and thrips was not applied until August 10 when sticky card catches reached about 40 whiteflies per week. Figure 1 illustrates 40 per week to be twice the level that was being maintained in the biological control house before new plants with whiteflies were introduced. A similar situation occurred with thrips. The thrips predator was applied on July 12, one month before the first thrips spray.

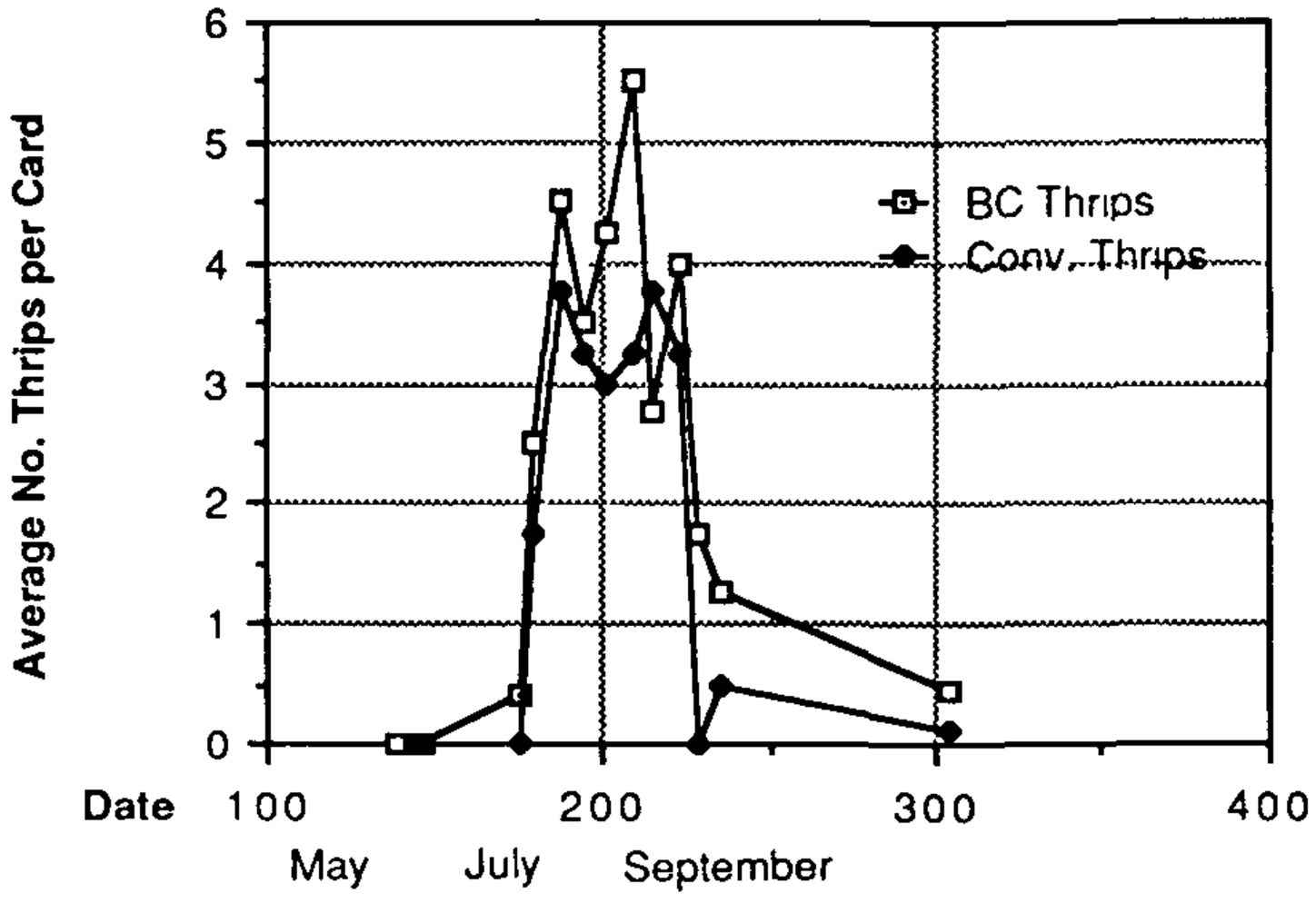

Figure 2. Weekly sticky card counts of thrips.

The total cost of the beneficials for the season was $271 plus freight (*Encarsia*, $135; lacewings, $36; *Amblyseius barkeri*, $100). As the numbers of beneficials purchased was relatively small, this cost is representative only of low-volume purchases.

The Steffen's growers felt that the control in the biological control house had yielded plants that were equivalent in quality to the conventionally controlled house.

Acknowledgements. Cooperators on this project were Dr. John H. Sanderson of the Entomology Department, Cornell University, and Arthur H. Steffen, William Moulton, and Joseph Guthrie of Arthur H Steffen, Inc. This project was partially funded by a New York State Agriculture Research and Development Grant Program.

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COMPOSTED SEWAGE SLUDGE: AN AID IN PROPAGATION[1]

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Nutrient rich compost is becoming more available as an increasing number of municipalities adopt environmentally sound methods of composting to recycle sewage sludge, yard waste, and garbage. The use of quality compost in plant propagation can provide many benefits, although the quality of compost will vary according to: raw materials used, age of compost, and management of the composting facilities.

MANUFACTURING COMPOST

Composting is as old as the "Garden of Eden"; however, technology in the science of composting is as "New as Tomorrow". Composting is more than simply placing organic materials in piles and providing sufficient time for decomposition. With current technology, composting can be completed in as little as 30 days depending on raw materials, composting systems, and desired quality of finished product.

Composting is an aerobic process requiring in excess of 5% free oxygen for optimum macro-microorganism activity. Organic materials with a carbon/nitrogen ratio between 35:1 and 25:1, approximately 50% water, and in sufficient mass to maintain temperatures near 150°F (50°C) will compost with maximum efficiency. Although pathogens and weed seeds are killed within 5 days under ideal conditions, composting is not complete. An additional 25 days is generally necessary for greater reduction of carbonatious materials to a C:N ratio near 10:1 and for N stabilization.

Quality compost is near sterile and can be handled without fear of pathogen and weed seed contamination. However, most of the nitrogen in fresh compost is in the ammonia form. For ammonia-sensitive crops it is necessary for the compost to "cure" for an additional 60 to 90 days to convert ammonia to nitrates.

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[1] MAES Contribution No 8110 and MAES Scientific Article No (Abstract).

To ensure that the compost is safe to use, EPA requires that temperature records of compost made from sewage sludge be maintained and available for inspection. Any deviation from minimum composting standards of 50 °C (120 °F) for 5 consecutive days (off-spec compost) requires that the composting pile be broken down and rebuilt or discarded in a safe manner. In nearly all instances composting temperatures of 55 °C or greater are achieved and composting is allowed to continue for 20 days or more for maximum volume reduction. Composted sewage sludge to be sold to home gardeners and farmers for producing food for human or animal feed use must be limed to a pH of 6.5 or above. However, nurserymen and landscape contractors can purchase unlimed compost because of the diversity of non-food crops they grow. They may also purchase off-spec compost for field production use only.

STORING COMPOST

Since the physical and chemical properties of compost improves with age, it is often recommended that compost be stored. Storage improves the uniformity of particles and increases the availability of plant nutrients. However, it is important that the compost be stored in windrows no greater than 2 meters (6.5 ft) high, 4 meters (13 ft) wide at the base, in a well drained area. To maintain quality, the compost should never be allowed to go anaerobic and the pile should be covered to protect from wind-blown weed seeds and/or rains.

COMPOST QUALITY

The most common fear in using sewage sludge compost is the presence of heavy metals. EPA maintains strict guidelines regarding acceptable metal levels for sewage sludges and it tests regularly to assure that standards are maintained. However, it is important to understand that most of the heavy metals contained in compost are essential to the growth and development of plants. The only exceptions to these are cadmium (Cd) and lead (Pb). Organic chemicals such as PCB's (polychlorinated biphenyls) are decomposed during the composting process.

Compost quality is highly dependent on good management of the composting system and on the kind of organics being composted. One should never use compost from a newly-opened composting unit for formulating potting mixes or for propagating, but it can be used safely for improving soils. It generally takes from 6 months to a year for a new composting unit to stabilize and continually produce quality compost suitable for use in formulating potting mixes and for propagation. Also, any alteration to composting

procedures or raw materials influences compost quality and consistency.

The quality of the compost will determine its uses. For propagation and for use in formulating potting media, compost particle size should not exceed 1.25 cm (1/2 in.). Large particles of undecomposed organic matter will cause competition between plant roots and microorganisms for available nitrogen.

Screening is the only effective means of removing large particles from finished compost. Finished compost should never be hammermilled to reduce particle size. Milling will expose cellulose fibers which will re-activate the composting process.

Depending on the raw materials and age of compost, most compost made from yard waste and sewage sludge will have a nitrogen level from 0.7 to 2%, a P_2O_5 level of 1 to 3%, and a K_2O level of 0.2 to 1.8%. The mineralization rate of nitrogen from most compost will be between 8% and 10%, depending on age. The mineralization rate determines the amount of nitrogen available at any time soil temperatures are near 21 °C (72 °F). Compost in cool soils will have a slower mineralization rate than compost in warm soils.

COMPOST IN SEEDLING PRODUCTION

Compost made from woodchips and sewage sludge has been demonstrated to be an effective soil amendment in seedbed preparation for the production of deciduous trees and shrubs. When applied at the rate of 112 dry T/ha (50 T/A) and incorporated just prior to fall seeding, it produced taller seedlings of: dogwood (*Cornus florida*), tulip tree (*Liriodendron tulipifera*), black walnut (*Juglans nigra*), red oak (*Quercus rubra*), black locust (*Robinia pseudoacacia*), and autumn olive (*Elaeagnus umbellata*) than similar plants grown with and without the use of chemical fertilizers. In the production of dogwood seedlings from freshly harvested uncleaned seeds, more seedlings were harvested from compost amended soil than from soils without compost. Also, tulip trees grown in compost-amended soils suffered little to no winter injury while 50% or more of top growth of seedlings grown in soils without compost died-back. Levels of compost in excess of 112 T/ha generally resulted in reduced seedling population without any substantial increase in top growth. None of the seedbeds amended with compost were fertilized.

A single application of composted sewage sludge at 112 dry T/ha is capable of supplying all of the nutrient needs for the production of 1-0 seedlings. Although residual nutrients remain in the soil after having grown one crop of seedlings, there was not sufficient N and K in the original amended seedbeds to produce an acceptable crop

of red maple (*Acer rubrum*) seedlings without supplemental applications of chemical fertilizers.

The use of composted sewage sludge at 112 T/ha in the fall preparation of seedbeds for white pine (*Pinus strobus*) and Norway spruce (*Picea abies*) resulted in reduced seedling population. However, applying the same amount of compost as a winter mulch over 1-0 seedlings resulted in an increase in top growth similar to applying chemical fertilizer and milled pine bark mulch at the same time (unpublished data).

COMPOST IN THE ROOTING OF CUTTINGS

Compost in combination with 75% perlite and 15% peat moss (v/v/v) has been used in the rooting of poinsettia (*Euphorbia pulcherrima*), evergreen euonymus (*Euonymus kiautschovica*), Japanese holly (*Ilex crenata* 'Helleri'), French hydrangea (*Hydrangea macrophylla*), and glossy abelia (*Abelia* × *grandiflora*) (unpublished data). The addition of compost to the rooting medium resulted in the development of larger rootballs and greater top growth, especially if transplanting of rooted cuttings was delayed a month or more after cuttings had rooted. Cuttings propagated in perlite or perlite and peat moss generally appeared chlorotic and initiation of top growth was delayed when rooted cuttings were neglected for the same period of time.

CONCLUSION

Not all composts are alike and each must be tested under production conditions in each nursery before it can become an accepted medium in the propagation of seedlings or the rooting of cuttings. The use of compost offers many benefits and it is a renewable resource. In addition to providing organic matter, compost can supply nearly all of the essential trace elements as well as a large percentage of the major elements needed by plants in a slowly available form. Therefore, it can reduce dependency on chemical fertilizers and imported organic amendments such as peat moss and pine bark. It makes economically good sense to use compost in the production of environmental plants and for improving our environment by recycling organic solid waste and reducing our dependency on landfills and the problems they create.

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DOUG CHAPMAN: Did root development change with the sludge application?

FRANCIS GOUIN: When we counted roots, we found that the number did not change but branching did. There was a larger mass of roots.

IMPROVEMENT OF OUR CULTIVATED TREES AND SHRUBS BY SELECTION

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Abstract. Research on trees and shrubs for use as ornamentals and for landscaping has been carried out since 1965 at the Research Center for Horticulture, Institute of Landscape Plants, Hornum, Denmark. On the base of the research it can be concluded that there are often cultivated, genetically very different clones under the same cultivar or species name Research has proved that through a systematic scheme of collecting plant material, followed by a trial and clone test, it is possible to select the best clones, and in that way improve the general standard of the cultivated plant material.

INTRODUCTION

The variation within the cultivated plants under a cultivar or a species name, includes all kinds of characteristics, such as hardiness, health of plants, flower abundance, and so on. The variation studies and trials have shown that hardiness and disease resistance are important characteristics that make good plant quality for the producer and the user of plants in the landscape. Also flower abundance, leaf density, habit, speed of growth and other characteristics can be used as a good base for selection.

To obtain results, which can be of value for both the producer and for the user of plants, it is necessary to test clones in comparative research, then select the best clones, and introduce those to the plant producer.

The selected clone at the Hornum Research Center is marked as DG (defined genetical) material. In some cases the selected clones can not be identified as an described cultivar. In such cases the selected clone is then given a new cultivar name, or an addition to the old name.

A selection research work has shown that identification of cultivars is often difficult, and that the safest method is to identify the material with its clone source. Nuclear stock plants of all the selected clones are kept permanently at the Research Institute. Research and clone selection is made in groups such as *Ligustrum, Ribes alpinum, Buxus, Aster,* and *Rhododendron*.

The selected clone is tested in our Research Center for serious diseases. If not free it may be treated to get a disease-free, nuclear stock called DP (defined patogene).

REVIEW OF LITERATURE

The first results from the test at the Danish Research Center for Ornamental Outdoor Plants were published in 1971 about *Ligustrum* (1). In 1975 results were published by Brander (4) about *Pyracantha* clone selection. Bjerkestrand (2) raised the same questions about *Philadelphus coronarius*. In 1970 Brander (3) described the method used in the clone selection research for ornamental outdoor plants at The Institute of Landscape Plants. In 1980 Humphrey (5) described similar results from the United Kingdom.

In 1982 Brander (6) published a detailed description in English about the methods used in the study of variation within clones and the reason to do this work.

MATERIALS AND METHODS

At the Research Center of Horticulture, Hornum, the materials used for the clone selection work are mainly supplied or collected in different Danish nurseries, from nurseries in other countries, and in collections from plants in private and botanic collections.

The collected plants are propagated from 1 single plant for comparative clonal research. Clones are tested for different growing characteristics—a genetic test. A clone which has the desired characteristics or is the best is selected to establish a nuclear stock plant. The nuclear stock plant is normally tested for serious diseases, such as viruses and different fungi, that are transferrable. If the tests shows the presence of disease it may be treated to get a disease-free plant, a DP plant, meaning defined patogene, which tells that we know something about the disease of the nuclear stock plant.

RESULTS AND DISCUSSION

Clone selection at the Institute of Landscape Plants. Research has shown that many of our cultivated trees and shrubs exist as many different clones with great difference in their characters. Examples from recent work at the Institute of Landscape Plants are shown in Tables 1, 2 and 3.

Table 1. *Aster dumosus* 'Herbstgruss von Bresserhof' results from test of clones

Clone	General fungi	Leaf impression	Flower abundance	General impression
7629	5 6[z]	5 0	7 4	6 0
7381	4 0	5 0	6 6	4 6
7333	4 8	3 8	5 8	4 4
7792	8 2	8 6	8 0	8 0

[z] Explanation of figures 10 = free of diseases, 1 = hard attack, For all other characteristics 10 means optimum (the desired stage) and 1, the lowest

Table 2. *Aster vimineus* 'Lovely' results from test of clones

Clone	General fungi	Flower abundance	Leaf appearance	Height of plants (cm)	Width of plants (cm)
7385	7.8[z]	7 0	8.0	65	70
7654	8 6	4 3	8 0	80	75
7342	8 0	7 8	8 5	80	85
7790	7 4	7 0	6 0	80	110

[z] See Table 1 for explanation

Table 3. *Ribes alpinum* results from test of clones (from Reference 7)

Clone/cultivar	Light 72-73-74	Shadow 72-73-74	Leafing 72-73-74	Leaf-fall 72-73-74	Winter hardiness 72-73-74	Number of days with leaves
'Dima'	8 5	9 6	5/4	31/10	9.5	209
'Hemus'	7 6	9 6	5/4	8/11	9 8	217
klon 6	2 6	9 6	13/4	17/9	7 8	157
klon 7	5 3	9 6	5/4	11/10	9 3	189
''Gul tysk''	5 3	9 6	5/4	18/10	9 8	196
''Gul tysk''	5 4	9.6	5/4	16/10	9 3	194
'Rudolf Smidt'	7 8	9 6	5/4	7/11	9 7	216
'Smidt's Type'	5 2	9.6	5/4	17/10	9 4	195
klon 18	3.2	9 6	5/4	21/9	8 7	169

Clone selection in nurseries. Not all plant groups have large variation problems but many do. Private nurseries could in many cases improve the plant material by selecting clones from their own mother plants. The selection should be made in the following way. Select clones which seem to comply with the desired characters. Select, for example, 5 clones, 4 good ones and 1 bad; rooting capability should be compared as part of the selection process. Then select the best clone for the base of new mother plants for production.

In such a project by private nurseries selection work has started in Denmark with *Rhododendron* 'Cunningham's White' and

different *Taxus* cultivars; in the U.S.A. *Pachysandra terminalis* and *Ajuga* reptans are being studied.

CONCLUSION

There seems no doubt that if we want to have good plant material for propagation we need to permanently keep the cultivars free of diseases and uniform, and the propagation maintained under high photosanitary conditions.

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BILL BARNES: If you take cuttings from a named cultivar and plant 10,000 of them in the field, and only one survives after a severe winter, is that a new plant and can we give it a name?

POUL BRANDER: Naming is a difficult question. Sometimes the variation is so large that you have to give it a new name. We sometimes give the plant a trademark to let people know that we have conducted the evaluation that I discussed. In some of the cultivars the variation is so huge that we have to do something about it, possibly give new cultivar names.

Thursday Afternoon, December 7, 1989

The Thursday afternoon session convened at 1:20 p.m. with David H. Bakker serving as Moderator.

DO WE NEED STOCK BLOCKS?

DALE G. DEPPE

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First of all, we need to define what a stock block is. A stock block is a group of plants set aside for the propagation department's use. Generally these are plants from which cutting wood or scion wood is gathered, but also stock blocks can be used as a seed orchard. This discussion will deal primarily with stock blocks used for the production of cutting wood.

"To supply the propagation department with cutting wood", that's an easy statement to make, but not so easy to do. How many of you have been able to collect the cutting wood you needed this year? How many of you attained a high percentage of rooting and rooted those big cuttings that transplant so well? Did you take only the wood that was the proper size or did you take some cuttings that were thin or short? How many times did you go back to the same plants and try to get a few more cuttings? Did you find out later that the sales department was blaming propagation for reducing the size of salable plant material. Did the container crew just finish pruning the only plants available of that cultivar on the nursery? Does it seem like the only plants that are sold out are the plants that you need for cutting wood? Is this starting to sound like your nursery? If so, then it's easy to say that your nursery has not invested in the future with stock blocks. If you are concerned about the future production capacity of your propagation department, if you are concerned about sales versus production in your nursery, then you'd better start investing in stock blocks.

When we talk about supplying cutting wood for the propagation department, we are talking about supplying the best cutting wood we can get. Many of you stick cuttings that should be thrown away. If the propagation department is taking cuttings from production plants, they are also taking what sales and marketing will let them have and probably when sales and marketing will let them have it. And let's remember that sales and marketing are probably right

when they put limits on propagation. Many of you agree that plant size and quality have been reduced by the removal of cutting wood. Yes, we try to justify the removal of cutting wood as making a better plant, more branching, tighter growth, bushier, etc., but when we see taking cuttings as plant pruning we are making a big mistake. When we take cuttings, we will always take a few too many, or cut the plants back a little too hard, or take the cuttings when the plants are growing at a maximum growth rate, thereby reducing the size of the overall plant. We have all seen plants that were damaged by the cutting crew, plants that only had a few cuttings removed but are now misshapened. These kinds of problems cost us all money. Nursery managers that tell you that taking cuttings from production plants is okay and does no harm are not taking a realistic look at what's happening. When we accept reduced growth and the loss of plant size we are accepting big money losses even to small nurseries. Taking cuttings from production plants is more expensive than having a stock block. Here are some examples of what's happening in your nurseries.

The cutting crew goes out into the container area of your nursery to take cuttings from *Juniperus horizontalis* 'Blue Chip'. If they cut from the smaller plants they remove a high percentage of the current season's growth. This reduction in plant size will cost the nursery one additional season of regrowth or at the very least the loss of one plant size the following year. The difference of one plant size in the sales price is about $3.00. For this $3.00, you receive 4 to 8 pieces of cutting wood; when these root at 75% you will have a cost of between 50 cents and $1.00 just for the cutting wood.

In the field production area of the nursery, the cutting crew takes cuttings from *Viburnum lantana* 'Mohican'. These plants are 18 to 24 in. and appear to be fine when the crew has gone on, but a month later when doing inventory these plants do not make a 2 to 3 ft size because only the uncut branches continued to grow while the cut branches had to wait for a new bud to set and then break. The difference in price is over $5.00 and the resulting cost of the cutting wood for each rooted cutting is more than 75 cents each. In some cases the money lost is not the worst of the problem. Bigger problems come later when our inventory is a mess and our customers do not receive the plants we sold them.

The answer is simple—plant a stock block. The start up costs of a stock block can be recovered the first year. As the plants grow, your costs are zero for maintaining these plants in relationship to the benefit. Taking cuttings from a stock block is much cheaper than from production plants. When all the available cuttings are taken from each plant the crew will do less moving around the field. They are easier to supervise and able to work in one area of the nursery instead of moving around to different fields. As your stock

plants grow larger, the crew will have to do less bending over to take cuttings from small plants and will work faster. Plant your stock block close to the propagation area; this will save your crew travel time and result in more cuttings taken per day. Are you starting to see that stock blocks will actually save you money, not cost you money? If saving money isn't enough reason to start planting, how about some more reasons for stock blocks?

The stock block area should act as a test garden for new plant material. Many of you have bought new plants or old plants that are not presently grown by your nursery and then planted them in the production area. Maybe you weren't sure if they would sell or didn't know if they were hardy for your area. By the time you found out what you had they were sold. Then you had to start over and try to find the plants again. When buying new plants, buy three times as many as you want; plant twice as many as you want in the stock block and the rest in the production area. Then when the plants begin to sell, your propagation department will be ready to supply you with the new cultivar.

The stock block area should act as a test garden for all the plant material you currently grow. Because many of us grow most of the plants we sell in containers stored under poly in the winter, we never really get to view our own plants in a natural environment. When asked if the plant material is hardy we will always say they grow fine for us. Because of the way we grow most of our plants, we also fail to ever see the plants at maturity. Many plant cultivars differ only in the mature height or spread of the plant. Many differ only in flower color. By propagating from immature or young plants we can continue to sell plants by the wrong name, thereby compounding the problem. I personally know of a nursery that sold over 200,000 plants of a particular cultivar before the stock block came into flower and showed that the plant was misnamed.

Spring Meadow Nursery, Inc. has bought stock plants from many large, reputable, well-established, "good as gold" nurseries and had to throw them out after the true characteristics became apparent.

The stock block area should act as a reserve for unanticipated production goals. When sales of a particular plant exceed the production and all the containers have already been pruned, where will you get cuttings from? When the stock block plants are available for late season cutting, your annual sales might be heading up.

The stock block area can be maintained free from herbicide use which may increase rooting of many plants, or free from heavy nitrogen use which causes weak growth and poor rooting. Stock plants can also be cut back extra hard each year in order to maintain juvenile growth. This would increase the rooting percentage of many plants.

By propagating from the stock block, the propagator will be able to take cuttings at the proper time. Timing is one of the key factors in propagation success. With all of your stock plants in one place the propagator can walk the blocks every few days and view the progress of cutting wood development. By eliminating improper timing as excuse for poor rooting we will all improve our success ratio. The cuttings taken from stock plants will be of a heavier size and have a higher level of stored carbohydrate than rapidly growing production plants. These stored carbohydrates will ensure the plants survival through the first winter.

As you can tell, I represent a biased opinion on the use of stock blocks. I truthfully can not think of a good reason against the use of stock blocks. I'm sure that some of you are thinking of a particular plant and saying that we don't need stock blocks for that plant. You're right, every plant that you're growing probably doesn't need to be in the stock block. But don't let that stop you from planting out the other 99% of your plants.

At Spring Meadow Nursery, Inc. we maintain and use over 20 acres of stock plants. They are planted on a spacing of 2 to 3 ft in the row with rows 7 ft apart. These stock plants support the sale of 1.5 million potted liners per year. We could grow our stock plants on a much closer spacing if it was needed.

I still think some of you are unconvinced. Think for a minute about your pruning crew out in the field pruning that plant for which you don't need a stock block. Now look at the ground. Do the plant prunings, on the ground, represent what you consider good cutting wood? Are the plant prunings 6 to 8 in. long, heavy, and the kind of wood the propagation department usually takes as cuttings? If they are, then I think we need a talk on plant pruning next year!

TOM McCLOUD: What is your fertilizer program?

DALE DEPPE: We are top dressing with a slow-release fertilizer in the spring and herbiciding with Surflan in a band along the row. Nothing magical about what we do.

COSTING VARIABLES IN PROPAGATION TECHNIQUES

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Probably one of the most difficult areas in nursery work is the area of accounting. We would rather be out in the nursery or greenhouse doing something productive than sitting at a desk making notes or filling out record forms. Of course, all of us have perfect memories and remember the context in which a decision was made several years after the fact. It is with this sarcasm in mind that I approach the subject of record keeping and costing variables.

I look back over the years at Zelenka Nursery and see how propagation has evolved. Think for a moment about your experiences. Some are pleasurable memories that give you great satisfaction, while others still give you a twinge in the pit of your stomach over how a project turned sour. What did you learn from those experiences? I was told when I first started propagating that I would learn propagation by killing cuttings. However, I also understood that when I did kill cuttings, I would not do it again the same way!

Setting up a propagation record of all the variables I had control over insured uniformity from year to year and made it easier to identify the problem variables that might be changed to improve the crop. The variables I keep track of now include:

- Source of cutting wood
- Quantity and date stuck
- Flat, bed, or container size planted and location
- Medium
- Density (spacing of cuttings)
- Hormone
- Stripped or unstripped
- Terminal or basal cutting and length (inches or nodes)
- Quantity and date pulled and/or potted
- Graded sizes
- Customer or department shipped to

These are records you would expect propagators to keep. But how do you, as decision makers, determine what is the best method of propagation.

Cost is one aspect that is often overlooked by everyone except the bean counters. It is easy, especially in a large organization, to be disassociated from the cost of a procedure, or more importantly, the cost of changing a procedure. Knowing what labor costs is

difficult enough with all the insurances, taxes, and the time it takes you to fill out the government forms. But, do you allocate maintenance costs, grounds upkeep, depreciation, etc. into your formula for costing the variable options you're considering? At Zelenka Nursery our costing is based on loaded labor rates (see chart). The expenses of the corporation officers and the grounds maintenance costs are allocated by the percentage of direct hours worked in the propagation department to the total direct hours of the nursery. The migrant expenses are added by the percentage of migrant payroll used in the department. The maintenance departments are allocated by the depreciation percentage of the department to the nursery total. All of these allocated expenses are added to the general ledger expenses of the department for a total expense. This is divided by total direct hours to give a rate per hour that we can use in projecting costs. Since expenses change annually with production, the loaded labor rate changes as well.

In the mid 70's we instituted a reasonable expectancy (RE) program for most production activities. We timed procedures, figured crew averages, and developed rates per man hour. These rates are used daily in assessing a crew's performance, monthly in budget reviews, and annually in projecting labor requirements. Labor is the single most expensive item in our budget so we pivot all of our costing on labor hours.

Now that we have established our costing basis and can figure the cost of a procedure, what do we compare it to? The value of the crop being produced. That value can be the price you have set, if you sell the crop, or as in the case of Zelenka Nursery, the cost of buying the crop if we did not produce it in-house.

There comes a time when you have to answer some tough questions about the standard operational procedures you employ. That came for us in the winter of 1986-87. We enlisted the aid of Dr. William H. Carlson, Department of Horticulture, Michigan State University. He had developed a system of self analysis with bedding plant and holiday plant crop growers. He was anxious to work with us and implement his system of action plan/cost benefit analysis in a woody ornamental nursery. At the onset we established parameters by stating our mission and beliefs. We also identified our strengths and weaknesses, both internally and in the nursery community. Finally, we focused in on six of our most critical weaknesses. Dr. Carlson acted as the catalyst by posing provocative questions and steering our answers to stay within our stated mission and beliefs. The planning process used by this system is called an action plan. It states the goal and is a step-by-step procedure for producing a crop. With each step, it identifies the person responsible, due date, and completion date. It forces the person

doing the planning to think out the details in great depth. Coupled with the action plan is the cost-benefit analysis. We projected three years in the future and valued our crops at the price we would pay to have them contract-propagated. Using our RE's and loaded labor rates (Figure 1) we projected costs, figured revenue, and calculated fixed assets required. This was all performed by the propagation department in greater detail than our accounting department does. When the exercise was completed, we verified the results with our cost accountant. Armed with all this data, we were able to more analytically assess our six most critical weaknesses and write action plans to improve each situation.

We now have a system established that is accepted as a critical tool in assessing change. Several basic procedures have undergone scrutiny with this thinking. Examples include:

- Stripping versus not stripping cuttings
- Medium selection (sand versus perlite)
- Preventative pesticide usage (targeted sensitive crops)
- Direct sticking in cells or containers

We did not necessarily make changes across the board, but employing this process made us more aware of the options, risks, and limits as well as costs. We also identified some dangerous assumptions. The use of percentages can be very misleading and using real numbers always paints a clearer picture. In our situation, if two items have different rooting percentages, it does not necessarily follow that the lower rooting percentage costs more to produce. Quickness of handling (labor) is a more expensive factor than rooting percentage and is a real cost drain to be dealt with.

Another dangerous assumption is making comparisons outside the parameters of our costing system. It is interesting to visit other nurseries and view the procedures. It is quite another matter to impose our costing values on their situation. We found it difficult enough for a group of Zelenka Nursery managers to agree on definitions and formulas within our circumstances. When we do identify areas needing improvement, or want to try a different procedure, it is written up as a research and development (R&D) project. It is followed through for three years with evaluations made at pre-determined intervals. Quantities and slight procedural changes can be made annually to refine and hopefully develop a more profitable means of producing our crops. After the third year a decision is made to cancel, continue, or adopt the project being considered. The span of time may seem quite long; however, the change that is made is quite predictable and cost effective.

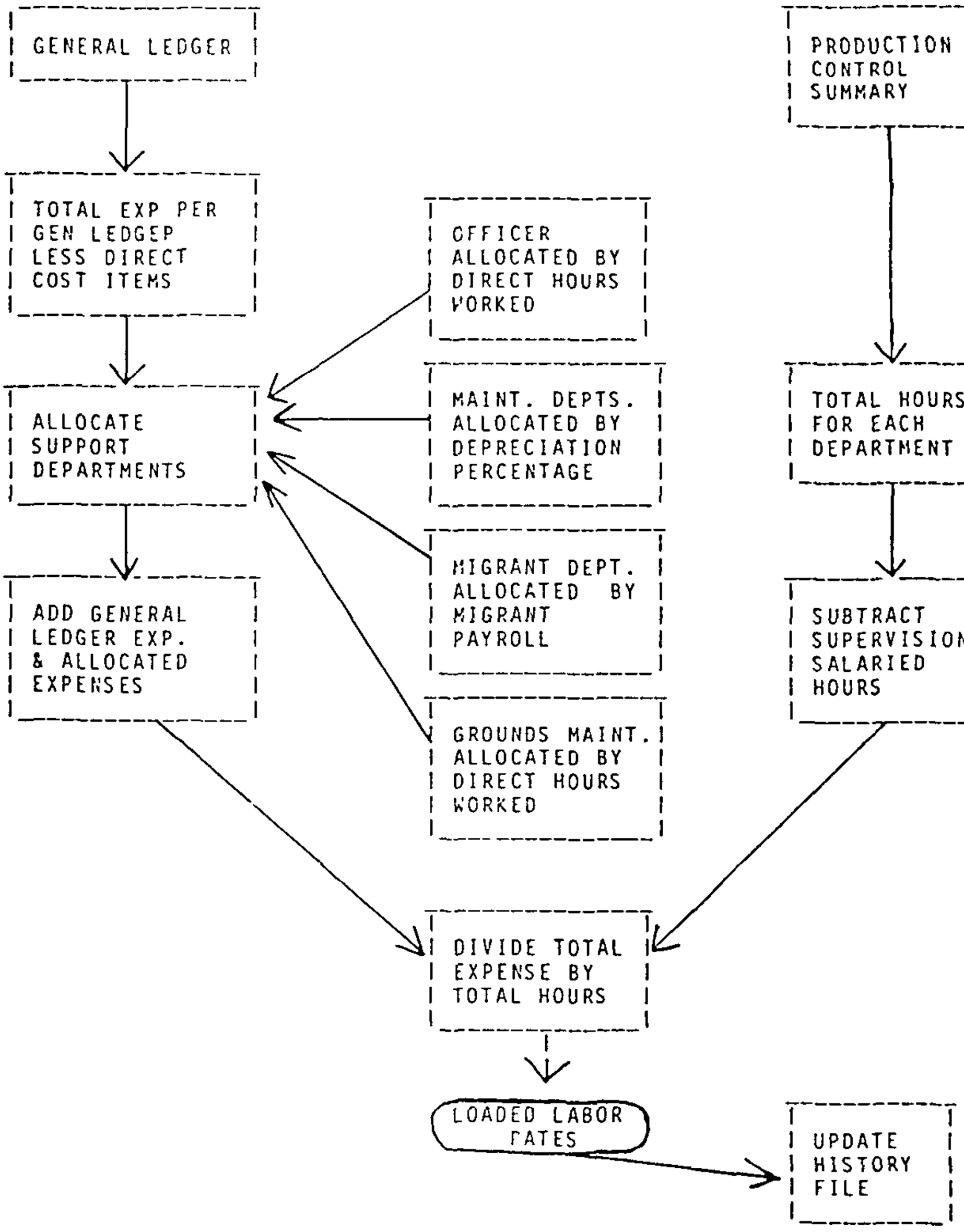

Figure 1. Loaded labor rates flow chart

I would like to be able to give you all formulas that would be THE right answer in costing your crops. Just like there is no right way to propagate a species, there is no one right way to figure the cost and set the price. We, as propagators, have to remember that we are businessmen and women. The importance of accurate record keeping and cost analysis may well determine what we grow. Likewise, it should determine how we market our product without selling ourselves short.

EFFECT OF THE USE OF PLUGS AND OF ROOTING MEDIUM ON GROWTH OF PRIVET

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Abstract. This study examined the effect of four cylindrical-shaped (Multipot series) and two rectangular-shaped (Rootrainer series) plug trays filled with four different rooting media on rooting and subsequent growth of privet (*Ligustrum vulgare*) Cuttings inserted in Multipot #4 (largest capacity) yielded the poorest rooting but subsequently the largest plants. There was a reversed tendency for cuttings inserted in Ferdinand Rootrainer (smallest capacity). Peat/perlite and peat/polystyrene media (1 1 v/v) were better for rooting than sand/peat and sand/polystyrene media There was no apparent residual effect of medium on later growth.

INTRODUCTION

With increasing production of woody ornamental plants in a totally containerized system, more nurseries are starting plants in plug trays. There are many types of plug trays, each with its own advantages or disadvantages, based on design and plug characteristics, but many are not suitable for rooting nursery cuttings (1). This study evaluated various plug trays filled with different media on the rooting and post-rooting effects on privet.

MATERIALS AND METHODS

Rooting. On June 6, 1986, 10 to 12 cm cuttings of privet (*Ligustrum vulgare*) were treated with 0.1% indolebutyric acid (Seradix No. 1 talc) and inserted into six different plug types (Table 1) filled with (1:1 v/v) sand/polystyrene, sand/peat, peat/polystyrene, or peat/perlite. An open tray with a fine mesh bottom served as the control treatment. The 28 treatment combinations were arranged in a factorial randomized complete block design with four replications. Rooting occurred under outdoor lath in intermittent mist (4 to 8 sec/8 min).

Table 1. Comparative description of trays evaluated.

Tray type	Tray		Cavity				Spacing between cuttings (cm^2)
	Length (cm)	Width (cm)	Depth (cm)	Dia. (cm)	Volume (cm^3)	# per tray	
Multipot[z] #1	35.5	22 2	8.8	3.1	57	67	16
Multipot #2	35.5	22.2	12 0	3.1	65	67	16
Multipot #3	60 9	35 5	12.1	3.8	99	96	25
Multipot #4	60 9	35.5	16.7	3.8	149	96	25
Ferdinand Rootrainer[y]	35.6	21 6	10.5	2 0x2.4[w]	40	96	7 5
Sixes Rootrainer	35.6	21.6	14.0	2.0x2.7[w]	90	72	9.0
Open tray (control)	35.6	21.6	10.2[x]	—	109	70	12.5

[z] Source: Rapok Capilano Ltd., Mississauga, Ontario, Canada.
[y] Source. Spencer-Lemaire Industry Ltd., Edmonton, Alberta, Canada
[x] Depth of open tray.
[w] Rectangular-shaped cavity.

On July 3, 10 cuttings per treatment in each replication were harvested to determine percentage rooting, root number per cutting (root number) and mean length of the 3 longest roots per cutting (root length).

Growing-on in Plugs. Trays with all remaining cuttings were removed from the mist, but kept under lath, fertilized weekly with 100, 49 and 83 mg/L of N, P, and K, respectively. On July 23 and October 5, 10 cuttings per treatment for each replication were harvested. Shoots and roots were separated, washed, dried and weighed. Trays with all remaining rooted cuttings were overwintered during 1986-87 in a minimum-heated (-5 °C) polyhouse.

Growing-on in Nursery. In mid-May, 1987, five rooted cuttings (liners) per treatment for each replication were transplanted to #2 nursery pots filled with a bark medium. Liners in the open trays were removed after dividing the matted medium-root mass into plugs measuring ca. 5.0 cm long x 2.5 cm wide x 9.0 cm deep. All liners were cut back to 15 cm to encourage uniform growth and branching.

Nursery pots were spaced 45 x 45 cm in the statistical design described previously. Water was applied by drip irrigation with 200, 87, 166 mg/L of N, P, and K, respectively, supplied 2 or 3 times weekly. In mid-September, plant height and number of lateral shoots were recorded. The plant tops were removed, dried and weighed.

RESULTS AND DISCUSSION

Analysis of variance showed no significant interaction of plug tray and medium effects; therefore only results of main effects are presented.

Plug Effects. Among the six plug trays (Figure 1) percentage rooting was best (95 to 96%) in Multipot #1 and Sixes Rootrainer, lowest in Multipot #4 (79%), and intermediate in the other plugs (84 to 87%). Roots were longest in Ferdinand Rootrainer (2.1 cm) and shortest in Multipot #4 (1.2 cm) (Figure 1). Corresponding data for percentage rooting and root length in the open tray were 90% and 2.0 cm, respectively (Figure 1). A similar trend was observed for root number but data (not shown) were not statistically significant.

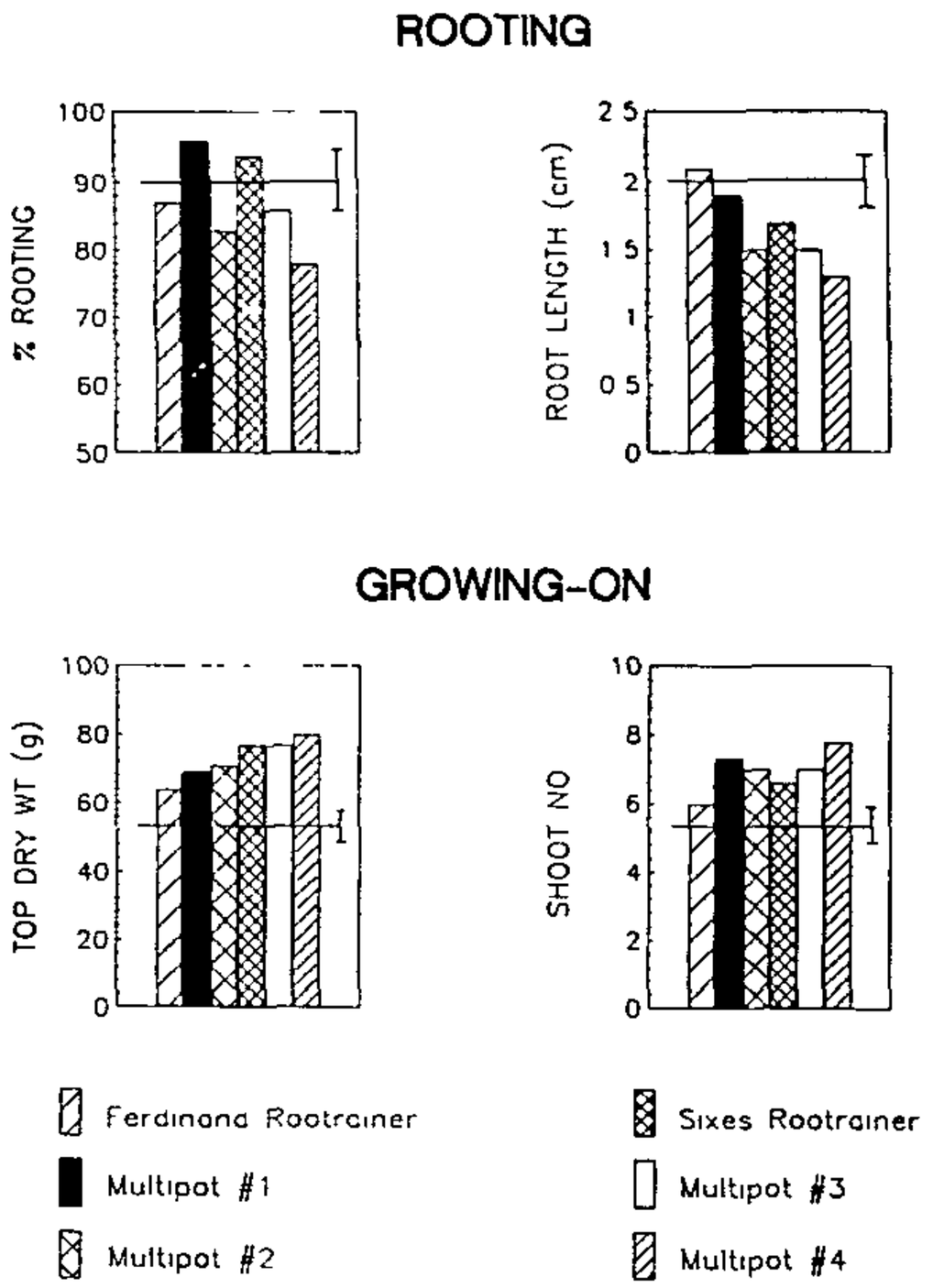

Figure 1. Rooting performance of privet cuttings in plug trays (presented in order of increasing volume, *left to right*) and subsequent growth of plants after one season in nursery pots. Horizontal lines represent data in open tray. Vertical bars represent LSD values at 5% level.

The rooting data as presented in order of increasing plug volume (Table 1) suggest an inverse relationship between rooting and plug volume Figure 1). In contrast, after one growing season in nursery pots, there was an apparent direct relationship of top dry weight

and shoot number per plant with plug volume (Figure 1). Poorest growth occurred in plants previously rooted in the Ferdinand Rootrainer and best growth in plants rooted in Multipot #4 (Figure 1). There was no effect of the plug trays on plant height.

Comparative data (not shown) collected soon after root evaluation (July 3) showed a similar trend in shoot and root dry weights. This trend was more accentuated by the end of the first growing season (Oct. 5), suggesting that plug effects are manifested quite early in the post-rooting phase while rooted cuttings are still in the plugs.

At the end of the first growing season, growth of cuttings propagated in open trays was similar in magnitude to or greater than those in plug trays. Thus, poorer growth of open tray plants in nursery pots a year later (Figure 1). was likely related to reduction in the root system during removal of rooted cuttings from the trays at transplanting and (or) to transplanting shock.

Media Effects. Percentage rooting and root length measured at the end of the rooting phase were lower in the sand/polystyrene and sand/peat media than in peat/polystyrene and peat/perlite media (Figure 2). There was no significant effect of media treatments on root number. Small or inconsistent differences in top dry weight, shoot number, and plant height at the end of the nursery growing-on phase suggest that propagating medium had no clear residual effect on later growth of privet.

Lower rooting in sand-amended media (Figure 2) may be related to physical properties such as lower porosity and oxygen supply in these media, and (or) to the high bulk density of sand (3). At the time of root evaluation, the media-root masses of sand/peat and especially sand/polystyrene were fragile and fell apart quite easily in comparison with generally intact and lighter root masses of the two peat-amended media.

The present study indicated that plugs influenced rooting performance of privet cuttings and had a residual influence on later growth. Cuttings inserted in trays with the largest plug capacity (Multipot #4) yielded the poorest rooting, but subsequently these plants had the best growth. There was a reversed tendency for cuttings inserted in the smaller capacity plugs, irrespective of the plug design.

This result may appear to be anomalous, but Threadgill, et al. (5) reported a similar occurrence in various broadleaf and evergreen nursery species. Of several media, 100% peat yielded the poorest root grades after propagation, but growth of plants in the same medium was greatest after a full growing season. This evidence indicated that the medium most suitable for propagation may not enhance post-rooting growth (5).

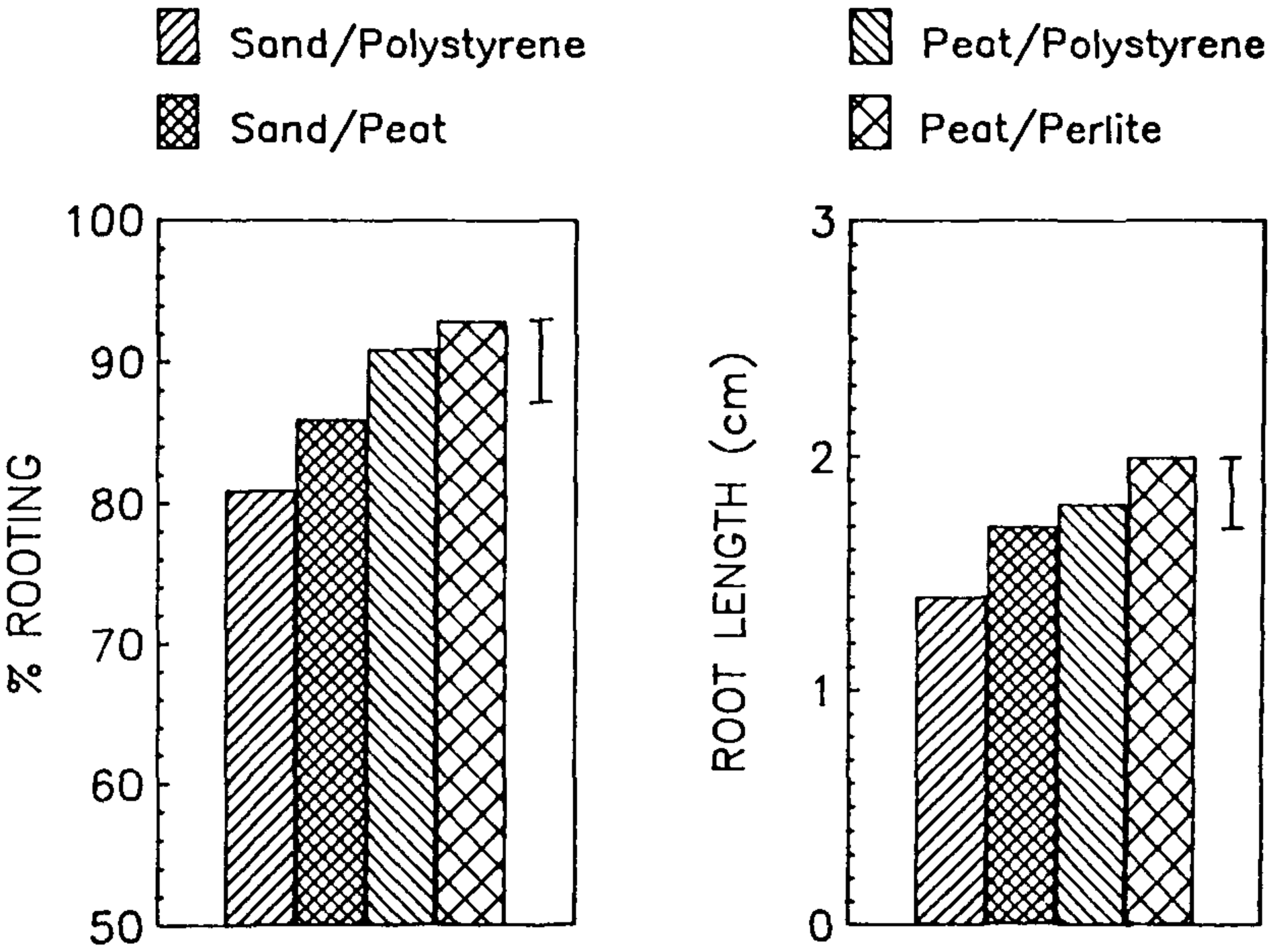

Figure 2. Rooting performance of privet cuttings in various rooting media Vertical bars represent LSD values at 5% level

Although the present study was not designed to examine plant response to individual plug tray dimensions, others have shown that dimensions of the propagating container can have a profound influence on plant responses during rooting and subsequent growth (2,3,5,7). Container dimensions also influence the interrelationship of media aeration and water relations (4).

Among various commercially available containers with different dimensions and varying degree of taper to the side, volume had a

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striking effect on the growth of woody tree seedlings, with height and stem calliper generally increasing as container volume increased (7). Small differences in container volume during propagation provided substantial subsequent increases in plant size and quality, both with depth and diameter, not just volume, influencing this response (6).

Acknowledgements. Appreciation is extended to Bob Hamersma for technical assistance and to Marion Hofstede for preparation of the figures

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MIKE ANDERSON: I did not see any statistics for your control.

CALVIN CHONG: In the post-rooting effects, all the plants grew better than the control. In the rooting phase the control was as good as some of the better ones that had rooted.

DOUGLAS HEVENER: How did the depth of the container affect the root system?

CALVIN CHONG: Pot size did not influence the results and small pots give as good results for field planting.

ROOT ZONE HEATING IN CONTAINER PROPAGATION

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Root zone heating has for many years been used in various types of nursery production. We, at Oslach Nurseries produce a large selection of conifer liners. We have used conventional propagation which consists of benches with hot water heating under the bench. This system proved unreliable and undependable in rooting a large number of conifers.

We, therefore, experimented with a new type of propagating structure and designed and built it especially for conifer production. Our first venture into root zone heating several years ago consisted of an in-ground bed lined with ½ in. polystyrene, with steel ¾ in. hot water pipes spaced approximately 10 in. apart. These pipes were embedded in cement sand and then further covered up with a layer of polyester to prevent damage to the system by rooting out of the bottom of the flats into the pipes and heat pipe areas. This system works quite effectively and we found that our production increased and the quality of our cuttings improved. At the same time we reduced our losses compared to the conventional rooting method. We then went ahead and designed and built a 24 ft. free-standing hoop house about 10 ft high at its peak. This house was covered with a clear double poly which was inflated with a squirrel-cage fan. A hot water boiler was installed and three beds were dug out and prepared in the manner previously described but instead of using galvanized pipe we decided to use a new product which was a high temperature flexible poly hose. This was installed the same way as the steel pipes. We have three beds in the house, each one has its own in-ground thermostat that has a sensing bulb placed between the hot water pipes and about ½ in. below the flats. Each bed is, therefore, controlled independently and can be turned on or off and set at various temperatures depending upon the crop being rooted. Each thermostat is connected to a zone valve that operates independently. The greenhouse is constructed with an exhaust fan at one end and louvers at the opposite end; this is to bring in cold air when required. The fan is generally sealed shut until the middle of February after which time we start to receive more light and find we cannot control the temperature in the greenhouse without exhausting air. Upon completion, we found that by maintaining the bottom temperatures on the conifer cuttings at about 68 to 69°F and a minimum top temperature of 35°F, we received excellent rooting results. We keep the top

temperature just above freezing. This is done by an independent ring of hot water radiators that are controlled by their own thermostat mounted at eye level. We find that the cool top temperature retards top growth in the month of December and January. We have excellent callusing and root initiation by the first week in February, which by that time, we find it difficult to maintain cool top temperature and therefore exhausting is necessary.

Since we keep the greenhouse very cool, little watering is required and we generally soak well once a week during the callusing period. We find that disease organisms are retarded and, therefore, spraying and drenching with fungicide is not necessary. All of our conifer cuttings are stuck in Kadon flats and the medium we use is straight perlite. We find that the flat system is ideal for this type of root zone propagation. The flats are then placed on the root zone bed completely sealing the heat into the bed and therefore the heat spreads out evenly on the bottom of the flats. By using flats the greenhouse also can be emptied in a very short time by the middle of May. We placed the flats under a lath house to harden off the rooted cuttings before they are either bedded or potted.

This system enables us to hold cuttings over a long period of time, thus spreading our work load out, especially during our busy season. We found with conventional bed rooting that the cuttings had to be out by the middle of May because of the high temperature conditions. Therefore, we were stuck with a large volume of plant material that had to be handled immediately during our busy season. This placed an added strain on our nursery operations. The house being cool has other advantages, the most important being that we are able to put a large amount of cuttings in a small area. We place approximately 100,000 cuttings in a 50 x 24 ft house. These cuttings are placed approximately 200 to 250 per flat. Such high numbers are unheard of in conventional houses with high temperatures where traditional propagators space their cuttings.

We have tried a large number of conifer clones and find that most clones respond well to this type of propagation on a constant basis every year. We also grow a range of ericaceous plants, including rhododendrons and blueberries. The medium we use for these plants is a 50:50 peat and perlite mix. Other than medium differences, the ericaceous plants are handled in the same manner as conifers in the root zone house. Our results are excellent and by the first week in May we have well-rooted rhododendron cuttings ready to go into a 1 gallon container. In conclusion, we find that this house is very easy to maintain and operate and gives us excellent results in our propagation schedule.

WHY WE MUST STILL BUD AND GRAFT

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Whenever new technologies in plant propagation are developed it is natural to take a critical look at old, long established methods to see whether they should be abandoned. Two of the very oldest methods of vegetative plant propagation are grafting and its later offshoot, bud grafting or budding. Twig or branch grafting is very old indeed, being mentioned in the old testament of the Bible and having been quite clearly portrayed in several ancient Egyptian tomb paintings. Cutting propagation is even older and found wide use in the ancient world, particularly in the propagation of grapevines and olive trees. Early propagators obviously experimented with cutting propagation of many fruit and nut plants and found that some important genera such as apples, pears, and stone fruits could not be rooted at all from cuttings. At some point, some genius learned how to graft woody plants either in the Orient or the Near East or, perhaps, independently in both regions.

Plant propagation by cuttings for many plant genera and by grafting or budding for others remained unchanged for many generations until the discovery of three new technologies which are now the cornerstones of much modern propagation. These were, in order, the discovery and refinement of root-inducing compounds and hormones prior to World War II, mist propagation in the post-war years, and finally tissue culture or micropropagation, which was developed in the past 20 years and is still being expanded and refined. Each of these new techniques made it possible to propagate new genera or species of woody plants which formerly had to be reproduced by grafting or budding if clones or cultivars were desired. Some very important ornamental plants such as rhododendrons, deciduous azaleas, magnolias, Japanese maples, some Japanese cherries and wisterias, for example, which were formerly propagated either by grafting or budding upon appropriate rootstocks, or by the slow and labor intensive method of layering, if superior clones were desired, could now be propagated by rooting cuttings.

For all the remarkable successes which the proper combination of the right hormones and mist propagation achieved in cutting propagation there still remained important plants such as birch clones, *Kalmia*, and some rhododendrons which still could not be rooted by cuttings in an economic and reliable manner. Further

research proved that many of these could be reproduced in tissue culture at low cost and in enormous quantities. Many writers have confidently predicted that grafting and budding, like plowing with a yoke of oxen, are antiquated techniques which will soon be abandoned in favor of more advanced and sophisticated ones. The purpose of this paper is not to be critical of the important advances in vegetative propagation but to draw attention to the many cases in which grafting and budding are still the most practical methods of propagation for clones for certain woody plants.

GRAFTING VERSUS CUTTINGS

New methods of cutting propagation have rightly replaced grafting or budding in the case of many important plants. Cutting-grown red maples are not susceptible to understock incompatibility which was a serious problem with budded trees. Grafted hybrid rhododendrons used to be short-lived garden plants because the favorite understock, *Rhododendron ponticum* was extremely susceptible to root rot from several fungi in our hot American summers. Cutting grown magnolias not only grow faster but are also free from the suckering problem with occurs when they are grafted on *Magnolia kobus* understocks, which used to be the standard practice. Cutting propagation is the method of choice for all of these plants.

However, in many cases cutting-grown plants will not survive cold winter conditions in which the grafted plants of the same clone in an identical situation are completely unharmed. Why this difference should be is still completely unknown. There are some theories, but the causes are probably not the same for each species or clone which exhibits this problem. *Cornus florida* 'Rubra' is a good example of these curious situations. The cuttings root easily enough. By a combination of extended day lighting and controlled temperature it is practical to bring the cuttings through the critical first winter without losses, which used to be the worst hurdle. However, when the plants go to the field for growing on into larger sizes, a slow but steady loss begins. No spectacular die-off occurs but in a few years all are gone. Similarly, cutting-grown *Acer palmatum* clones, particularly 'Bloodgood' are not long-lived. I vividly recall at Princeton a plastic covered can house filled with 'Bloodgood' in one-gal. cans one cold winter many years ago. Three thousand of the plants were own-rooted and 3, 000 were grafted on *Acer palmatum* seedlings. Both grew well the previous summer and averaged 15 in. in height. The following spring I noticed that some of the plants began to droop after leafing out. In three week's time every own-root plant was dead but no grafts were lost.

I was interested in Michael Dirr's recent article on rooting *Hamamelis* × *intermedia* 'Arnold Promise'. Six years ago we rooted 1,500 cuttings of this clone, carried them over the winter successfully and grew them on in 1-gal. cans. They grew beautifully, the best we had ever produced. In the fall we planted 500 out to be grown on, and over-wintered the rest in an unheated plastic house. The following spring all the plants in the field were dead, as were the plants remaining in containers. Of the latter all that we sold never leafed out, nor did those we had shifted up into 2-gal. cans. George Leiss reported similar problems with own-rooted *Hamamelis* cuttings at Sheridan Nurseries in Ontario. It may be that the mild winters at Athens, Georgia are warm enough so that cutting propagation of this popular shrub is practical. We still graft or bud all of these three plants, not because we like the extra work, but because we cannot afford such losses.

Years ago much work was done in Holland in attempts to root cuttings of various *Betula pendula* clones such as 'Laciniata', the cutleaf weeping birch. Techniques were developed to root softwood cuttings fairly easily but overwintering losses caused the project to be abandoned. *Pyrus calleryana* 'Bradford' and other clones can be rooted from softwood cuttings but overwintering results can be so extremely variable that budding is still the major method of propagation.

It is now possible to propagate orchard fruits such as apples and pears from tissue culture. Nevertheless own-rooted apples have not replaced traditionally grown trees because of some advantages for budded orchard trees. One is winter hardiness. Apples budded on hardy understocks like 'Antanovka' will survive winters in cold climates whereas the same clones budded on common apple (usually 'Red Delicious') seedlings or on their own roots will die. For reasons of easier spraying, trimming and harvesting, more tree fruits are now grown on dwarfing or semi-dwarfing clonal rootstocks and such combinations must be budded. The same fruiting cultivars on their own roots make full sized trees, be they propagated from softwood cuttings or by tissue culture.

There are cases in which plants on their own roots make such poor root systems that they are difficult or impossible to transplant. The Howe Nurseries in Pennington, N.J. had a disastrous experience with this problem in the 1920's. Their propagator worked out a method of rooting Koster's blue spruce (*Picea pungens* 'Koster') by taking late summer cuttings from bottom branches and they were soon rooting many thousands each year. When planted out, they grew vigorously and a fortune seemed to be assured. However, when the plants reached saleable sizes it was found that they developed but a couple of long, thick roots and they could not be

dug or transplanted successfully. At Princeton Nurseries we had the same unfortunate results with *Sophora japonica* clones grown from hardwood cuttings. They rooted in commercially acceptable percentages but their root systems were too sparse to be transplanted from the field.

PLANTS WHICH WILL NOT ROOT

Despite all the valuable advances in cutting propagation, rooting compounds, mist systems and light manipulation, there are still many desirable ornamentals which cannot be rooted at all or will do so in too small percentages to be successful. Most of these are trees , but there are some shrubs as well. Oaks and beeches are notorious examples of plants which will not root. The many popular clones of *Fagus sylvatica* refuse to root and must still be grafted to produce liners. Hans Hess reported success in rooting *Quercus robur* 'Fastigiata' many years ago but other species will not root. Any grower who produces large quantities of our native American oaks, has encountered super trees or unusual variants well worth producing, but they cannot be rooted. If they are to be vegetatively propagated at all, they must be grafted, despite some rather high levels of incompatibility in the case of oaks.

Magnolia denudata [syn. *M. conspicua*] is a curious example of a tree that will not root although most of the clones of its hybrid offspring *M.* × *soulangeana*, root quite easily. *Magnolia denudata*, still in the first rank of the hardy white magnolias, must be grafted, preferably on *M. kobus*. *Prunus sargentii* is another very desirable tree which will not root, unlike most of the other Japanese cherries.

GRAFTING VERSUS TISSUE CULTURE

While many plants which cannot be propagated by means of stem cuttings can be propagated by tissue culture, there are some disadvantages to the latter method that are beginning to appear. One of these problems is mutation. Tissue culture propagation produces many young plants from such extremely juvenile cells that the mutation rate is very much higher than what occurs in nature or in cutting propagation. Both of the most important clones of *Acer rubrum*, which are being widely grown from tissue culture, are exhibiting percentages of trees which are not the original clone. As yet it is not clear whether these are true mutations or whether some mixed trees get into the cultures. However, the results are some trees which are certainly not true to name. In the case of evergreen hardy rhododendrons and some deciduous azaleas the production of mutant plants is unacceptably high. Many growers are finding extreme variations in growth habits, leaf size, and flower color.

In the case of the cutleaf weeping birch mentioned earlier, plants grown from tissue culture are quite different from budded plants, being juvenile in appearance with greatly shortened internodes. The original form has been reproduced by grafting or budding unchanged for over 200 years.

Grafting still must be used to reproduce the desirable clonal forms of beeches and oaks. Oaks in particular have yet to be reproduced in tissue culture labs despite the best efforts of skilled technicians.

ADVANTAGES IN GROWTH RATE

There is yet another additional advantage to budding or bud grafting that is well known to shade tree growers, and that is rapid growth in the field. This is especially true of red-foliaged trees like *A. platanoides* 'Crimson King' that are evidently deficient in chlorophyll. It is possible to root cuttings or pot graft these maples on seedlings and get good stands in the field. However, such trees may take several years to reach 6 ft in height. The same clone, budded in the field on vigorous understock may reach 9 ft in height in the first summer following budding. Many expensive years of field culture are thus avoided.

Similar results favor bud propagation over cutting propagation in other tree species. At Princeton we have been successful in rooting clones of *Tilia cordata* and *Zelkova serrata*. However, subsequent growth when they were outplanted in the field was very disappointing. Field-budded trees grew more in one year than the cuttings did in 3 or 4 years. Where incompatibility with properly selected understock is not a problem as in *Tilia, Gleditsia, Zelkova, Fraxinus*, and *Acer saccharum* and *A. platanoides*, field budding is certainly the method of choice.

Even the most ardent shade tree grower will agree that field budding is not a cheap method of propagation. Skilled budders are hard to find and the daily cost of each budding crew is substantial. Understock must be grown or bought and field-grown for the summer in which they are budded. Cutting off the tops of the budded seedlings , suckering and staking the buds to prevent blow-off in summer storms are also costly. However, when the growing structures, labor, and culture costs necessary to grow the tiny plantlets received from a tissue culture lab up to a size suitable for outplanting are considered, the costs of the two methods begin to converge. When the tremendous growth rate of a yearling bud is accounted for, the picture changes and bud grafting has the advantage, particularly given the importance of a straight trunk in a shade tree.

No propagator today is very happy about the rising costs of grafting and bud grafting. Skilled workers are scarce and harder to find. Production rates, particularly in bench grafting and pot grafting are considerably lower than they were a generation ago. Despite the many marvelous techniques which have been developed so that so many plants that had to be grafted in former years can now be easily propagated by simpler methods, grafting in all its forms is still a very necessary part of the propagator's world.

VOICE: Just wanted to comment on the Bradford pear. In 1979 I put out some cutting-rooted Bradford pear and we still have those plants. They look great.

BILL FLEMER: Bradford pear is one of those plants that develops poor root systems when grown from softwoods. We lined out 600 to 700 at our Allentown Specimen Nursery, and when we went to dig them, the root systems were so poor that they just fell over in the balls and we had to discard them. That is one group of plants which tends to produce better by budding.

PETER VERMEULEN: Just a comment on your comment on *Picea pungens*. We have some that are on their own roots that have been there 40 years. With the new root enhancing techniques we have today would you like to qualify your comments.

BILL FLEMER: There probably are cultivar differences. *Picea pungens* 'Koster' produces poor roots but I think that 'Thomsen' produces particularly good ones. Certainly if you dig them up and transplant them a number of times you can develop better roots.

BOB SCHUTZKI: With all the known benefits of clonal rootstocks on fruit trees why have there not been more work done on clonal selection of rootstocks for ornamentals?

BILL FLEMER: Part of the problem is that most are very difficult to root, take the maples such as Norway maple for example. We use seedling rootstocks for those that are difficult to root. Many people are going to clonal rootstocks (M-7 for example) for flowering crabapples because you do not have the suckering

problem. Usually the clonal rootstocks that you would want are so difficult to root that there is no point at all to it. When you can root the cultivars, as with red maple you might as well root them.

DAVE BAKKER: Has anyone rooted *Syringa reticulata* 'Ivory Silk'?

BILL FLEMER: We have rooted it from softwood shoot cuttings very easily and some from hardwoods (low percentage).

FRASER HANCOCK: We have also been rooting it but it has proven to be a slow rooter.

HOW TISSUE CULTURE CAN BE THE ANSWER

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Since 1985 I have been the tissue-culture plant grower at A. McGill & Son Nursery in Fairview, Oregon. In the last few years I have seen quite an increase of interest in tissue-culture plants. Our only supplier of tissue-culture material is Microplant Nurseries which is a joint venture of A. McGill and Son and Knollview Nurseries. After a shaky start we have come a long way. Currently A. McGill and Son grow by tissue culture:

15 red maple cultivars
15 crab apple cultivars
2 ornamental cherry cultivars
4 birch cultivars
2 linden cultivars
1 sugar maple cultivar
1 amelanchier cultivar

We have been very successful in producing a field-ready plant for our growing fields and also for outside sales. Motivated by our motto of "Quality from Vigilance" we have worked to ensure a live tree in every hole, the result has been producing material we can be proud of.

HOW CAN TISSUE-CULTURE BE THE ANSWER?

As a tissue-culture plant grower, answering that question automatically puts me in the position of a "biased" authority, though I work to keep as objective a view as I can. There are quite a few advantages to growing trees by tissue culture; here are several examples:

1. Crabapples, less suckering means saving money.
2. Marketing of new cultivars in a much quicker fashion.
3. Solving the problem of incompatibility—think of red maples.
4. Securing the number of trees you want to plant of a certain cultivar when the seed source is not constant—think of linden.

Tissue-culture plants begin in the hospitable environment of the lab; there is plenty of nourishment, the heat source is constant, and the lighting is controlled to meet their demands. But at some point the plants must be exposed to all the elements of Mother Nature. That is where I come in. Those of us in the greenhouse stage of the business act as the transitionary stage between the lab and the harsher outdoor environment. I would like to now take you step

by step through the process of getting the plants from the lab to the field.

We receive the plants in large boxes from our lab, Microplant Nurseries (3,000 to 4,000 plants, if rooted, per box—or approximately 10,000, if microcuttings, per box). The plants are then kept at a temperature of 35 to 45 °F. It is very important to plant as soon as possible. Freshness is the key. Always be ready to plant immediately, stay in contact with your lab so as to know exactly when the plants will arrive.

The containers we grow in are 1¾ in.x 1¾ in.x 2 in. plastic pots and are fabricated specifically for us by the McConkey Co. in California; 80 pots fit in an Anderson flat. Some people use plug trays (98 cell); others plant them in 2½ in. x 2½ in. x 5 in. tree pots. Therefore take your pick and make it work for you. I am sold on individual pots because somewhere along the line there is grading involved. Without grading, big-leaf maples will shade out the smaller trees. I feel it is more difficult to grade when using plug trays.

The soil mix must be a well drained soilless greenhouse mix. I use 50% fine composted (aged) hemlock, (fine fir also works well), with a 50% PreMoist, a W. R. Grace product. The PreMoist has some fertilizer value in it. Other people using different mixes have reported satisfactory results.

Flat filling is done with a Gleason flat filler. The flats are then moved to the greenhouse bench. There the flats are watered thoroughly. Make sure the growing medium is very *wet*. For some reason I do the watering myself, mostly because I want to make sure everything is wet through, sometimes this is difficult with bark. If it is not right, I have myself to blame. In the last going over I add 100 ppm calcium nitrate and Benlate, as the label directs as a drench. The calcium nitrate stock mix is prepared as follows: 2 lb calcium nitrate and 2 lb Benlate are mixed in two gal. of water. The stock is run through a 1:200 Smith Injector.

Our planting tool is a modified Grow-Straight, patented by J. Frank Schmidt. The crew stays together during planting, I do not want one person starting one end of the bench and one at another. The reason for this is because this is a critical time for the little plantlet and I have to keep some moisture on them all the time. So keep the crew together so you can do that easily with a fine mist nozzle. On very hot days I use the Baumac fogging machine and we plant in the fog. This makes it possible for us to plant 8 hours a day, as it keeps the plants and crew cool. Put the machine on automatic and set for 85% humidity—it works great. Our benches are tented and as soon as a bench is planted we close the tent tight to keep the humidity in.

A Mistomatic will take over and go off every 20 min. for 4 to 5 sec, just enough to keep the plants from wilting. Adjust when you feel the plants are getting too wet. A warning in this respect is: watch cloudy days, there are more sophisticated devices on market than the Mistomatic, such as the P.R. 2 made in California.

Another very important factor is the effect of chilling. Some plants need a bit of chilling before they get planted, especially crabapples, which need at least 6 weeks of 38 °F before planting. If they do not get that they will not grow. This is very important when you make early spring plantings of crabapples; when making summer plantings of crabapples the chilling is not necessary.

Depending on climatic conditions and plant type, rooted plantlets will need to be tented for 5 to 14 days for weaning. Microcuttings will need 2 to 4 weeks in the tents. As soon as the new growth appears and the plants seem "established", gradually reduce misting and expose plants to normal greenhouse conditions. The sooner the plants are out of the tented environment, the better. After you have gradually cut back on the misting, remove the tenting. This is best done early in the morning on a cloudy day. Be prepared to watch very closely and apply water as needed. Some people continue to use shade cloth for several days after the plants are out of the tents. Bottom heat is still recommended if the weather is cold. Ultimately, the plants should be able to stand regular greenhouse conditions.

As soon as the plants are in the open greenhouse start a liquid fertilizer program. I mix a stock solution in 10 gal. of hot water from the following constituents:

6 lb potassium nitrate
2⅔ cup phosphoric acid, 75% industrial strength
6 lb ammonium nitrate, 34-0-0
5 lb urea, 46-0-0
8 lb magnesium sulfate, 9.8%, (epsom salt)
1 lb iron chelate
2 oz Peter's Special Trace Elements
2 oz manganese

This stock solution is injected through a 1:200 Smith Injector. I run the whole thing through a water boom system. Experience has taught me not to use this mix on 'Heritage' and river birch; they are burned. On these two items I use 100 ppm Peter's 20-10-20. I fertilize three times a week depending on the weather, if cloudy I slow it down. Fertilize the plants thoroughly and keep the plants growing!!!

To keep the temperature in the greenhouse tolerable I use 55 to 80% shade. This last summer was difficult for me, because we had so many cloudy days. As the plants start growing we have to do some grading to get those little plants from under the bigger ones.

Otherwise they get shaded out. The bigger plants (8 in.) go outside to harden off for 3 to 4 weeks—the longer the better. The fertilizer is cut off as soon as the plants go outside, where the plants will still grow 4 to 6 in. until all the fertilizer is used up. The plants are clean to start with and disease is not too much of a problem. Keep a bit of Benlate on the plants in the early spring, according to the label. This tends to keep *Botrytis* at bay. In addition to the Benlate, use plenty of ventilation.

Aphids at times infest the crabapples and birches; I usually fumigate 2 or 3 times with nicotine. I do not like to use other sprays like Malathion because the plants are soft and have a tendency to burn easily.

When the plants are hardened-off enough so the mechanical planter can take them, we make a planting. We make 4 to 5 plantings during the spring to fall growing season. Cut-off date for our last planting is usually September 15. This gives the plants enough time to get established for the winter. At the time of planting we bury a "T-tape" under the plants so we can drip irrigate any time we want. By the time the planter is on the end of the row the water is not too far away. The drip system stays with the plants until digging time, 2 to 3 years later. This allows us to economically water and fertilize our fields any time we desire.

The end product, of course, has to compete with a budded tree or seedling. If you compare the different ways of growing with tissue-culture trees, the tissue-culture will match up very favorably. We dig beautiful trees with excellent root systems.

One last word, I believe there is a tremendous opportunity for tissue-culture trees in the future; both in field production and in the container yard.

THE ADVANTAGE OF USING SEEDLINGS IN SHADE TREE PRODUCTION

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INTRODUCTION

The mission of this paper is to present some thoughts on the place of sexual propagation in the nursery industry. There needs to be an intentional balance of sexual and asexual propagation used by our industry to fulfill world-wide environmental plant needs, i.e. ''Global Releaf''. This discussion assumes careful screening and selection of seed sources. I have purposely not referred to specific plants since I feel it is important for the reader to ''dream'' and think of his or her applicable plants.

ADVANTAGES OF SEXUAL (SEED) PRODUCTION

Variability. It is essential in programs such as ''Global Releaf'' for the propagator, as the expert, to see that a balanced variability is maintained in plant production. This should ease pressure on Integrated Pest Management Programs and aid in the reduction of chemical controls. It is crucial that seed sources are carefully screened and matched to specific environmental situations.

Aesthetics. Part of the beauty of our environment is that not all plants of a species are exactly alike. Variability is pleasing to the eye. Wouldn't life be boring if all humans were exactly alike! I'm sure the law profession would be against it!

Economics. It is simply cheaper generally, to propagate plants sexually than asexually. Where this is the case, we need to carefully analyze our environmental needs to see if they are enhanced by variability.

Shorter response time to high volume needs. Many times sexual propagation can be used in specific cases to fulfill a market demand considerably faster than asexual propagation. Demands for plants will increase dramatically through such programs as ''Global Releaf''. Private industry needs to be prepared to meet these demands with quality and quantity plant material—or face increased governmental competition from state and federal nurseries.

Ease of transportation. Seed is much simpler and easier to transport than cutting wood, buds, or unrooted micro-cuttings. Seed can be easily transported.

Ease of storage. Seed can be easily stored in small areas with minimum care for long periods of time. Stock plants require high maintenance and relatively larger spaces.

Juvenility. Seed automatically refocuses the plant to a juvenile state. This has many advantages for the propagator.

No graft incompatibility. This is a very important advantage since this problem can occur over a long period of time.

Root systems may be better. Sometimes root systems of seedlings are superior to asexually propagated plants.

Greater chance for the propagator to observe variation. Many improved plants have been first observed in seedling lots by propagators. This is a tremendous source of improved and new plant material. There are thousands of propagators but only hundreds of plant breeders!

Sexual propagation is the best way. Some plants simply are more vigorous, or their characteristics are best maintained by sexual propagation.

Broader preservation of 'gene' bank. Sexual propagation provides a world wide genetic storage facility. It gives a broad perspective to the problem rather than a few facilities scattered around the world subject to "tunnel vision" and or catastrophic situations. It provides a world-wide laboratory to screen for pest and pollution resistance.

Less net impact on environment. It is important every individual, industry, and government analyze their specific environmental impact. The propagator is not immune— in fact we should be the leaders! In many cases, sexual propagation has a lesser negative impact on the environment. Less oil, gas, electricity, polyethylene, rooting hormones, water, nitrates, etc. are often consumed by sexual compared to asexual propagation. Here is a chance to really dream and analyze.

DISADVANTAGES OF SEXUAL PROPAGATION

Every plant is not identical.

CONCLUSION

As professional propagators and educators we all have a leadership responsibility to intentionally dream and evaluate the environmental impact of sexual and asexual propagation of plant material. This must then be translated by us into action! The ball is clearly in our court as professional propagators and horticultural educators.

WHY WE SHOULD USE SEEDLINGS INSTEAD OF GRAFTS AND BUDS

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A number of years ago the National Landscape Association began periodically tallying the species of trees its members were satisfactorily using on their projects. Their most recent survey of the top 15 species of shade trees and the top 15 species of flowering trees indicates the basic list has not changed much in the past 20 to 25 years. The dramatic change, however, has occurred in the use of named cultivars of the species most commonly used. To properly discuss this change one should look at the changes occurring in the nursery business.

PROPAGATING FOR A CHANGING MARKET

Historically the nursery business has been a grower-oriented business where the grower basically decided what plants to grow and how to grow them. Once produced they were made available to the retailer for sale.

Today, improved selections of most species of shade and flowering trees have been made and propagated asexually, most commonly, by budding or grafting and made available to the trade. Rooting cuttings of shade and flowering trees is increasingly becoming a standard nursery practice. These selections most often are superior individuals emphasizing certain characteristics such as form, fall color, fruitfulness, fruitless (where fruit is a problem), disease resistance, and other characteristics that set the cultivar apart from the native species.

Many cultivars have been patented and substantial money has been spent on promoting their sale and use. Urban foresters, designers, and architects desiring special shapes and forms of plants to complement their designs have created a demand for more cultivars. The retailer also has become more demanding in what they want particularly in the area of flowering, fruiting, fall color, and form.

The result is we no longer have a grower-oriented industry but instead have a market-orientated industry forcing growers to produce what is demanded in the market place. In the long run I believe that some mistakes are being made to satisfy this demand.

SEEDLING IMPROVEMENT

Contrary to my assigned title I believe we need to approach this subject from the viewpoint of seedling improvement. This improvement can come about by continued selection of genetically superior plants for use as understock and for growing on to be used directly in the landscape, urban forest, and other purposes such as conservation. As propagators we should address all aspects of propagation and their interdependence in an effort to make progress and not to be arguing sexual vs. asexual propagation. I am convinced the answer to work toward quality plant improvement and enjoy the best of both worlds. We need not have a trade-off between uniformity and risk.

Plant species differ greatly in their abilities to withstand pests and environments. This favors the argument that a broad genetic diversity is necessary to survive under wide and varied growing conditions and pest attacks within a year and from year to year. The dangers from clonal plantings of the same genotype occur because they have the same set of resistance genes. When these are overcome or exceeded, catastrophic losses can occur. Certainly this is an argument in favor of using seedlings to maintain a broad genetic base.

Seed selection can solve many problems related to pests and environment. The original geographic source of seed (provenance) is of paramount importance in plant use whether it be in the landscape, urban forest, or out-planting for conservation purposes. Will a clone selected in one part of a natural range survive and grow in other parts of the range or in some instances far removed from its native range? Here the possibility of selecting proper seedling understock with seed coming from the original geographic area of the clone becomes important. Also there could be a factor here that presents another problem with grafted and budded materials, incompatibility.

INCOMPATIBILITY

There is substantial suspect that incompatibility is in many instances virus-related, the virus being present in either the scion or rootstock. A seed source from the local area could be resistant to the problem virus, illustrating the importance of seedling stock used for budding and grafting. To further emphasize the importance of seedling understock, we find increasing evidence where seedlings from crosses bearing a common parent will yield better bud stands, and exhibit faster, more vigorous growth, is no doubt a factor linked to hybrid vigor of the seedling. Due to common parentage and genetic makeup one can conclude the risks of

incompatibility are greatly reduced. We have made this observation for a number of years of seedlings produced by crossing *Pyrus calleryana* 'Bradford' × *P. calleryana* 'Redspire'. The F_1 seedling is then used as understock for either clone, showing great improvement in compatibility.

GLOBAL RELEAF

Currently, the environment and specifically the "greenhouse effect" is setting the stage for programs such as "Global Releaf," with goals of planting millions of trees in urban areas across the country.

Recent discussions with our local and state foresters indicate they will be specifying planting of native species primarily produced from seed with provenance of foremost consideration. Their primary reason, to maintain a broad genetic base for better pest and disease resistance and be better adapted to local environmental conditions and to give a naturalistic effect.

When addressing the subject of seedlings vs. asexually propagated plants one must not overlook major genera where seedlings are still the primary means of propagation, such as *Quercus*.

Also those species that come true from seed should not be overlooked. These normally occur in certain species of plants such as *Malus*, and *Crataegus*. Most commonly these occur through apomixis where the seed embryo develops from an unfertilized egg or from the nucellus.

ECONOMIC FACTORS

Any commercial propagation program must be cost-effective. These are extremely competitive times, with less available competent help to perform labor-intensive skills such as budding and grafting. There can be no argument that seedling propagation is the most economical cost-effective way to propagate plants.

Recent years have seen us producing more woody seedlings under controlled greenhouse conditions in bottomless containers. Here we are able to greatly accelerate growth and to realize a much higher degree of uniformity, which persists after these liners are planted into the field.

By now you may have a good idea of the name of our recipient. He has received numerous awards and honors for his research and extension work and has freely given much to the International Plant Propagators' Society over many years. Our recipient is a Past President of the Eastern Region, as well as being the incoming IPPS International Board President.

May I present the 1989 Award of Merit to Elton M. Smith.

Friday Morning, December 8, 1989

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COINCIDE: PHENOLOGICAL APPROACH TO PEST MANAGEMENT

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Ladybugs may be an excellent control for green bugs on a vegetable crop. But where do you get 10 million; how do you disperse them; how do you get them to eat the pest; and how do you prevent them from flying away? What is important is the cost. The cost for control cannot exceed production costs. It is easy to see that economics would call for the most efficient pesticide at the least cost. We are talking about chemical control. At the present time we still rely on MORE chemical pesticides that are toxic to a wide range of animal species than on those directed to a few.

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Fortunately, we are moving in the right direction by removing the most persistent pesticides and those showing an ability to cause cancer or birth defects. But we have a long way to go before we have a *Bacillus thuringensis* that is specific to each of our insect pests. Research on botanical anti-insect compounds, soaps, oils, repellents, and other chemicals shows great promise. The use of biotechnology for the selection of pest-resistant plants and for the infusion of pest-resistant genes into plants also shows great promise. However, replacement is still years away for our standby insecticides of the 80's such as Diazinon, Sevin, Dursban, Malathion, and Orthene, to name a few.

What all this boils down to is that in 1990 we still have to recommend Cygon, Dursban, or Lindane (depending on what state you live in) to "control," actually prevent, the bronze birch borer. Our low-toxicity alternatives are few and far between.

If the situation indicates that a pest population has reached the threshold level for economic damage and chemical control becomes warranted:

1) We must choose the most effective pesticide that has the least toxicity to non-target plants and animals.
2) We must spray when the pest is vulnerable.
3) We must spray only the pest.
4) We must monitor to determine whether the pest is controlled.
5) We must determine the economic gain (or loss).

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SAS: Spray and See. There are still many people in business that apply 3 to 4 cover sprays each year to control insect pests. Many homeowners still think that this is the correct way to take care of their landscape plants. I seriously doubt that one can legally spray all of the landscape plants on the average urban landscape with a single insecticide that will control all the pests. I have seen several properties where 3 or 4 cover sprays are used each year and have still seen birches dying because of bronze birch borers or spruces with heavy mite infestations. Most of the landscapes that I have seen require pest control on only one or two plants, not all the plants. Think of the loss of beneficial and neutral insects. Think of the exposure of the environment to unnecessary chemicals when cover sprays are used. This system should be replaced. We have a

difficult job ahead educating that cover sprays may create more problems than they solve.

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IPM: Integrated Pest Management. There have been numerous studies that clearly demonstrate that IPM programs efficiently and effectively control pests with minimal use of toxic chemicals.

One area of IPM that needs more information is finding the precise time of the vulnerable stage of the insect pest. For example, cottony maple scale can be effectively controlled in the spring with a dormant application of oil. The pest is rarely noticed until after the leaves emerge and the ground, patio, picnic table, car, etc. are covered with sap and sooty mold. By this time the females begin laying eggs in cottony masses that are protected from most insecticides. Also at this time the twice-stabbed lady bug is busy eating the scale eggs. When do people spray? When they see the enlarging cottony masses. They may also see the white fuzzy ladybug larvae and mistake them for scales. The scales are most vulnerable when they hatch. When do they hatch? That depends on where you live. In northern Illinois it is usually early July. According to the Illinois Cooperative Extension recommendations for 1989, to control cottony maple scale: ''Spray acephate, malathion, or diazinon in July after crawlers have hatched; repeat 10 days later. Footnote: Treatment dates are listed for central Illinois (Urbana). In southern Illinois apply 2 weeks earlier and in northern Illinois 2 weeks later''. That is not what I call precision.

Let me give another example: Fletcher scale. Eggs hatch in early summer and the young nymphs are vulnerable to chemical sprays. Over wintering females are also vulnerable during the first warm weather of spring. However, the eggs, which are covered by the female's shell, are not vulnerable to most insecticides. Spraying before egg hatch is worthless and may be harmful to innocent insects. The Extension Service recommendation: ''Apply malathion in early April and repeat in early June. Footnote: Treatment dates the same as for cottony maple scale.

Even if you have a scout-monitoring IPM program it is difficult to know when the crawlers have hatched at every location. Some sites may be near the Lake (Michigan) which has a warmer winter and cooler spring than outlying areas. Again, there is a lack of precision.

Now there is a system that offers precision concerning the timing of the vulnerable stage of an insect pest. This system is also simple, accurate, and ingenious. I refer to **COINCIDE.** **COINCIDE** is based on the phenology of indicator plants and the life cycle of an insect pest. This is not a new concept.

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Synchronous Phenological Indicator (SPI). To my knowledge no one has ever given this phenomenon a name. I refer to it as synchronous phenological indicator or SPI for short.

The life cycle of the insect is closely associated with degree-days or day-degrees (DD). If we know the DD of the egg hatching of cottony maple scale or Fletcher scale, we know when to control. The degree-day value is constant whether you are in Madison, Wisconsin, or Lexington, Kentucky. However, the calendar dates are different.

With an IPM program how do you arrive at the DD at each location? Weather conditions, proximity to the lake, location on the shady side of a building, all will cause it to vary. This can be resolved by linking some indicator plant with the timing of the insect life cycle.

Don Orton, nursery inspector for the Illinois Department of Agriculture, has been inspecting nursery plants in the State of Illinois for over 20 years. He has compiled extensive notes on insect pests of ornamental plants, their vulnerable stage, and some indicator plant that **COINCIDES** with that stage. An indicator plant should:

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OVERWINTER SYSTEMS FOR HERBACEOUS PERENNIALS

STEVEN M. STILL, TRACY DiSABATO-AUST, TIM RHODUS

Department of Horticulture
The Ohio State University
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There has been a substantial increase in the production of herbaceous perennials (here referred to as perennials) in the past several years. Much of this production increase has occurred in container production. In areas where winter temperatures approach or go below 0 °F, perennials require some type of winter protection.

Research in overwintering container perennials has not kept pace with the needs of the industry. There has been limited published research on root and crown hardiness of perennials. Research is needed to determine the minimum soil temperature to which roots of different perennial species can be subjected.

Some research has been done in identifying successful overwintering methods for perennials; however, this area still needs much attention. Various overwintering methods are utilized by growers across the United States and Canada. Most of what is known is based on grower experience. Growers may be providing high priced overwintering measures that provide more protection than necessary. However, until root hardiness of an array of perennials has been determined, growers have no choice but to apply the methods that are available to avoid plant loss.

The objectives of our research were to: (1) determine the cold hardiness of ten species of perennials by controlled freezing studies, and (2) evaluate the effectiveness of various overwintering structures on the survival of container-grown perennials.

CONTROLLED FREEZER STUDY

Ten perennials were selected for the study based on grower suggestions concerning hardiness and public popularity. These plants were: *Achillea filipendulina* 'Parker's Gold', *Lythrum* 'Robert', *Campanula glomerata* var. *acaulis*, *Coreopsis grandiflora* 'Sunray', *Gaillardia* × *grandiflora* 'Monarch Strain', *Erysimum hieraciifolium*, *Kniphofia uvaria* Pfitzer's hybrids, *Chrysanthemum coccineum*, and *Geum quellyon* 'Mrs. Bradshaw'.

Plugs of the above species were planted into one-quart containers in September and grown with normal production practices. In December, plants were drenched with Benlate and Daconil 2787.

1. Structureless, single layer thermal blanket covered with a single layer of 4 mil white copolymer film.
2. 12 foot tall hoop poly house covered with 4 mil white copolymer film. Perennials were left uncovered in the house.
3. Structure was identical to #2 except the perennials in this structure were covered with a thermal blanket film and a 4 mil white copolymer film.
4. 12 foot tall hoop poly house covered with 1 layer of 4 mil white copolymer and 1 layer of 4 mil clear copolymer inflated with a squirrel-cage fan. Perennials were left uncovered in this house.
5. Structure was identical to #4 except the perennials were covered with thermal blanket and 4 mil white copolymer film.
6. Control plants were placed in a minimum temperature greenhouse at 32 °F.

The species placed in the storage systems were the same as those utilized in the freezer study.

The plants were drenched with fungicide according to industry practice. Rozol, a rodent bait, was placed in several locations within each treatment. Snarol slug bait was spread around the perimeter of each treatment. The foliage was cut back on the taller growing species to reduce the potential for disease and improve ease of covering. All plants were irrigated to container capacity 24 hours prior to covering.

Copper-constantan thermocouples were placed approximately 2 in. deep in the center of a container in each system to measure soil temperatures. Ambient air temperatures were also recorded.

The plants were covered when night air temperatures remained near 20 °F and were uncovered when night air temperatures were near 30 °F. The quality rating index of survival was the same as used in the freezer study.

The minimum container soil temperature recorded for the winters of 1986 and 1987 are listed in Table 1. Table 2 lists the regrowth evaluations for the ten species of perennials in the six storage systems.

Species subjected to overwintering during 1986 were usually of lower regrowth quality than species tested in 1987. This was due to lower temperatures in 1986. The most effective system in 1986 was the single layer poly house with the perennials covered with a thermal blanket. The poorest quality occurred with plants overwintered in the single layer poly house with no thermal blanket over the perennials.

In the winters of 1988 and 1989, additional systems were added. In 1988 the treatments included the ones from the previous winters plus:

After natural cold acclimation the plants were placed in a cooler maintained at 30 °F until the freezing studies were conducted.

The plants were exposed to the following soil temperatures: 30 °, 27 °, 24 °, 21 °, 18 °, 15 °, 12 °, 9 °, and 6 °F.

There were 3 replications of each species within each of the nine temperature treatments repeated over 4 blocks (weeks) of time. After exposure to the treatment temperatures the plants were placed in a greenhouse for forcing at a temperature of 70 °F. A qualitative analysis was done by a panel of 4 judges to rate the saleable quality on a scale of 1 to 5 with 1 being dead, 2 alive but unsaleable, and 3-5 saleable, with 5 the highest quality. Plants were judged after 4 weeks of regrowth.

The controlled freezing study showed great variation in the hardiness levels among the different species. Saleable plants were found to occur from temperatures of 12 °F for a hardy species to 27 °F for the most tender species. There was a direct relationship between temperature and regrowth quality.

Of the ten species, *Achillea, Lythrum*, and *Gaillardia* survived the lowest temperature. All three were of saleable quality after exposure to soil temperatures of 12 °F. These three species would be most likely to survive in any type of overwintering protection.

Species surviving intermediate temperatures included *Campanula* and *Coreopsis*. Saleable plants of *Campanula* occurred at exposures of 15 °F whereas plants of *Coreopsis* were saleable at exposures of 18 °F.

The following five species are considered tender species in this research. The temperatures at which saleable plants were found are listed to the right of each species.

Chrysanthemum coccineum, 21 °F
Erysimum hieraciifolium, 21 °F
Digitalis × *mertonensis*, 24 °F
Geum quellyon 'Mrs. Bradshaw,' 24 °F
Kniphofia uvaria Pfitzer's hybrids, 27 °F

Several of the above five species are ones that growers often have had problems overwintering. This is especially true with *Kniphofia* which is often placed in a minimum heat storage (30 °F) to prevent winter damage.

OVERWINTERING STUDY

The overwintering study to evaluate the effectiveness of various overwintering structures on survival of container-grown perennials was conducted over a four-year period (1985-1989). In the first two years the following overwintering systems were studied:

Table 1. Minimum container soil temperature recorded for the winters of 1985-1986 and 1986-1987 in six different overwintering systems

System	1985-1986	1986-1987
Minimum heat (MH)	0 5°C (33°F)	1 1°C (34°F)
Single layer poly house with no thermal blanket covering the plants (SU)	-7 1°C (19°F)	-3.3°C (26°F)
Single layer poly house with thermal blanket and milky poly covering the plants (SC)	0.5°C (33°F)	-1 6°C (29°F)
Double layer poly house with no thermal blanket covering the plants (DU)	-1.6°C (29°F)	-1 6°C (29°F)
Double layer poly house with thermal blanket and milky poly covering the plants (DC)	0.5°C (33°F)	-3 3°C (26°F)
Thermal blanket and milky poly covering the plants (TB)	-4.9°C (23°F)	-1 1°C (30°F)

1. A structureless system composed of a single layer of 4 mil white copolymer film over the perennials.
2. A structureless system of a 12 in. layer of wheat straw between 2 layers of 4 mil white copolymer film.
3. No cover on perennials stored outside.

Seven perennials were overwintered in 1988 and are listed in Table 4.

The lowest temperature recorded in 1988 occurred on January 6 (Table 3 lists the air temperatures and soil temperatures of containers in each system). The lowest soil temperatures were recorded in containers stored in single layer poly systems, either in a hoop house or structureless system. The temperatures in these two systems show the same trend as the single layer system in the first two winters.

Table 2. Regrowth ratings[z] for 10 species of herbaceous perennials after overwintering in six different systems[y] during two winters

Species[w]	Regrowth ratings 1985-1986[x] MH	SU	SC	DU	DC	TB	1986-1987[x] MH	SU	SC	DU	DC	TB
Achillea	4 1 BCD	4 0 CD	4 2 ABCD	4 5 ABCD	3 8 D	4 8 AB	5.0 A	4.6 ABC	4.7 ABC	4.7 ABC	4.7 ABC	5.0 A
Gaillardia	4.1 ABC	1.5 F	3.5 CD	1 6 F	2.5 E	2 9 DE	4 7 AB	3 5 CD	4 5 AB	3.9 BC	4 5 AB	4 9 A
Lythrum	4.8 AB	4.4 B	4.5 AB	5 0 A	5.0 A	4 4 B	4 9 AB	4 9 AB	4.9 A	4 7 AB	4 9 AB	4 8 AB
Coreopsis S.R.	—	—	—	—	—	—	4 8 AB	3 3 D	4 2 CD	4 9 A	4 1 C	4 8 A
Coreopsis B.S.	4.6 AB	1.5 C	3 5 ABC	5 0 A	3 4 ABC	2 4 BC	—	—	—	—	—	—
Erysimum	—	—	—	—	—	—	4 9 A	4 6 A	4 5 A	4 9 A	5 0 A	4 5 A
Digitalis	5 0 A	2.6 C	4.8 A	3.7 B	5.0 A	3 5 B	5.0 A	3 5 B	5 0 A	4 8 A	4.9 A	4.3 AB
Geum	4 0 BC	1.0 E	3.5 CD	1.7 E	2 8 D	1.7 E	4.7 AB	4 4 AB	4.9 AB	4 6 AB	5 0 A	4.9 A
Kniphofia	—	—	—	—	—	—	4.7 A	3.3 B	4.9 A	3.2 B	4.4 A	4.6 A

[z] 1 = dead, 2 = unsaleable, 3-5 = saleable with 5 of highest quality

[y] MH Minimum heat
SU Single layer poly house with no thermal blanket and milky poly covering the plants
SC Single layer poly house with no thermal blanket covering the plants
DU Double layer poly house with no thermal blanket covering the plants
DC Double layer poly house with thermal blanket covering and milky poly covering the plants
TB Thermal blanket and milky poly covering the plants

[x] 1985-1986 mean of 16 plants per system
1986-1987 mean of 24 plants per system

[w] *Achillea* = *Achillea filipendulina* 'Parker's Gold'
Digitalis = *Digitalis* × *mertonensis*
Gaillardia = *Gaillardia* × *grandiflora* 'Monarch Strain'
Geum = *Geum quellyon* 'Mrs. Bradshaw'
Lythrum = *Lythrum* 'Robert'
Chrysanthemum = *Chrysanthemum coccineum*
Erysimum = *Erysimum hieracifolium*
Coreopsis S.R = *Coreopsis grandiflora* 'Sunray'
Coreopsis B S = *Coreopsis lanceolata* 'Baby Sun'
Kniphofia = *Kniphofia uvaria* Pfitzer's hybrids

[v] Mean separation within species only

Table 3. Air temperatures in various storage systems and soil temperatures in containers on January 6, 1988.

Air temp	-2 °F
Air-single layer polyhouse	9 °F
Air-double layer polyhouse	19 °F
Soil temp —Double layer polyhouse with thermal blanket	32 °F
Soil temp.—Double layer polyhouse with no thermal blanket	32 °F
Soil temp.—Single layer polyhouse with thermal blanket	32 °F
Soil temp —Single layer polyhouse with no thermal blanket	22 °F
Soil temp.—Thermal Blanket	25 °F
Soil temp —Poly covering	19 °F
Soil temp —Straw sandwich	29 °F
Soil temp —No cover	5 °F

The quality data for the species in 1988 (rated 1-5, 5 best) are shown in Tables 4 and 5. In the structureless system (Table 4) the poorest quality occurred in the no cover system, which was to be expected. *Kniphofia* and *Geum* also had poor regrowth quality when stored under single layer poly. The overall average of all species was also lowest under no cover and the single layer poly system.

Table 4. The effect of four different structureless winter storage systems on the regrowth quality of seven perennials in the 1988 winter study.

	Structureless systems			
Plant	Single layer poly	Thermal Blanket + poly	Straw sandwich	No cover
Achillea filipendulina 'Parker's Variety'	4 20*	4.20	3.73	2 53
Geum quellyon 'Mrs. Bradshaw'	2 93	4 20	3 60	1 00
Lythrum 'Robert'	4 33	4 13	4 60	1 07
Kniphofia uvaria Pfitzer's hybrids	2 27	4 13	3 20	1 00
Chrysanthemum × *superbum* 'Alaska'	3 47	4.20	4 47	1 07
Coreopsis grandiflora 'Sunray'	4.80	4 93	4 73	3.67
Gaillardia × *grandiflora* 'Dazzle'	3 33	3 20	2 73	2 07
Average	3 62	4 14	3 87	1 77

*1 = dead
2 = alive, not saleable
3-5 = saleable, 5 = highest quality

In the polyhouse systems (Table 5), plants stores in the single layer polyhouse with no additional cover over the plants had the lowest regrowth quality. (3.19). *Kniphofia* which is a tender species had high quality ratings except in the single layer no cover system. Table 6 lists the plant quality across all species as influenced by overwintering systems. The poorest regrowth quality occurred in the systems with only a single layer of milky copolymer.

Table 5. The effect of four different polyhouse winter storage systems on the regrowth quality of seven perennials in the 1988 winter study.

Plant	Polyhouse systems			
	Double layer layer thermoblanket	Double layer no cover	Single layer no cover	Single layer thermoblanket
Achillea filipendulina 'Parker's Gold'	3 67*	3 20	3.07	3.20
Geum quellyon 'Mrs Bradshaw'	4 67	4.40	3 80	4.07
Lythrum 'Robert'	4.47	4.13	4 60	4.93
Kniphofia uvaria Pfitzer's hybrids	4 67	4 93	3.20	4.80
Chrysanthemum × *superbum* 'Alaska'	3 80	4 00	4.00	4 33
Coreopsis grandiflora 'Sunray'	4 00	4 67	4.27	4 40
Gaillardia × *grandiflora* 'Dazzle'	3 33	3 53	3.60	3 33
Average	4.03	4 12	3 19	4 15

*1 = dead
2 = alive, not saleable
3-5 = saleable, 5 = highest quality

In 1989, two additional structureless systems were added and several new species were evaluated (Table 7). The new systems evaluated were (1) 6 to 12 in. of salt hay over the containers with a 4 mil milky copolymer covering the hay and (2) two layers of remay (a tobacco cloth-like material) over the containers with a 4 mil milky copolymer covering the remay.

Table 6. Average plant quality rating across seven species of perennials stored in various winter storage systems in 1988.

System	Plant evaluation
Polyhouse Single layer with thermal blanket	4.15
Structureless thermal blanket	4.14
Polyhouse Double layer—no thermal blanket	4 12
Polyhouse Double layer—with thermal blanket	4 03
Structureless Straw Sandwich	3 87
Polyhouse Single layer—no thermal blanket	3.79
Structureless Single layer poly	3 62
Structureless No cover	1.77

The minimum air temperature in the winter of 1989 was 9 °F. Consequently, the soil temperatures of the systems did not go as low as in previous years. However, the trends of previous years were still manifested by several of the less hardy species. Data in Table 7 show this trend. In the single layer poly cover, *Kniphofia*, *Aster* 'Mönch', and *Verbena rigida* had poor regrowth quality. These three species are considered by many growers to be species that are hard to overwinter.

Table 7. The effect of six different storage systems on the regrowth quality of 12 perennials in the 1989 winter

Plant	Structureless Systems					
	Single layer poly	Thermo-blanket	Straw	Salt hay	Tobacco cloth	No cover
Achillea filipendulina 'Parker's Gold'	4 2	4.1	4 3	4 7	4.6	2 4
Achillea millefolium 'Paprika'	4 9	4 7	4 7	4.7	4 9	3 7
Alchemilla mollis	5.0	4 7	4.8	4.9	4.7	2.3
Aster 'Mönch'	3 6	4 2	3.9	3 7	4.1	1.1
Coreopsis lanceolata	4 9	4 9	4 9	4 8	4 8	4 1
Digitalis × *mertonensis* 'Temple Bells'	4 9	4 9	4.7	4 6	4.9	1.6
Gaillardia aristata	4 3	4 3	3 3	4.1	4 4	3 3
Geum quellyon 'Mrs Bradshaw'	4.6	4 8	4 8	4 9	4 8	1.0
Kniphofia 'Royal Castle'	3 1	4 7	4.0	4 3	3 5	1.0
Pennisetum setaceum 'Hameln'	3 6	4 4	4.4	4 6	4.2	1 0
Phlox divaricata	4 5	4 6	4.8	4 8	4 4	3 4
Verbena rigida	2.8	3.7	3 2	3.1	3 0	1 0
Average	4.2	4.5	4 3	4 3	4 4	2.0

The winter of 1989 was not a good year to evaluate the remay cloth system. Growers in southern zones have successfully used remay cloth for frost protection in the spring and for winter protection. It needs to be examined further before any recommendations can be given for its use in northern areas.

EASTERN REGION QUESTION BOX

The Question Box Session was convened at 8:40 a.m. with Ralph Shugert and Bruce Briggs serving as Moderators.

MODERATOR SHUGERT: Question for Dr. Waxman. What pregermination treatments do you apply to seeds of eastern larch?

SID WAXMAN: Stratify for 30 to 60 days and then plant.

MODERATOR SHUGERT: Question for Dale Deppe. How often do you replace stock block plants?

DALE DEPPE: We do not have a system of continuous stock block replacement. When we first plant we usually plant about ¼ of the number that we eventually will need. So we have had to replant additional blocks later as we increase production. By pruning back the stock blocks hard we have had good success rooting the cuttings with the stock blocks and have not had to replant.

RALPH SHUGERT: When I worked for the old Cole Nursery we used to keep blocks for 8 years. That timing was just the owners decision and may have been related to juvenility. We would start a new block after 6 years so it would be ready for use after the eighth year of the old block.

PETER VERMEULEN: Our stock blocks of dwarf and unusual stock plants have proven valuable. As they mature and we must thin them out, they command a very good price. They will never be in excess.

MODERATOR SHUGERT: Question for Sid Waxman. Does grafting change the form or growth of witches'-broom seedlings of dwarf conifers?

SID WAXMAN: I think selecting the scion and not the understock is more critical. In most situations, such as white pine, I have seen very little stretching out of the grafted plant except when you use a strong upright terminal shoot as a scion. I think that lateral shoots are the best. Strong terminal shoots are not to be recommended for dwarf conifer plants.

MODERATOR SHUGERT: Question for Michael Dirr. In your talk you mentioned that fertilizer is more important than lights in promoting bud break after rooting. Isn't this contrary to research in the last few years?

DICK BIR: I just visited Mike and we discussed that very point. Yes, it is contrary, and it was just working for him on the lace bark elm trees. After rooting them he was fertilizing to get bud break and it was more important than light.

RICK LEWANDOWSKI: I would like to comment on that. Mike is in Georgia and is rooting some of these plants in late April and has a considerably extended growing season. So I would caution you on his statement relating to fertilization being more important than light.

MODERATOR SHUGERT: Soliciting comments from the floor on the efficiency of white versus black shade cloth or lath. Can it be used to advantage on other than ericacious stocks?

DICK BIR: I showed the slide so I guess I should answer the question. I have only seen it used on ericacious plants—rhododendrons and mountain laurel, with excellent results. They were growing much better than those growing under black shade in the same nursery.

STEVE MCCULLOCH: We ran a little experiment comparing white poly versus black shade cloth and found that temperatures under white were much lower than under black.

MODERATOR BRIGGS: In regard to alcohol-based quick-dips, is there any difference in the burn experienced with different types of alcohols?

STEVE MCCULLOCH: We do not use alcohol to dissolve plant hormones, but acid or base in the lab. Outside we just use commercial preparations.

BILL BARNES: Research done at the University of Tennessee comparing various solvents for auxins showed that serious plant damage can occur from methyl alcohol, isopropyl alcohol, and acetone. It was also noted that denatured alcohol may contain denaturants such as benzene or toluene. These substances are causing the problem with denatured alcohol. If you get pharmaceutical grade alcohol or ethyl alcohol (95%) from the liquor store it does not have these elements and you do not get the toxic symptoms. Work that Calvin Chong and I are doing has shown that when the auxin concentration gets above 5000 ppm, the loss of root quality and basal burn are significantly different with alcohol than with propylene glycol. Propylene glycol at these high concentrations of auxin causes much less damage than alcohol.

MODERATOR SHUGERT: To Michael Dirr. Do you prefer a certain solution for rooting hormones like K-IBA or Dip-n-Grow? What are advantages and disadvantages of each?

VOICE: Mike is using K-IBA extensively. K-IBA looks good, it is soluble in water so you do not have the ethanol problem. Since it is dissolved in water it is not absorbed as well as from the alcohol solutions. He also uses a wide range of other rooting products.

BILL BARNES: With high solvent solutions you are often running into toxicity. K-IBA being water-soluble is much safer. However, you must use K-IBA at a higher concentration. We use K-IBA at 20,000 ppm to root 'Bradford' pear cuttings and get 80 to 90% success. If you use it in an alcohol solution you have to use something in the order of 5000 ppm and get less rooting. I do not know what would happen if you went higher with the alcohol solution, possibly damage to the cuttings.

One solution to the solvent problem is to dissolve the auxin in 1% KOH. IBA is completely soluble and you get no basal burning with an extremely fine root system. This suggestion was based on research in the Journal of Environmental Horticulture. That research showed that IBA dissolved in KOH is more effective than an equal concentration of K-IBA. The KOH appears to have an independent effect, possibly pH.

MODERATOR BRIGGS: Has anyone tried pretreating hardwood cuttings with IBA prior to placing in winter storage for spring sticking?

DAVE BAKKER: We did some *Prunus* × *cistina* cuttings last year with powder and found that the usual spring treatment was better.

PETER VERMEULEN: We tried some *Juniper*, *Taxus*, and *Ilex* hardwood cuttings that way some years ago. The fall cuttings were treated, put in poly bags, and placed in cool storage (cold cellar) for spring sticking. Some of the *Ilex* actually rooted in the bag.

CALVIN CHONG: We used to take cuttings in November, treat them with 5000 ppm IBA, and put them in a closed barn in sand for the winter. By late March/April some of them had rooted or callused and were ready to be planted out. In most years the technique worked quite well but we had a few failures.

ED LOSLEY: I know a Lake County nurseryman who rooted yews and arborvitae by taking cuttings in early winter, treating with

hormone, packing upright in flats of sphagnum moss, and sticking them in cold frames in early spring. He did this with a great deal of success.

BRUCE BRIGGS: If you look back at some of the old Proceedings you will see that they used some bottom heat to callus cuttings and then put them back in cold storage to retard development. You might review that.

MODERATOR BRIGGS: What is the status of IBA in regard to the new registration required by the EPA?

DALE DEPPE: Just to add a question to that. Are we going to have time to put in an order before they cut it off?

RALPH SHUGERT: I believe that there is going to be plenty of warning.

CALVIN CHONG: It will cost $5 million to get approval for IBA use. The feeling when I attended the horticulture meetings this past year was that there is money to be made from IBA and that some company will put up the necessary funds for registration.

DAVE BAKKER: I bring in some powders from Europe, and they warn users not to smoke when using IBA powders. To put that warning on the can, someone must have done the research to make that statement.

MODERATOR SHUGERT: To Francis Gouin. My experience with sludge is that there is little life, (weeds, earthworms, etc.) even after it has been stockpiled for over a year. Have you observed this?

Have you ever successfully grown viburnums in a container mix with more than 10% sludge?

FRANCIS GOUIN: Yes, we see the same. You will get June beetles if not covered and that is a problem sometimes. Yes, we have grown viburnums and used up to 30%.

MODERATOR SHUGERT: Does anyone have information about field growing *Daphne* × *burkwoodii* 'Sommerset' or 'Silver Edge', or any other hardy (Zone 5 to 6) daphne? If so, I would be interested in learning the cultural techniques for successfully producing the plant.

PAUL VAN DER KROFT: We have a very sandy soil with a high pH, and it is no problem. *Daphne* × *burkwoodii* does best in alkaline soils, contrary to most of the other daphne types. Any fertilizer we put on today is gone tomorrow, which goes along with the need for lower fertility.

MODERATOR SHUGERT: If the seed of woody plants germinates at the wrong season, what should I do with them? For instance, if they germinate in November can I just let them grow all winter, the next spring, the next summer, let them go dormant and carry on, or do they have to have a dormant period? If they do how do I induce it?

RALPH SHUGERT: If I did not time things right or made an error with seeds, such as *Malus* and they should sprout in the stratification box, my experience has been that if they have not germinated too much that you can sow them, even on the frozen ground, and cover with a mulch.

MODERATOR SHUGERT: Does anyone know of performance decline in *Philadelphus coronarius* 'Aureus'? Many growers in southern Ontario have witnessed poor and erratic growth on this plant compared to the way the plant grew 20 years ago. Is there a virus or genetic decline?

DAVE BAKKER: *Philadelphus coronarius* 'Aureus' is very susceptible to root knot nematode and they should check for that pest. Fumigate if you have nematodes and put clean rooted cuttings into the soil. That plant also does not do well on low pH, but does on high alkaline soils. Wet soils are also a problem.

RALPH SHUGERT: You can use Basamid to control the nematodes.

MODERATOR SHUGERT: Questions for Mark Richey. Are you using any mist on your *Taxus* cuttings stuck into perlite?

MARK RICHEY: We try to keep the humidity up by wetting the walk ways in the house and if the foliage feels warm or we get a sunny stretch we will hand-water. Generally we are quite cloudy and that is the key. In sunny places you cannot do the same.

MODERATOR SHUGERT: Is anyone using a herbicide in their liner beds that they are comfortable with?

DAVE BAKKER: We use Treflan, at 1 lb a.i./acre. There are exceptions: arborvitae, *Microbiota, Chamaecyparis* and *Euonymus.*

FRANK GOUIN: Surflan has been effective. This year we are using a combination of Pennant and Gallery on the seed beds. Goal is still part of our program on conifer beds. We have been using Pennant on yellow nut sedge.

RALPH SHUGERT: On our sandy soil we need more than one application for yellow nut sedge control.

FRANK GOUIN: In Maryland, in the middle to the end of March, we have excellent control on heavy and light soils. I read the statement out of Tennessee on Paraquat use in the middle of the summer and it does kill the nutlets in one month.

MODERATOR BRIGGS: Question for Dr. McGown. Do you see a narrowing of the earth's vegetation gene pool by using asexual reproduction through tissue culture? For example, many food crops are being selectively bred for disease and pest resistance. Is this something that we really want to be achieving if it reduces the viability and gene pool of our world plants?

DEB MCGOWN: No, I do not think so. In commercial plant tissue culture we are looking at only propagating plants that can be economically propagated that way. My philosophy has always been that if you can do it from seed, then do it from seed because it will be a cheaper plant. When you look at urban landscapes I think we are probably increasing the genetic diversity.

DICK ZIMMERMAN: You are not reducing the genetic base with tissue culture techniques any more than you would be using cuttings or grafting.

MODERATOR BRIGGS: Where is the research describing the nature of variation in tissue-culture clonal stocks? Is it induced on original explant tissue by media components? Is it failure to recognize callus proliferation that looks like axillary proliferation?

DICK ZIMMERMAN: Some of the variation is there. We also know that as a plant ages, changes occur, for example—plody; that is not noticeable unless you take the cells out of the plant. Axillary buds in tissue culture will not show any difference. Callus culture, however, will allow those cell changes that I mentioned above to be expressed.

MODERATOR BRIGGS: Is anyone culturing flowering dogwood tree forms? If so, is this a high or low nutrient requiring plant?

DEB MCGOWN: We grow the kousa types and use 2 to 4 μm BA.

STEVE MCCULLOGH: We grow the groundcover type; it is much different than the tree type and grown on a high salt (MS) medium and BA. The tree types have a low salt requirement.

MODERATOR SHUGERT: Is there a publication listing patented and/or trademarked plants?

BILL FLEMMER: The National Association of Plant Patent Owners, which is a subsidiary of the AAN, has a newly updated version that is coming out this spring, I think. They have just put it on a computer. It will list patented plants up until the most recent plant patents. A list of trademarked plants is also being prepared.

MODERATOR SHUGERT: Does anyone know of any silver maple cultivars with very fine and deeply dissected leaves? I have some at my nursery and am interested in the possibility of introducing a new cultivar.

DAVE THOMPSON: Longwood Gardens has a cultivar called 'Borus Graciosa'. It is probably the most dissected type of maple that I have ever seen and it has excellent fall color.

BOB OSBORNE: There is a plant breeder in New Brunswick, Canada that contacted me about propagating a threadleaf form.

MODERATOR SHUGERT: Can biocontrol take care of black vine weevil?

FRASER HANCOCK: We bought some years ago a nematode that attacked the grub form. We found it quite effective. I could find the name of the company if someone is interested.

ED LOSLEY: The only known biological control of black vine weevil is a nematode.

VOICE: I am from Connecticut and the product Fraser was talking about is Biosafe and is sold by Peaceful Valley in California.

MODERATOR SHUGERT: Does anyone have cost comparisons between sewage sludge versus other soil amendments?

BRUCE BRIGGS: Depending on where you live it can cost nothing to $8.00 per cu. yard.

DAVE THOMPSON: We have been using it for the last 6 years in our soil mix, but we have decided to discontinue this year mainly because of supply problems. We ran into drainage problems because of a high silt content (30%). Our mix, which was peat moss:sharp sand:sludge (1:1:1, v/v/v), was used to grow a wide range of conifer, broadleaf and deciduous plants. We had excellent success except for those plants that were a little intolerant of wet feet. We were able to cut our fertilizer bills in half with sludge.

MODERATOR SHUGERT: Question for Bakker. Why are you using sand and not perlite on Alberta spruce?

DAVE BAKKER: It works and I would not change because the cost is minimal for either medium. Perlite will work under mist but cuttings take forever to root and is therefore not an effective use of a mist system.

NEW PLANT FORUM, JACK ALEXANDER, MODERATOR

SIDNEY WAXMAN: *Pinus densiflora* 'Sunburst' is a dominant plant selected from many seedlings collected from a witches'-broom found on the grounds of the Morton Arboretum, Lisle, Illinois. This tree was selected from among 70 seedlings because of its bold branches and bright-yellow, extra-long needles that radiate about each terminal bud. *Pinus densiflora* 'Sunburst' would be a good choice as a specimen or as a contrasting tree among other conifers. 'Sunburst' grown from seed has attained a height of 10 ft and a width of 12 ft in 10 years.

Pinus strobus 'David' was a seedling collected from a witches'- broom in Granby, Connecticut. It is faster growing than most of the other white pine dwarfs. After 25 years it has reached a height of 15 ft. and a width of 11.5 ft. This tree was selected because of its growth habit and form. While most other dwarf white pines are either equal in their height and width dimensions, or wider than high, this selection is taller than wide and should be a good addition in a landscape setting. Its branching is interesting in that there are clusters of cloud-like branches on its outer fringes

Pinus strobus 'Witches'-brew' is an unusual semi-dwarf white pine that was among several hundred seedlings collected from a witches'-broom in Hillsboro, New Hampshire Its growth habit is interesting because of its strong asymmetric branch development and its dark green foliage. This selection should be pruned occasionally to provide the type of plant structure that is desired Grafts of 'Witches'-brew' have grown to a height of 2 5 ft and a width of 2.5 ft in four years.

RICK LEWANDOWSKI: *Fothergilla gardenii* 'Blue Mist' is a selection of dwarf fothergilla named and introduced by staff at the Morris Arboretum of the University of Pennsylvania in 1984. It was registered in 1989. Though vouchered as part of the living collection when the University began its administration of the Morris Estate in 1932, the parent plant was not recognized for its unique qualities until 1979

'Blue Mist' is a striking example of dwarf fothergilla with its distinctive glaucous bluish-green foliage intensifying with maturity to a dark, glaucous, gray-green color. In the autumn the foliage becomes pale yellow to orange and occasionally russet-red. Fall color is not as intense as other dwarf fothergillas. As is typical of the species, 'Blue Mist' bears fragrant pure white flowers without petals in dense bottlebrush-like spikes in late April in Philadelphia

'Blue Mist' is a suckering shrub that grows to a height of 2 to 3 ft with an equal width The leaves are borne on slender unbranched or sparsely branched upright stems resulting in an irregular plant habit It prefers evenly moist, well-drained acidic soils and partial shade While 'Blue Mist' grows best in particularly shaded locations, it develops its best fall color with higher light conditions. 'Blue Mist' has proven hardy to USDA Zone 5b and is generally unaffected by insects or diseases

'Blue Mist' is an excellent, low-growing, carefree shrub that creates interest in the garden throughout the growing season Because of its size and cultural attributes, it is particularly valuable for small gardens in masses, as a specimen, or as a foundation plant

A number of nurseries have begun to produce *Fothergilla gardenii* 'Blue Mist' and the Morris Arboretum (University of Pennsylvania, 9414 Meadowbrook Avenue, Philadelphia, PA 19118) is distributing limited quantities of material to nurserymen. Softwood cuttings root easily and at high percentages (90% +), when treated with 0 4 to 0 8% IBA-talc or quick dips.

DAN STUDEBAKER: *Taxus* × *media* 'Ohio Globe' (formerly identified as Mitiska #5) was selected by Laddie Mitiska Nursery in Amherst, Ohio from seed of a 'Hatfield' source 'Ohio Globe' is a male cultivar with leaves having a bluish-green color cast. It is moderately slow growing and more easily maintained in a globe shape (even when unsheared) than even *T.* × *media* 'Brownii'. 'Ohio Globe' roots fairly easily from cuttings and is a very hardy cultivar that usually suffers little winter damage. Dr. L. C. Chadwick of Ohio State considers this as one of the best taxus cultivars

Taxus × *media* 'Slavin' originated from a single plant growing in Rochester, N Y. that was observed by Eldon Studebaker on the 1964 Eastern Region pre-conference tour of the Rochester City Parks system. Dick Fenicchia, a long time member of IPPS, reported it was probably a *T. cuspidata* type and it was entirely hardy in the Rochester area. We began growing it the next year when he sent our nursery three cuttings. It is a low, spreading type with drooping branch tips, not unlike *T. baccata* 'Repandens' which is not hardy in our area. A 25 year old plant is 6 ft tall and 9 ft wide Moderately slow growing type that keeps its shape with minimum pruning. Roots with some difficulty at times, probably because of the thinness of cutting wood.

This taxus is named in recognition of Bernard Slavin, long time superintendent in the Rochester, N Y. Parks System.

WILLIAM FLEMER III: *Prunus* × *yedoensis* 'Afterglow' (Plant Patent # 5730) This exceptionally vigorous form of the Yoshino cherry is a seedling of the pale pink Akebono cultivar of *P* × *yedoensis*. It was noticed in a row of 'Akebono' seedlings because the flowers were a rich pink color that did not fade to white as the flowers matured. The flowers of the Yoshino cherry are white or pale pink in color. The Yoshino cherry is one of the most vigorous growers of all the Japanese cherries and is especially suited for street tree and park planting from Zone 5 south

'Afterglow' is a rapidly growing tree, forming a flat-topped specimen 40 ft or more tall, and as wide at maturity It bears masses of large single pink flowers in late April and is a choice cultivar for street tree use or mass plantings, either alone or in combination with the normal white Yoshino cherries

'Afterglow' cherry is noticeably more cold-hardy than ordinary Yoshino cherries which have suffered serious bark splitting in cold winters. 'Afterglow' was unharmed

When trimmed up to give pedestrian clearance, 'Afterglow' cherry is an ideal small tree to plant beneath overhead utility wires or whenever space is limited Its broad spreading crown gives ample shade without excessive height. Like other Japanese cherries, it is a showy tree for massing in park plantings, especially along lakes and rivers where its clouds of pink flowers are reflected in the water.

Hydrangea quercifolia 'Snow Queen' is a cultivar of the native oakleaf hydrangea. It is notable for the large size and the pure white color of its flowers. The parent shrub, which was discovered on the Princeton Nurseries, has many more sterile florets in the flower panicles than is the case with the species. This means that the panicles are fuller looking and more decorative They are a clear snow white color when they open in early July and gradually turn pink as they mature in August Unlike the fully sterile forms of this species, the panicles are held erect on stiff stems even after the heavy summer rains, when the flower panicles of sterile plants droop down and become hidden in the foliage.

'Snow Queen' grows to a height of 5 to 6 ft and is winter hardy in Zone 5. It is one of the few deciduous shrubs which grow well in the shade as well as in the full sun. The bold, handsome foliage that resembles oak leaves, is dark green color in the summer and turns a beautiful red-purple color in the fall. The peeling bark of the stems and orange buds are attractive in the winter months. It is an ideal shrub for combination plantings with conifers and broadleaf evergreens.

CHRISTOPHER ROGERS: *Enkianthus campanulatus* 'Showy Lantern' For the past two decades Weston Nurseries has been selecting *E campanulatus* for uniform deep pink flower color Our selected pink seedlings vary only slightly, but we felt the public needed a predictable cultivar 'Showy Lantern' blooms late May to early June with deep pink flowers It is robust and upright with dense branching to the ground Its dark green foliage turns rich scarlet in early autumn and remains brilliant for well over a month It is hardy to USDA Zone 5. 'Showy Lantern' is being propagated in our tissue culture lab

H. WILLIAM BARNES: *Morus alba* 'Holicong Weeping' was found as a seedling at Coles Nurseries It is heavily pendulous to the point that it completely lacks apical dominance If a weeping stem is staked to a vertical position it will die back to the point at which a lateral branch assumes a pendulous position Some degree of an upright character can be achieved by gradually elevating the terminal to no more than 45 degrees By continually staking and allowing for the terminal to droop a sinuous stem can be attained If a straight stem is necessary the best approach is to graft onto a high standard An interesting variation is to allow the plant to sprawl across and down an embankment or a high wall The result is a creeping tree with vine-like characteristics, or a small tree which cascades upon itself The mother tree, which has never been staked, is 4 ft high by 8 ft wide with a 3 in. caliper The leaves of this plant are deeply lobed This leaf characteristic appears to be consistent as I have never seen an entire leaf 'Holicong Weeping' can be propagated by softwood cuttings with a 1000 ppm IBA quick-dip and placement under mist Overwintering does not seem to be a problem In the landscape the plant would be effectively utilized as a specimen placed strategically to attract the most attention

Populus simonii is native to Northern China It is a tall tree with an eventual height of 60 ft and width of 30 ft The branches are tightly ascending giving the tree a broad oval shape This outline is refined by a multitude of thin silvery branches and its symmetry is quite pleasing The leaves are oval with a dark green upper surface and a pale glaucous underside. It is quite hardy, Zone 2, and appears to be quite tolerant of drought and poor soils The tree could be conveniently used as a single specimen tree or in a grouping to provide a screen effect

JIM AULT: *Hydrangea paniculata* 'Unique' is a floribunda type with 12-in long upright inflorescences bearing an equal mix of fertile flowers and glistening white sterile flowers. The plant begins to bloom early to Mid-July (USDA Zone 6b) and remains effective for four to six weeks, followed by pink coloration of the sterile flowers Our plant at 17 years of age is 10 ft tall by 10 ft wide, with upright to arching branches 'Unique' does not appear to basal sucker and requires little pruning The plant was obtained in 1972 from Gulf Stream Nursery but does not appear to be commercially available today Rooted cuttings are available from Longwood Gardens (P.O Box 501, Kennett Square, PA 19348)

Sorbus rufoferruginea 'Longwood Sunset' The Longwood sunset mountain ash is heat and disease tolerant, and features rich burgundy autumn color and long-lasting orange fruit. The parent plant is 20 ft tall and 20 ft wide after 25 years, with a uniformly rounded crown. 'Longwood Sunset' has not shown susceptibility to scab or experienced premature leaf drop in six years of observation, including the abnormally hot and dry summer of 1988. Fall foliage coloration lasts for 2 to 3 weeks in October Fruit ripening begins in August. The orange berries contrast nicely with the fall foliage, and then remain colorful until early December Other plants of the species have been growing at the University of Minnesota Landscape Arboretum (USDA Zone 4) since 1962. It is likely that 'Longwood Sunset' is equally hardy and can be recommended for use in USDA Zones 4 through 7. Scionwood is available from Longwood Gardens (P.O. Box 501, Kennett Square, PA 19348)

ELWIN ORTON: The four cultivars of *Ilex opaca* discussed below were introduced to commerce from the Woody Ornamentals Breeding Program at Rutgers University At this time, all of them have been under test there for 30 years and have proven fully winter-hardy in USDA Plant Hardiness Zone 6a (-5 to -10 °F), and exhibit high vigor and superior foliage characteristics

'Jersey Knight' is probably the best known staminate cultivar of *I. opaca* in the trade today It was selected in the wild at Locust, New Jersey, by members of the New Jersey Holly Research Committee and was tested for a number of years under the designation Brown No 9 I formally introduced this cultivar to commerce as 'Jersey Knight' in 1965. Plants of 'Jersey Knight' flower heavily and provide an abundance of pollen, exhibit high vigor, and display excellent, dark green foliage twelve months of the year. Thus, plants of this cultivar are very attractive and are a welcome addition to the landscape even without the benefit of berry display

'Jersey Princess' resulted from a controlled cross in which 'Jersey Knight' was the staminate parent. Plants of 'Jersey Princess' develop a conical form, exhibit high vigor, are exceptionally winter-hardy and possess the darkest, glossy green leaves of any specimen of *I. opaca* this researcher has ever seen 'Jersey Princess' was introduced to commerce in 1976.

'Dan Fenton' resulted from a controlled cross of 'Maurice River' × an unnamed staminate plant growing in the 55-acre holly orchard of the New Jersey Silica Sand Company at Millville, New Jersey. It was named in honor of the late Daniel G. Fenton, a co-founder of the Holly Society of America and a nationally recognized promoter of American holly. Plants of 'Dan Fenton' develop a broad, conical form and exhibit dark green leaves of a rather unique shape (squarish) for *I. opaca* and produce good crops of bright red fruit. The leaves are exceptionally dark green but are not quite as glossy as those of 'Jersey Princess'.

'Jersey Delight' resulted from a controlled cross of 'Old Heavy Berry' × 'Isaiah'. Plants of this pistillate cultivar are narrow conical in form and exhibit heavily textured leaves. The foliage color is not as dark as that of 'Jersey Princess' or 'Dan Fenton' but the leaves reflect sunlight in a manner that makes them appear glossy from a distance. The fruit display is superior to that of these other two cultivars

Under conditions prevailing at our test gardens in central New Jersey, plants of all four of the cultivars listed above exhibit winter hardiness, vigor, plant form, and foliage characteristics superior to that of many of the older cultivars of *I. opaca* in the trade today. I will be pleased to provide interested propagators with cutting wood of any of these four cultivars.