APPLICATIONS OF GENETIC ENGINEERING IN HORTICULTURE: A PRACTICAL PERSPECTIVE

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The commercial opportunities available from the application of biotechnology to agriculture are large. Groups working with this technology are looking far beyond simply increasing yields. Those yield increases are certainly possible, and in many cases undoubtedly will occur, but the real benefits will come from improved quality resulting in better prices, reduced costs of producing a crop, and a greater reliability of harvest resulting from greater tolerances to a wide range of pest and stress phenomenon.

RECOMBINANT DNA TECHNOLOGY FOR PLANT IMPROVEMENT

The use of recombinant DNA technology, or genetic engineering, is an important step in widening the base from which genetic traits can be mobilized for use in plant improvement. The tools of recombinant DNA and the universality of the genetic code make it possible to express in plants genes from essentially any organism, including unrelated plants as well as animals, bacteria, and viruses. Proper expression of foreign genes in plants requires the use of appropriate regulatory sequences which are fused to the DNA fragment encoding the structural gene.

TOOLS FOR PLANT GENETIC ENGINEERING

Genetic engineering of plants today is largely based on the use of a tool called a vector, which is constructed from part of a common bacterium. This vector is usually referred to as the Ti plasmid (called Ti for tumor-inducing). This tool, or vector, has been isolated, and subsequently modified in the laboratory, from the common soil bacterium, *Agrobacterium tumefaciens*. This bacterium is the cause of the disease called crown gall in plants. When the normal bacterium infects a plant, it transfers a portion of its genetic code, or DNA, to the plant chromosomes. Expression of the genes carried on this foreign bit of DNA cause the crown gall disease. In the laboratory, the Ti plasmid has been "disarmed" by deleting the bacterial genes that when expressed in the plant lead to tumor formation, while keeping the basic ability to transfer foreign genes. Any foreign gene or DNA properly linked in the laboratory to the Ti plasmid vector is transferred when the vector is allowed to infect plant material in culture.

As a plant pathogen, *A. tumefaciens* has a wide but not global

host range. Crown gall disease occurs primarily in dicotyledonous plants. The monocotyledonous plants, which include our major cereal grain species such as maize, wheat, barley, and rice, are not susceptible. This does not necessarily mean that transfer of the T-DNA does not occur in these crops, however. Even in dicots, certain combinations of Ti plasmid strains and plant cultivars do not give rise to crown galls, but the transfer of T-DNA occurs. Several laboratories are testing whether Ti-based vectors will be useful for monocot transformation.

There is interest in other vector methods for transferring foreign DNA to plants, including the use of viruses, transposable elements, microinjection, and direct uptake of DNA from the culture medium (or via liposomes) by plant cell protoplasts. These methods, which work efficiently in animal systems, are however not yet as well developed for use in plants.

Genetic engineering in plants requires a manipulation in the laboratory to first transfer the gene(s) of interest into cells or tissues in culture, followed by manipulation of those cultures to obtain again whole, fertile plants. This is now possible for an increasing number of species, including many important in agriculture. This second process, called regeneration, is achieved by manipulation in the medium on which cultures are grown of the levels of growth substances, or phytohormones, which govern expression of functions required for morphogenesis. Regenerated plants can be derived from single totipotent cells in culture in several plant species. With a much greater number of species it is possible to maintain in culture clumps of cells or cells in suspension that maintain the ability either to proliferate structures that mimic embryogenesis or that are organogenic (adventitious production of organized shoots and roots). Thus, plant cells can be manipulated, as by exposure to Ti-based vectors containing foreign genes, and subsequently whole plants containing the desired gene can be obtained. For many applications it will not be necessary to go to single cells for routine transformation because organized plant tissues can be exposed to the vector in culture and regenerated transformed plants obtained directly from these treated tissues.

HERBICIDE TOLERANCE: A CASE IN POINT

To illustrate this technology, let me take the case of work done at Calgene, Inc. in California. Prior to the "invention" of recombinant DNA gene transfer methods for plants, the utility of herbicides was based on screening plants and organic compounds to look for combinations that were workable. Different species of plants, both crops and weeds, are naturally differentially sensitive to phytotoxic chemicals. This differential sensitivity, or selectivity, is the basis of herbicide use. Thus, naturally-occurring herbicide

tolerance has been sought and easily found. What we now can do that is different is to engineer plants rather than chemicals—with the result that, at least in certain cases we can doctor crop plants to go with the chemicals of choice—indeed the chemicals that are *environmentally* of choice—rather than be limited to the compromises dictated by the limitations of naturally-occurring genetic variability and organic synthesis.

The objective of the Calgene group's research is to obtain plants having tolerance to a very broad-spectrum and environmentally-safe herbicide, N-phosphonomethyl glycine, or glyphosate. The herbicide acts by specific inhibition of an enzyme, 5-enolpyruvyl-shikimate 3-phosphate (EPSP) synthase, in the shikimate pathway for biosynthesis of aromatic amino acids. This is a pathway present in plants and bacteria, but not in animals.

The strategy taken was to seek a mutated version of the bacterial gene encoding EPSP synthase that was less inhibited by glyphosate. This gene was obtained by mutagenesis of *Salmonella typhimurium,* cloning from a gene library, and subcloning into plasmids in *Escherichia scherichia coli.* Through a series of manipulations the gene was obtained on a small piece of DNA, completely sequenced, fused to regulatory sequences designed to give expression in transformed plant cells, inserted into a Ti-based vector, and transferred to tobacco cells in culture. Regenerated tobacco plants expressing the mutant bacterial gene exhibited tolerance to spraying with the herbicide. The tolerance levels achieved so far are insufficient for commercial use. But this result demonstrates conclusively that a plant metabolic pathway can be complimented by a bacterial gene product, and is the first instance in which an agriculturally useful trait has been expressed *via* genetic engineering in a crop plant.

ENGINEERING OTHER TRAITS

The choice of herbicide tolerance as an early objective in the development of this technology was not an accident. Few desirable plant traits are encoded by single genes. In addition to herbicide tolerance, single-gene determinants are known for resistance to certain plant diseases, tolerance to other environmental stresses, and certain other characteristics such as flower colour, dwarfism, and various simple morphological traits. The traits of major commercial interest, on the other hand, are often quantitative in nature; that is, they are determined by the coordinated expression of many genes. Yield, photosynthetic efficiency, the ability to make important secondary products (steroids, terpenoids, alkaloids, etc.), and the biosynthesis of important primary plant products (fatty acids, seed proteins, etc.) are examples.

It would, however, be incorrect to conclude that genetic engineering technology will not be useful in obtaining new quanti-

tive phenotypes. For example, once the control mechanisms in a complex pathway are understood, it may well be possible to modify the pathway usefully by modulating the expression of a key enzyme in that pathway. Use of chimeric genes that are differently (e.g. developmentally) regulated, or of genes encoding enzymes that are regulated by substrate or product in a different way, are two possible strategies. Use of technology to turn genes down or off in pathways that lead to undesirable products (for example, cyanogenic glycosides in cassava) is another.

I have mentioned flower colour as a character controlled by a single gene. Calgene Pacific was established in 1986 to work specifically on ornamental and forestry crops as targets for the application of its genetic engineering technology. Flower colour was chosen as its first project.

To establish a business base in the ornamentals area, Calgene Pacific created a Horticultural Group in July 1987, with the purchase of major holdings in three different domestic nursery operations. These are Plant Growers Australia in Melbourne, a supplier of containerized nursery stocks with particular emphasis on Australian native ornamentals; Bloomfields Nurseries (Australia) in Sydney, a large greenhouse operation with heavy emphasis on supply to cut-flower growers; and Biotech Plants in Somersby, one of the largest tissue culture labs in Australia and the producers of the "Bush Gems" range of hybrid kangaroo paws. The Calgene Pacific Horticultural Group is producing a wide range of products for the Australian domestic market, and has moved into the export market, where most of its future growth will occur.

With this base business in place, and with particular emphasis on the cut flower market, Calgene Pacific is well placed to commercialize its first genetically engineered products. These will be a range of elite cut-flower lines in which the colour has been specially modified. The first target is the colour blue which does not exist in carnation, chrysanthemum, or rose. This work is well advanced in our laboratories and is in collaboration with scientists at the Knoxfield Horticultural Research Station in Victoria.

The cut flower market is an attractive target for Calgene Pacific. The wholesale value of cut-flowers worldwide is in excess of US$12 billion per year. The industry demands approximately US$1 billion per year in propagating materials. Novelty is one of the most important factors involved in the marketing of cut-flowers. Thus new colours are expected to be well received by growers and by the consumer.

The future holds a long list of promising opportunities for the use of genetic engineering in the horticultural industry. In addition to colour modification, Calgene Pacific is working on a program to greatly enhance the post-harvest life of cut-flowers. These two projects alone offer extensions into other horticultural crops.

Colour is important in fruits and vegetables as well as in flowers. Enhanced post-harvest life is important in almost all horticultural crops. Horticultural crop growers will also benefit from herbicide tolerance, disease and insect resistance, drought and frost tolerance, and other novel traits being introduced to vastly improve the quality of their crops, to reduce their costs of production, and to help them to reliably produce their crops in the face of the every day uncertainties of weather, pests and disease. The tools exist to develop these products. Those groups willing and able to commit the funds and energy to applying these tools have a most attractive and potentially rewarding opportunity.

CHEMICAL CONTROL OF PLANT GROWTH

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This paper reviews current commercial developments in plant growth control of nursery plants in Australia, particularly in New South Wales.

MATERIALS AVAILABLE

Growth regulator chemicals available in Australia were reviewed recently (9). Regarding synthetic plant hormones of the gibberellins only GA_3 is used to a very limited extent for plant growth control. This also applies to the cytokinin N6 benzyl adenine (BAP). Otherwise, growth regulator chemicals such as paclobutrazol (Bonzi®) (now registered), chlormequat (CCC), and daminozide (SADH) would be preferred. Dikegulac-sodium (Atrinal®), is not available commercially in Australia.

It should be noted that, with the exception of paclobutrazol, which has been developed specifically for use on ornamentals, registered uses and formulations of both chlormequat and daminozide are limited. In New South Wales use permits are available for out-of-label usage.

Paclobutrazol is formulated as a 4g per litre suspension concentrate registered as Bonzi®. It is taken up passively through leaves, stem tissue, or roots. That which enters through stems and roots is transported in the xylem to growing points. Active compound reaching sub-apical meristems inhibits gibberellin production.

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The direct morphological consequence is a reduction in vegetative growth. There is also a stimulation of flower production in some species.

Daminozide is available as a wettable powder containing 850g/kg active ingredient (Alar®). It is mainly absorbed slowly through leaves and best results are obtained under slow drying conditions. Daminozide slows down and reduces the amount by which cells expand after they are formed at the growing point, causing shortening of the internodes. It also reduces apical dominance so that increased branching and flower bud formation results. With both daminozide and paclobutrazol there is often an increase in chlorophyll, giving darker foliage.

Chlormequat (Cycocel®) is a liquid formulation containing 100g/litre active ingredient. The mode of action is not fully understood but it is an anti-gibberellin which results in reduced internode length in sensitive plants.

SPECIES RESPONSES

Paclobutrazol has been demonstrated to be active on over 60 species of ornamental plants without phytotoxicity. The magnitude of effect is usually proportional to the rate of application. There is generally a wide margin of safety between rates required to give desired horticultural effects and those at which phytotoxicity could occur. Because of this activity, combined with a lack of adverse side effects, it is anticipated that paclobutrazol will exhibit good cost/effectiveness compared with other plant growth regulators. This has been found on, for example, *Impatiens wallerana* 'Super Elfin Blush' in America (1).

Results of trial work with paclobutrazol at the Horticultural Research Institute, Knoxfield, Victoria have been reported by Wilkinson and Padgham (10). They also include guidelines for use as a soil drench and spray on a wide range of ornamentals, some of which are not shown on the current label. Several of these and others not described have been treated commercially with growth regulators. Results are discussed below.

Indicum Hybrid Azaleas. Data from Wilkinson and Padgham (10) comparing Bonzi® and Alar® are shown in Table 1. However, a number of commercial cultivars have been screened at a Bonzi®

Table 1. Effect on plant height and flowering of *Rhododendron* 'Pink Phryne' when growth regulators are applied.

Treatment	No. of appl.	Produce rate (ml/litre) or (g/litre) +	Final plant height (cm)	Total flower number
Bonzi spray	3	31.3	16.8	18.5
Alar spray +	1	6.0	16.0	12.2
Untreated	0	0.0	21.0	12.4

spray rate of 125ml/litre. Only some cultivars responded well showing good branching and enhanced flowering (Barrett, unpub.). Further work is needed to ensure that there is no delay in flowering and to determine sensitive cultivars.

Australian Natives. The quest to develop the Australian native flora as ornamental potted plants is of much interest. Some species are vigorous growers requiring the use of growth regulators. Geraldton wax (*Chamelaucium uncinatum*) is one such plant. Shillo, *et al* (6) reported that both chlormequat and daminozide controlled height. However Lamont (2) found no response to daminozide but both chlormequat and paclobutrazol (soil applied) were effective, paclobutrazol also increasing flowering.

Geraldton wax is now being treated commercially by a number of nurserymen.

Paclobutrazol also reduced height in *Pimelia linifolia* 'Diamond Head' when applied as a compost drench whereas foliar-applied daminozide was ineffective (Lamont, unpub.).

Work by Price (unpub.) showed that pot drenches of paclobutrazol can be used to reduce the growth of *Crowea* (hybrid), *Callistemon citrinus* 'Western Glory', *Grevillea* 'Poorinda Constance', *Erica cerinthoides*, *Ceanothus papillosus* var. *roweanus* 'Blue Pacific' [Californian native; ed.] *Melalueca lateritia*, *Acacia floribunda*, *Eucalyptus nicholii*, and *Kunzea baxteri*. *Boronia megastigma* 'Lutea' appears to be resistant, which has been confirmed by commercial experimentation. Bonzi® increased flowering in the species shown in Table 2.

Table 2. Effect of Bonzi® on flowering of two species

	Erica cerinthoides		*Ceanothus papillosus* var. *roweanus* 'Blue Pacific'	
	Bud no.	Flwrs open	Bud no.	Flwrs open
mg a.i./pot	14/8/86	9/9/86	1/9/86	9/9/86
0.0	4.2	1.0	0.2 C	0.0 C
2.0	9.7	2.5	6.7 A	1.1 AB
4.0	8.7	3.5	6.2 A	1.3 A
8.0	9.7	4.4	2.8 B	0.5 BC
5% L.S.D.	10.8	4.3	3.4	1.1

Other species tested which show promise include *Ceratopetalum gummiferum* 'Magenta Star' and *Eriostemon myoporoides* 'Swanson', with good height control, increased branching, and more early flowers.

Boronia heterophylla has responded well to a foliar applied cytokinin, N6 benzyladenine (BAP) (9). This material will provide development of side shoots without any severe retardation (3). This may be of particular interest in view of the lack of sensitivity to paclobutrazol in *Boronia* species.

Chrysanthemums. Daminozide has been used widely to control growth and is very effective. Paclobutrazol applied as a spray has not been effective in certain cultivars and may have to be applied twice. There may be a delay in flowering.

Climbers and Creepers. Chlormequat has given some growth control in Bougainvilleas at high rates. Paclobutrazol is being tested by a number of nurseries but it is too early to assess results.

Mandevilla sanderi and *Clerodendron thomsoniae* have been well controlled with paclobutrazol applied as a spray with no effect on flowering. Leaves were darker green.

Fuchsias. Atrinal® was used on this plant with some success. Paclobutrazol has been shown to be effective in USA (5) and has been experimented with by several growers in New South Wales as a spray. Certain cultivars such as 'Winston Churchill', 'Lord Byron', and 'La Fiesta' have responded well. With some other cultivars a delay in flowering is suspected and growth control may be inadequate.

Hydrangeas. Alar® has been used by a few growers. Some cultivars may not benefit from the use of plant growth regulators. Paclobutrazol has been compared with daminozide in USA giving similar responses (4).

Impatiens. This is a very popular ornamental in USA and Europe and is gaining popularity in Australia. Plant growth regulators are widely used in the USA and some recent research has been referred to (1). Paclobutrazol is proving very successful in New South Wales giving good growth control and enhancing flowering.

Poinsettias. Both Alar® and Bonzi® have been utilized here as spray applications with good results on all cultivars tested. These materials have reduced plant height whilst maintaining an attractive darker green colour and enhancing bract colouration. Results with paclobutrazol in the USA were reported in 1981 (8).

Other Plants. Several plants have been tested with Bonzi® by nurserymen where benefits were expected, particularly for growth control. These include *Acalypha* 'Summer Love' (good response); begonias; *Bouvardia* (variable); geranium (good); *Pentas lanceolata* (variable); and *Verbena tenuisecta* (purple and white forms) with excellent results particularly in the production of cuttings.

Zantedeschias. These plants respond well to plant growth regulators (7).

DISCUSSION

The availability of paclobutrazol has stimulated renewed interest in the use of plant growth regulators in Australia. However, as limited research is being undertaken, nurserymen are experimenting themselves.

Results to date suggest that despite the potency of

paclobutrazol and its lack of adverse side effects, timing and concentration are important.

It is also evident that cultivars in some species, such as chrysanthemum, may show differing responses. In the case of *Boronia*, no response has been found.

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Bonzi® is a trade mark of Imperial Chemical Industries PLC
Alar® is a registered trade mark of Uniroyal Inc
Cycocel® is a registered trade mark of American Cyanamid Company.

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PROPAGATING MUSHROOMS

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The major world producers of mushrooms are France, U.S.A., China, Holland, United Kingdom, Taiwan, Italy, and South Korea. The world annual production of cultivated *Agaricus bisporus* exceeds one million tonnes.

In Australia, mushroom cultivation began about 1930 when Dr. Noble, then Chief Biologist of the N.S.W. Department of Agriculture, was able to establish mushroom growing in outdoor ridge beds in the County of Cumberland. Production became established in disused railway tunnels at Wynyard, Helensburgh, Lithgow, Bowral, and Glenbrook. Nowadays mushrooms are grown in specially insulated buildings where temperature, humidity, and CO_2 are carefully controlled. The Australian industry at the present time has about 80 growers producing 15 thousand tonnes of mushrooms per annum with a gross value of A$50 million.

Mushroom Spawn. "Spawn" is the name given to the mycelium of the mushroom. Spores are produced from special structures called basidia on the gills of the mushroom. These spores, when germinated, give rise to the mycelium. Until 1900 spawn for cultivation of mushrooms was obtained from fields or horse manure stables where mushrooms had been produced. Since 1900 a sophisticated and technical spawn making industry has developed. The original commercial spawn was made by sterilizing horse manure and adding a suspension of mushroom spores. The spores would germinate and colonize the manure. In 1932 Dr. James Sinden of Pennsylvania State University was able to produce spawn on sterilized cereal grains. Grain spawn is now the major source of mushroom spawn worldwide. Its advantages over manure spawn are its ease of handling, production, and its reliability.

Spawn Preparation. Spawn is made by growing mushroom mycelium on sterilized cereal grains. Wheat, rye, sorghum, and millet are the most commonly used grains. The grain is boiled in water to obtain a moisture content of 45 to 50% by weight. Excess water is drained off and the grains mixed with gypsum and limestone. Gypsum prevents the grains sticking together and results in a product that is easy to handle. Lime is added to adjust the pH of the grain to around 6.5. It is important not to overcook the grain allowing it to split as this results in fluffy growths of mycelium called sectors which are undesirable in mushroom spawn. The cooked grain is filled into containers, either autoclavable polypropylene bags and bottles, or glass jars, and sterilized for 1½ to 2 hours at 121°C. The extended autoclaving time is necessary to kill

"flat sour" bacteria that are present naturally on grain.

When the grain is cooled after sterilizing it is inoculated with a pure culture of inoculum, shaken, and incubated at 25°C. Colonization takes 10 to 14 days.

Spawns And Their Characteristics. Present day spawns, unlike varieties of green plants, are known by code numbers rather than by names e.g. U1, X1, B92, S53. There are 4 types of spawns that are classified on the basis of the colour of the mushroom cap and on the tendency of the cap to produce scales. The four types are:—

1. Smooth White Strains
2. Rough White or Off White Strains
3. Cream Strains
4. Brown Strains

The demand for use of each type of strain varies from country to country and whether the mushrooms are destined for fresh or canned sales. Environment plays an important part in the growing of strains, e.g. a rough white strain will be similar to a smooth white strain under conditions of high humidity and low air movement. A brown strain will be cream in colour under conditions of low humidity. Off white strains are the major strain type grown throughout the world. They have good keeping quality and lower costs of picking than white strains. They are grown on farms infected with mushroom virus disease because of the widely held view that virus is not transmitted from smooth white to off white strains.

Maintenance of Mushroom Strains. Various techniques are used to maintain mushroom strains. The simplest way to maintain strains is to subculture the mycelium onto a suitable agar medium. Lambert (10) stated that strains can be maintained in this way for many years and have a fairly good chance of keeping their vigor. Other workers (3, 4, 8) have confirmed this. It is important to monitor the type of mycelium that is produced and eliminate any culture whose growth appears abnormal. One of the abnormalities is a slow appressed mycelial growth, another is a fluffy mycelium that produces sectors on agar and stroma on the cropping beds. Lambert (10) anticipated that spawn grown on grain over a long period might change into the fluffy type. Mycelium stored on an agar medium e.g. Malt Agar, Potato Dextrose Agar, Compost Agar, needs to be subcultured occasionally to prevent drying out.

The storage of mycelium by immersion in liquid nitrogen (−196°C) has been shown to be an ideal method for storage of *Agaricus bisporus* whose mycelia do not produce asexual spores. Liquid nitrogen was first used by San Antonio and Hwang (13) to store mushroom cultures. Mushroom strains have now been stored for up to 10 years without any change in their character (2, 14).

Obtaining New Strains of *Agaricus bisporus*. Until 1972 when a proper understanding of the breeding system of *A. bisporus*

became known, spawn makers obtained new cultures through selection of mushroom sporophores. Multispore cultures of *A. bisporus* are known to have differences in yield, growth rate and other characteristics. (4, 10, 15). The start of the pure white mushroom in commercial cultivation began when in 1927 a clump of pure white mushrooms were found in beds that had been spawned with a cream strain (7). These white fruit bodies were propagated by multispore culture. Spores are collected by standing a mushroom with a stretched veil on a sterile petri dish or filter paper. The mushroom matures and drops spores onto the dish or filter paper. The spores are then germinated on agar media producing hyphae that fuse to form the multisporous culture.

Cultures derived from single mushroom spores show much greater variations than multispore cultures. Lambert (9), noticed that monosporous cultures of the cultivated mushroom are usually fertile but rather variable. This variability in different properties such as the appearance of the mycelium on agar, growth rate, shape of the fruiting bodies, and productivity makes it possible to develop new strains of *A. bisporus* by the isolation and selection of monosporous cultures. (5, 6, 8, 10). Single spore cultures are obtained by dilution of a suspension of spores similar to the classical technique for obtaining single spores of bacteria.

In 1972 the breeding cycle of *A. bisporus* was elaborated by Raper and Raper (12), Miller and Kananen (11), and Elliot (1). *A. bisporus* was described as a secondarily homothallic basidiomycete with a bipolar system of sexuality. This knowledge meant that interstrain breeding was possible. *A. bisporus* differs from other Basidiomycetes in that there are two spores on each basidium and when two nuclei of the different sexual factors occur in the one spore then this monospore is fertile. For breeding of *A. bisporus* it was necessary to work with cultures from basidia, which as an exception bear four spores instead of two and consequently have only one nucleus each. Obtaining much monosporous cultures is however a long and difficult process. In 1981 Dr. Fritsche of the Dutch Mushroom Experimental Station introduced the first hybrids produced by this process. The hybrids called U1 and U3 have since enjoyed spectacular success throughout the world. These new hybrids combined the desirable qualities of the off white and pure white spawn types. The pure white strains have the advantage of a smooth white cap but tend to lack size and weight; the off white strains, by contrast, produce mushrooms of a better weight and therefore less cost to pick. These new hybrids produced higher yields, lowered picking costs, and had better shelf life.

The development of successful protoplasting methods in *Agaricus* have taken some time but they now offer the prospect of producing inter-species hybrids. There is clearly potential for the use of the new recombinant DNA technology from other fields to

produce new mushroom strains with desirable characteristics.

The mushroom industry today, as in the past, depends for its success and continued survival on the ready availability of good quality spawn.

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A STANDARD FOR POTTING MIXES

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Until now there have not been any regulations for either the quality or quantity of potting mixes sold in retail packs. That situation should change in Australia before the end of 1988 by the setting of a Standard through the Standards Association of Australia. The need for such a Standard was highlighted by Handreck (2), who found an incredibly wide range of properties amongst mixes sold in retail packs in Australia.

A draft of the Standard is about to be released (June 1, 1988) for a 3-month period of public comment. That comment will then be considered by the committee which has the task of developing the Standard, so some of the details given here are likely to have been modified before the Standard is finalized.

STEPS IN SETTING AN AUSTRALIAN STANDARD

Australian Standards are set by the Standards Association of Australia, which is an independent body set up under Royal Charter in 1922. It cooperates with governments, industry and commerce in the preparation of Standards for a wide range of products and practices. An Australian Standard is a document containing a concise set of requirements, including, where appropriate, the procedures to be used to ensure compliance. Standards are set by consensus of committees of experts in the particular field. Compliance with an Australian Standard is voluntary, but it is in a manufacturer's interest to promote his products as conforming to the appropriate Standard.

Any individual, organization, or group of organizations can request the Association to prepare a Standard. The request for a Standard on potting mixes was made by CSIRO Division of Soils and the Australian Institute of Horticulture in December, 1986 and was supported by the Australian Nurserymen's Association.

Investigations by the Standards Association indicated that there was indeed a need for a Standard for potting mixes as sold in retail packs, so it formally agreed, in February 1987, to form a committee to prepare a Standard. The committee eventually formed contained representatives of CSIRO, the Australian Institute of Horticulture, the Allied Traders and Retailers groups of the Australian Nurserymen's Association, some state government departments and the Standards Association.

AIMS OF THE STANDARD FOR POTTING MIXES

At the first committee meeting in August, 1987, the committee

considered and modified a draft prepared by myself, as chairman. It was decided that the Standard should apply primarily to mixes sold in retail packs, although it was realized that once a Standard existed, it could be used by nurserymen to specify bulk mixes. The primary aim of the Standard was to ensure that gardeners were not sold potting mixes which were toxic, had poor physical properties, were deficient in nutrients, had excessive nitrogen drawdown rates, or were sold in bags which did not state the volume of mix and/or had misleading instructions and descriptions of capabilities. It was recognized that the Standard would also protect reputable manufacturers from unfair competition from those who did not practice good quality control, used inferior materials, or smaller volumes than might be inferred from the use of pack identification numbers such as 'No. 3 pack'.

THE MAIN FEATURES OF THE STANDARD

The following is a summary of the main parts of the draft of the Standard as it is at present. Again I stress that this is subject to change through the process of public comment. The Standard starts by outlining the scope of the Standard and by defining a number of terms to be used. The Standard will recognize a general-purpose mix and a premium grade mix. It will not be permissible to use the word Premium on a pack which claims that the contents conforms with the Standard UNLESS the mix is capable of giving good plant growth for at least a month without the addition of fertilizer. There are several categories of special mixes recognized, including those for orchids, cacti, acid-loving plants and those intolerant of even modest levels of phosphorus.

All packs conforming to the Standard are required to be marked with the volume of contents. Permitted volumes are 2.5, 5, 10, 15, 20, etc. litres. There is a standard procedure given for determining volume. Packs are required to give accurate information on the time when fertilizer must be used to ensure good plant growth. This will usually be at potting for general-purpose mixes and after about 1 month for Premium mixes.

The physical properties defined are air-filled porosity, total water-holding capacity and wettability. There is currently an interlaboratory study of different methods of determining air-filled porosity, involving 14 laboratories. A method will be chosen by participants before the end of the public comment period and included in the final Standard.

The central part of the Standard is contained in two tables which list ranges of concentrations of nutrient elements and other properties with which the mix must conform. Of course the concentrations of nutrient elements which can be extracted from a mix vary with the method of extraction, so it has been necessary to decide upon a method which is able to provide reliable information

about the levels of available nutrients in potting mixes. Many such methods are in use around the world (1, 4, 6), but for this Standard it has been decided to use 0.002 molar DTPA (diethylenetriaminepent acetic acid) in a ratio of 1 volume of mix to 1.5 volumes of extractant. This decision was based on the recommendation of a workshop attended by analysts from around Australia and held in Brisbane in March, 1988. While not all of the ranges of nutrients suggested at this stage are fully authenticated by rigorously controlled experiments, it was considered by participants in the workshop that existing information from local research (K. A. Handreck, personal communication) and from overseas (3, 5) was acceptable.

It was recognized that there were many advantages in adopting the same method throughout Australia. In the past, each laboratory has used its own methods and the ranges used for interpretation purposes have not necessarily been based on experimental data. Those laboratories interested in the analysis of potting mixes are now in the process of changing over to the agreed methods.

These requirements for concentrations of nutrients will ensure that mixes conforming to the Standard will have adequate base levels of all trace elements except molybdenum and all major elements except for nitrogen (but note the discussion below on nitrogen). There is at present no simple test for the concentration of available molybdenum in potting mixes. Authentic cases of molybdenum deficiency are very rare, so it is considered that not having a minimum requirements for molybdenum will rarely cause difficulties for users. The requirements for trace elements will be especially useful in overcoming the currently common problem of mixes not having adequate levels of available iron.

The Standard requires that most mixes have pH values in the range 5.3 to 6.5, with those sold as suitable for acid-loving plants required to be between 4.7 to 5.5. These requirements will eliminate mixes which are too alkaline for adequate iron supply or too acid for adequate calcium supply.

All mixes must be non-toxic for both the germination of seeds and the growth of roots. Again, a standard test is given.

The ability of the mix to supply nitrogen is a critical property, as nitrogen is the nutrient which most commonly first limits growth in soilless media. Most such media have a high proportion of wood wastes (bark, sawdust, shavings). Their continuing decomposition while in the bag or pot reduces the supply of soluble nitrogen to plant roots. There is currently no method for rapidly assessing the magnitude of this nitrogen drawdown effect. After many hours of deliberation, the committee preparing the Standard decided on the requirement that all mixes have a C/N ratio of no more than 150. This gives some guarantee that soluble nitrogen has been added to the mix. Combined with the requirement for an upper limit to

salinity and for freedom from toxicity, the C/N ratio means in practice that sawdusts, at least, must be composted before use in potting mixes. Thus, while a general-purpose mix may not have any soluble nitrogen at potting, the somewhat diminished nitrogen drawdown inherent in a C/N ratio of less than 150 and the instruction on the bag that fertilizer must be used from potting, should allow users to achieve good growth from the beginning. This is a considerable improvement on the current situation where many bags suggest that fertilizer is not needed for several weeks, yet the mix in the bag has little or no soluble nitrogen.

The requirement that Premium mixes must sustain good plant growth for at least one month means that there must be soluble nitrogen in the mix for that period. In practice, this requirement makes it essential that wood wastes be composted before use in Premium mixes, and sometimes slow-release fertilizers will need to be incorporated before bagging. Of course such requirements will mean that Premium mixes will sell for premium prices, but at least purchasers will get value for their money.

The committee is still somewhat unhappy about the requirements for nitrogen but, without further research it has concluded that it has gone as far as it is possible to go at present.

Unless there are last minute complications, it is anticipated that the "Standard for Potting Mixes" will be established before the end of 1988. But it will be some months after that before manufacturers clear stocks of old bags, arrange for registration with the Standards Association, embark on testing programs to ensure that their mixes conform to the Standard, and so on. During and after this time there will need to be a campaign to inform consumers of the improved situation, so that they begin to look for bags whose contents conform with the Standard. The mix manufacturers group of the Australian Nurserymen's Association has this in hand, but garden writers and talkback radio comperes will all be asked to cooperate in providing information. Hopefully, chain stores will begin to specify that their mixes conform to the Standard when calling for tenders.

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TISSUE CULTURE OF INDUSTRIAL CROPS

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I have chosen to speak on tea, coffee, oil palm, black pepper, and cocoa. Plantek has commercial tissue culture experience in all these crops. The economic importance of these plants to Asia and the Pacific region can be seen in Table 1 which shows that three quarters or more of world production of oil palm, tea, and black pepper come from this region.

Table 1: Some Important Industrial Crops in Asia and the Pacific Region.

	Production (1000 t)			Export (million US$)	
Crop	World	Asia-Pacific		World	Asia-Pacific
Coffee	5897	798 (14%)		9639	930 (10%)
		Indonesia	327 (41%)		
		India	170 (21%)		
Tea	2247	1641 (73%)		1844	1230 (67%)
		India	656 (40%)		
		China	451 (27%)		
Palm (oil)	7420	5642 (76%)		294	216 (74%)
		Malaysia	4000 (71%)		
		Indonesia	1148 (20%)		
Black Pepper	163	122 (75%)		215	159 (74%)
		Indonesia	45 (37%)		
		India	28 (23%)		
Cocoa	1739	155 (9%)		2051	188 (9%)
		Malaysia	101 (65%)		
		Papua	36 (23%)		

Production data from: Regional Office for Asia and the Pacific (RAPA), FAO Bangkok, Publication: 1986/14;

Export data from: United Nations Yearbook of International Commodity Statistics, 1985.

[1] Senior Scientist

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Cultivation on a plantation scale requires a stable supply of a large numbers of uniform and healthy planting material. Clonal propagation is therefore one of the most direct applications of tissue culture to plantation agriculture. As an example, I would like to quote from our experience with tea. We have estimated that starting with 500 axillary buds, a total of three to four hundred thousand plants could be ready in less than two years for 20 ha of planting, by means of tissue culture. The traditional method of single-node leaf cutting would take seven years to produce two hundred thousand rooted cuttings sufficient for planting 15 ha. Despite such potential benefit, however, plant tissue culture has, so far, been under-utilized in the production of tropical industrial crops. A survey was made by Dr. Irwin Chu (2) on 205 commercial tissue culture laboratories world-wide. He found only 6% of these to be working on tropical plantation crops as compared to 58% on orchids. Obviously, there can and will be wider commercial applications of tissue culture techniques to the tropical industrial crops.

TISSUE CULTURE OF FIVE TROPICAL INDUSTRIAL CROPS

I will first discuss four industrial crops that are relatively amenable to tissue culture methods. They are: oil palm, coffee, tea, and black pepper. The rationale for tissue culture and the basic methods will be looked at. I will then discuss cocoa as an example of a difficult crop to tissue culture.

Oil Palm—*Elaeis guineensis*

Oil palm is the most productive crop for edible oil yielding 5 t/ha/yr compared to less than 1 t/ha/yr of the annuals (6). At present, oil palm planting material is all raised from "hybrid" seeds; vegetative propagation is unknown. Success in clonal production was first reported by Unilever in 1974 and by IRHO in France in 1976. Current plantlet production by tissue culture is about 0.5 million against current world demand of about 100 million (6). To date, all successful work has been achieved by the process of somatic embryogenesis from calli derived from various explants such as roots and young leaves.

Tea—*Camellia sinensis*

Tea is a natural outbreeder. Traditionally, large scale planting is based on single leaf bud cuttings obtained from selected bushes. However, research in Kenya shows that elite tea bushes are very rare—only one bush in 400,000 combines plant vigour and the right tea making properties (8). Therefore, *in vitro* clonal propagation as a potential means to multiply elite cultivars is now receiving considerable attention.

Two methods are used at Plantek to micropropagate tea plants. These are bud enhancement and somatic embryogeny. Bud enhancement involves increased axillary branching using lateral

and terminal buds. In somatic embryogeny, embryoids are obtained from calli originating from various explants such as cotyledons from mature seed and shoot tips, or leaf lamina from *in vitro* shoot culture.

Coffee—*Coffea* spp.

The genus *Coffea* comprises about 70 species of which *C. arabica* accounts for 70% of the world coffee trade. Two of the main breeding objectives to improve this species are, (1): to introduce rust resistance from *C. canephora* and; (2) to obtain beans without caffeine from *C. bengalensis*. However, of all the species *C. arabica* happens to be the only self-pollinator, which makes it difficult to introduce new traits by sexual means. As an alternative, somatic hybridization through protoplast fusion is being seriously considered. In the case of the coffee plant then, *in vitro* culture is not only a method for propagation but also a possible means for plant improvement.

At Plantek, the two main *in vitro* methods used are shoot multiplication and somatic embryogenesis. In shoot culture, excised shoot tips and nodes were cultured on Murashige-Skoog (MS) medium supplemented with BA. Microcuttings from these explants were harvested and subcultured at regular intervals. In somatic embryogenesis, embryoids were obtained after eight weeks on MS medium supplemented with IBA and BA.

Black Pepper—*Piper nigrum*

Black pepper is a tropical climber. Traditionally it is vegetatively propagated by stem cuttings with six nodes from vines. Current cultivars are all susceptible to *Phytophthora* spp. foot rot. Very active breeding programmes for foot rot resistance are now taking place. Tissue culture will be a very useful tool for rapid clonal propagation of resistant cultivars for replacement planting when they become available.

At Plantek, pepper has been successfully multiplied by adventitious shoot formation when seedlings and embryos are cultured on a full MS medium supplemented with cytokinin. Using mature plants as an explant source has proved to be more difficult. We are now trying to overcome excessive production of phenolic compounds and of mucilages by the explants.

Cocoa—*Theobroma cacao*

Research on cocoa since the early 1950s has shown that this species is difficult to tissue culture as, indeed, are many other woody plants. Although abundant calli could be formed from most explants, organized development from them has not been possible. Recently, Litz (4), showed that axillary buds could be induced to proliferate from shoot tips and nodes but further growth could not be sustained. He also showed that callus derived from leaf discs could form somatic embryoids at low frequency on media having

high levels of cytokinin and activated charcoal. These embryoids grew from globular stage to the late heart stage but not any further. At Plantek, we are testing if micrografting could rejuvenate the scion to make them more amenable to tissue culture handling.

COMMERCIAL PRODUCTION BY TISSUE CULTURE

Commercially, tissue culture has been widely accepted as a viable means to achieve rapid propagation of desirable clones in large numbers, to produce uniform and disease-indexed planting materials, to carry out unseasonal production, to maintain and to move clean germplasm, and to manipulate phenotypes such as the production of juvenile and compact growth form. Tissue culture is also now considered to have commercial potential as a delivery system for genetically engineered products and for heterozygous products for hybrid seed companies.

As a result of economy of scale, automation, and other improvements in efficiency, production cost in tissue culture has not gone up as much as the cost of conventional production (7). Although this conclusion is drawn from large scale tissue culture production for horticultural crops in the United States, we can reasonably expect this to also hold true for tissue culture production of the tropical industrial plants.

Commercial application of tissue culture is not without its fair share of problems. Some of the difficulties are: production scheduling, seasonality of demand, high labour cost, and product variations. The most commercially undesirable of these problems is perhaps variation. Although it is unclear what causes genetic variation in tissue-cultured plants, it is still possible to contain the problem as the two following examples from tropical plantation crops will show.

The first example comes from the banana plant. Tissue-cultured plants grown in Jamaica resulted in as much as 30% off-types. In this case no explanation could be given since the plantlets were obtained from adventitious buds arising from corm tissue, in a similar way to plants produced conventionally from suckers (5). On the other hand, variation has not been a problem to other growers (Mohamed Aaouine, personal communication). It is now considered that variation in banana tissue culture may be controlled by keeping a low ratio of the number of plantlets to be produced to the number of explants used.

The second example comes from oil palm tissue culture laboratories in Malaysia using root tips as explants. In this case, sterile fruit bunches were produced by some clones (3). Since oil palm trees do not bear fruits until they are three years old, this problem has serious economic consequences. It now appears that this problem may be related to the type of explants used because tissue culture systems using young leaves as explants have had no

problem with sterility according to Indonesian scientists (1). Recently in Singapore, at a plant biotechnology conference, Dr. Eeuwens of Unilever showed that the problem of abnormal flower development in the tissue culture system using root tips could be epigenetic, i.e. non-hereditory and reversible. Some of the initially sterile clones are now reverting back to fertility. The problem of variation may also be related to the duration of callus in culture. In general, if a tissue culture procedure involves the callus stage, this phase is preferably maintained as short a time as possible to reduce the chances of variation.

CONCLUSIONS

I would like to say that at Plantek, we are also interested in other industrial crops. The following plants may be of common interest to Australia. First, macadamia nut, which is indigenous to Australia. Second, cashew nut, of which you have maintained a good germplasm collection at Darwin and Cairns. Third, *Calamus* spp., collectively known as the rattans, which must be abundant in your tropical rainforests and, lastly, tree species of *Acacia* and *Eucalyptus* which are now regarded as important plants for fuel-wood and agroforestry.

Abbreviations:

BA: 6-benzylaminopurine
GA_3: gibberellic acid
IBA: indole-3-butyric acid
MS: Murashige and Skoog (1962).

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COMPUTERIZED ASPECTS OF NURSERY MANAGEMENT

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This paper will discuss briefly, the following topics: *first*, the evaluation, purchase, and use of computers for nursery management; *second*, the need for financial and production budgets and how they can be facilitated by the use of spreadsheets; *third*, some of the types of systems currently being used by an increasing number of nurseries; and *finally* the need for the use of modern technology in the efficient operation of many businesses.

EVALUATION, PURCHASE, AND USE OF COMPUTERIZED SYSTEMS

Pressures exerted on nurseries because of factors such as fluctuating demand, the dynamic nature of consumer trends, and the improving technologies in production and office administration, have resulted in increasing competition in the market place and therefore increasing competition for business survival. Therefore, it is essential for nursery management to forecast as accurately as possible these fluctuations and changes, while, at the same time keeping up-to-date with the growing numbers of plant cultivars, continuing improvements in available technologies, and other modern developments. Hence, accessibility of information relating to a wide range of fields is of paramount importance, and one way of improving such access is through the use of computers. However, it is not in a company's interest to implement a computerized system if the application cannot be justified practically and/or economically.

Massey and Cooney (1) suggested that 6 questions need to be answered in the initial stage of evaluation of the use of a computerized system:

1. Do the expected benefits exceed the costs?
2. For what types of applications (e.g. word processing, accounting, etc.) should a microcomputer be purchased?
3. To what extent should obsolescence be a concern?
4. Will you need a general-purpose or single purpose computer?
5. Is leasing a microcomputer more cost-effective than buying?
6. Is a maintenance agreement cost-effective?

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In assessing each of these questions it is important to consider *first*, how well staff will adapt and appreciate a computerized system of nursery records, making training an important consideration; and *secondly*, how well can the perceived operation and function of the nursery be accommodated by the system.

If after evaluating the above it is decided that a computerized system is required, then a careful examination of available systems should then be undertaken. There are three possible approaches in the purchasing of any computer system.

a) Go straight out and purchase the hardware and software and then adapt the business functions to that system;

b) Purchase the hardware and software which has been altered to meet the most important business functions; or

c) Have a specialist design a software package which will function within the bounds of your current operation.

In analyzing the software and hardware a further series of questions presented by Massey and Cooney (1) need to be answered.

In evaluating software:

1. Does the program produce correct answers?
2. Will the software handle the volume over a two-year investment life?
3. Is the software user-friendly?
4. Is the documentation adequate?
5. Will the vendor provide training and advice?

In evaluating hardware:

1. Will the software actually run on the system?
2. Is the purchase from a mail-order house or local vendor?
3. Will the vendor install the system and provide start-up training to employees?
4. What is the expected turnaround for repair work?
5. What kind of printer should be bought?

Having outlined a procedure for analyzing the relative merits of installing and selecting a computer and the desired software, some of the areas for the direct application of computer technology in nurseries will now be discussed.

Several nurseries have now incorporated computer-based systems for many reasons including the following:

- Accounting procedures—e.g. simple cash analysis, the maintenance of creditors and debtors files, profit and loss statements and trial-balance presentation.
- The receiving, selection, invoicing and dispatch of orders—e.g. at Tubegrowers and Forest Native Nursery, a stocktake is performed each month and plants deemed ready for sale subse-

quently coded. As each customer's order is picked out on the computer which designates the location from where the plants are to be selected, stock inventory is automatically updated. Staff working with such "picking lists" are required to quickly check the number of each species that should be left in the appropriate location, and any alterations as a result of deaths, etc. are sent back to the office for editing. Therefore, the success of the system relies heavily on the accuracy of staff reporting.

- Payroll management—whereby a single employee of one nursery group is able to completely process the pays of approximately 350 employees in only 2 to 2½ days. This figure will vary depending on the use of modern banking facilities, the need for employees to be paid by cash or cheque and other variables.

- Database management of plant production and maintenance. Production records are updated at each stage of growth or potting and so current stocks are known and readily available for scrutiny at any time.

One of the great benefits of computerized management systems is that the information required to run the business is always available. Collating and storing information using a central computer system allows the nursery to operate in a cohesive manner. If the necessary information is processed correctly and without unnecessary delay then the smooth operation of the business is virtually assured. Having said this, the benefits of training additional selected staff in using the system in their field of expertise or responsibility must not be ignored. Consequently, if the owner or manager is absent from work due to illness or other unforeseen circumstances, the business can still operate efficiently. Not only that, but employees are certainly more likely to adhere to instructions and procedures if they have some idea of the reasoning behind those operations.

BUDGETING AND THE USE OF SPREADSHEETS

Whereas junior managers are generally required to be involved in only one section of the business, senior management is required to undertake a variety of supervisory tasks such as stock control, the processing of orders and invoices, supervision of plant production and plant maintenance, payroll, and so-on. However, in many instances little attention is paid to the importance of financial forecasting and cash-flow management. Too often, crucial management decisions are ad-hoc or spur of the moment responses to changes in short-term expectations. Budgets and plans outlining longer-term goals allow progress to be monitored objectively and any changes in expectations relating to the development and success of the operation are more readily quantifiable and account-

able. I wonder how many managers responsible for the overall planning and operations of nurseries around Australia have readily available budgets relating to, for example, the percentage of wages as to total sales or production, the costs of each factor of production, or even the cost of each unit of production. One computer programme which allows this type of management facility is the programme Lotus 1-2-3. Spreadsheets such as Lotus 1-2-3 are an excellent facility for carrying out routine job costings and budget projections.

As most of the businesses which would find Lotus 1-2-3 useful are large and would use the programme on a regular basis, it is important to have a structured approach to spreadsheet development. Only then will documentation be efficient and effective in the long-run. Anderson (2) suggested that the development process can be broken down into three phases:

1. *Preliminary planning*—Analysis of the problem and development of a general approach to the solution;
2. *Spreadsheet development*—actual creation and testing of the spreadsheet;
3. *Documentation*—*Adding identification and operating* instructions to the spreadsheet and creating an external printed description of the system.

The initial development of such a spreadsheet is a laborious task; however, the range of possible manipulations of the data on completion can only be described as comprehensive. Nevertheless, like any other computer function, the manager must know exactly how he/she wants to be able to use the spreadsheet before its development and therefore the planning process is of paramount importance.

WORD PROCESSING

Word processing is a function which helps speed up document preparation and revision, and can provide a filing system for the firms correspondence (1). I currently use Microsoft® Write Version 1.0 for the preparation and revision of papers. My hardware consists of a Macintosh Plus with one internal drive, an EMAC-20D Hard disk drive with 20 MB capacity, a Macintosh Mouse, and a Panasonic KX-P1081 Dot Matrix printer.

Microsoft Word Version 1.0 has many functions, of which some of the most notable are:

- A function for spelling checks of words or whole documents. Write automatically checks the spelling of any words throughout a document against the main dictionary and or any other user dictionaries that you may have developed.
- *Character formatting which is as simple as the push of a*

button and allows the operator to either change a characters font and size; apply character emphasis formats to make characters bold, underlined, shadowed, etc.; raise (superscript) and lower (subscript) a characters position relative to the line of text in which it appears.

- A cut/copy and paste command which enables text to be deleted or copied and transferred to other parts of the text, or other documents not only from Write but also from other packages such as Cricket Graph and StatView 512+.

CONCLUSIONS

The success or failure of a business may well depend on how willing and able its senior management is to adopt modern technologies in the production of its products and in the administration of production. Computers provide an efficient and, in most cases, an economic means of collating, storing, and presenting information quickly and accurately. Nevertheless, no computer system or any other modern form of office automation can work effectively and efficiently in a disorganized work environment. Before contemplating the purchase of modern technologies such as computers, their designated use and applicability must be predetermined. No doubt, those nurseries making the best use of such technologies in the future will be the ones which succeed.

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CELL-RAISED TRANSPLANTS—VEGETABLES AND NURSERY STOCK

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The concept of cell-raised transplants was first conceived in the United States. Mr. George Todd, in conjunction with personnel of Cornell University, using expanded polystyrene (EPS) as their medium, designed and manufactured what we now know as the Speedling® seedling flat.

This flat made its debut in 1978 and consisted of 200 cells of an inverted pyramid shape approximately 75 mm deep with a 25 mm opening.

Since that original concept, the name Speedling® has become synonomous with vegetable seedling raising in most of the developed countries of the world.

Whilst the nursery industry and, in particular, the conservative farming community, were slow to accept the principle of cell-raised plants it is now apparent, particularly in the U.S.A., that the system is well entrenched. Adaptations of the principle continue to be presented to the market in myriad form.

As what now seems to be a logical progression from the original concept of cell-grown vegetable transplants, there has been a gradual use of cells for the propagation of nursery stock. More recently, direct plantings from cells to the field have been made with tree and fodder crops.

THE PRINCIPLE

Transplant propagating flats were traditionally of wooden construction, usually filled with soil or loam. When plants were ready for transplanting, the root mass had to be separated often causing considerable damage and subsequent mortality or poor growth in the field.

The cell concept sought to individualize each plant, lessen the possibility of root damage and subsequently transplant shock, giving each plant the opportunity to perform as well as its neighbour during propagation.

The choice of the inverted pyramid structure came after considerable mathematical calculations and from nursery and field observations. It proved to be a resounding success. (G. Todd, Pers. Comm).

The inverted pyramid was given a small hole at the base of the structure and the entire flat, because of the rigidity provided by EPS, was supported on rails in the nursery so that air could pass

underneath, thus pruning roots as they pushed through the opening.

It quickly became apparent that traditional housing and methods of supplying nutrient to the plants were inadequate; as a result, new low cost greenhouses with travelling irrigators and nutrient programmes to match, were evolved.

PROGRESSION OF THE CONCEPT

By the mid-1970's the techniques for successful propagation of cell transplants, particularly in regard to vegetable crops, were well in place.

By the early 1980's cells were being used for the raising of nursery stock such as trees, flowers, and shrubs from seed, cutting propagation of carnation in Israel and for the transfer of tissue-cultured material.

More recently, in Australia, tree and fodder shrub species propagated via the cell principle have been directly transplanted in the field.

Such a progression is desirable from an economic viewpoint, particularly in regard to reafforestation, fodder provision, shelter, and soil erosion control.

However, it should be realized that not all species adapt well to the treatment and that environmental and soil conditions play a large role in successful establishment.

PROPAGATION OF TREE AND SHRUB SPECIES

Flat selection: EPS is economical and easily handled in the nursery; however it has some drawbacks due to its insulating properties and the fact that it is a relatively soft product.

Some species, particularly *Asparagus*, *Acacia*, *Eucalyptus* and *Brachychiton* to name a few, will penetrate the sides of cells with their vigorous root system. In some instances therefore, rigid plastic flats may be of assistance in reducing the problem, as long as adequate bench support is provided.

Recently a new product, Styrodip®, has come on the market. Claims are made that when EPS flats are treated with this material, much of the root penetration and subsequent damage problems during extraction are eliminated.

Cell size has been shown to be significant in relation to establishment and maturity. Weston and Zandastra (1) and Dufault and Waters (2) found that a larger initial root system, which promotes increased uptake of water and nutrients and undergoes greater new root initiation, may account for earlier maturity of plants grown in larger cells.

Most success has been gained by using a cell with a volume of 22 ml particularly with the deep rooting species. A 16 ml cell has also been used with limited success in field transplanting but for the

purposes of nursery stock production has proved adequate.

Media: The success of cell type seedling propagation owes much to the use of a simple medium formulated on a 1:1 basis from peat and vermiculite. However, due to economic constraints, much work has been carried out on alternative sources of materials for this purpose.

Experience with *Melaleuca alternifolia* grown in 1:1:1:1 pine bark, sand, loam, and peat has shown that considerable root distortion resulted if particle sizes were too large. This condition caused slow establishment and eventual retardation of the plant in the field.

Both vermiculite and peat have good water and nutrient holding capacity and provided a horticultural grade of vermiculite is used, an air-filled porosity of 10 to 15% can be expected. This range is considered to be ideal for seedling raising mixes, (3). Polystyrene beads can also be added but should not constitute more than 10% of the mix.

Fertilizer: Peat is an acid material and requires the addition of neutralizing agents in the form of dolomite lime. If African vermiculite is used, however, some correction should be made for the fact that it usually has a pH of about 8.

Best results have been obtained with a pH of the media around 6.4. Further additions of superphosphate, iron, sulphate, trace elements, and usually a wetting agent, will give a balanced medium.

Sowing seeds of some Australian native species has proven extremely difficult. With *Melaleuca alternifolia,* seed counts often reach 55,000 per gram. *Atriplex nummularia* (old man salt bush), on the other hand, weighs only 30 seeds per gram.

Various methods can be used from vacuum seeders to gel type solutions but in most cases there will be some need of hand thinning after emergence.

The cell system of propagation has required the formulation of foliar feeding programmes adapted to environment, species, cell volume, and media (Thomas, Pers. Comm).

It has been found that the principles of nutrient application applied to cell-grown vegetable transplants, can be adapted to other plants. However, the frequency of application must be modified, according to species and weather conditions.

The growing period in cells for most vegetables varies from 25 to 70 days. With other species it can be much longer, for example, atriplex—150 days, and most eucalypts, 80 to 100 days.

The basis of most successful nutrient programmes for cell-type propagation involves the injection of fertilizer into the irrigation water which is then applied to the cells via travelling irrigators. These "background" type nutrient programmes usually consist of a solution made from calcium and potassium nitrate and, depending on water supply, may carry other chemicals such as chlorine.

In conjunction with the "background" programme, applications of soluble fertilizer are made via the irrigators at varying predetermined periods. Usually the soluble is a complete type, incorporating trace elements.

With cell propagation, many minor deficiencies can be encountered and constantly need correction. Iron is an example, particularly in winter when the plant's ability to take up this element can be severely affected.

Field Transplanting of Tree and Shrub Species: It is imperative that adequate soil preparation be undertaken prior to transplanting. Usually, the area to be planted should be left fallow for at least 12 months and during that period, ripped to a depth of 45 to 50 cm.

Immediately prior to planting, the use of a small rotary hoe will eliminate large clods and provide a flat, fine tilled surface for a transplanting machine.

Many different types of transplanting machinery are available. From an economic and practical viewpoint, the model 3000 Mechanical Transplanter with water injection and ground drive mechanism has been found to be most suitable.

The most successful plantings from cells, which have grown on to maturity, were carried out in the Southern Tablelands of S.E. Australia during spring (Walker Pers. Comm) and on the western slopes and plains of New South Wales during early autumn.

In all cases, water injection mechanisms were used in association with the transplanters and in the case of the southern areas, absorbant gels were added to the injection water at the rate of 1 gram per litre. Each plant received 400 to 500 mls of solution as it was placed in the ground.

CONCLUSIONS

There seems little doubt that the concept of direct transplanting from cell containers to the field, can be a worthwhile proposition, that is provided the necessary criteria of soil preparation and correct propagation of the material to be transplanted are followed.

Established stands of Australian native species for windbreaks, shelter, and particularly fodder vindicate the concept.

Considerable work is needed however, in determining correct growing times in cells, particularly for larger species. Preliminary evidence suggests that this timing can critically influence the eventual performance of the plant in the field.

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CULTIVATION OF AUSTRALIAN PLANTS—200 YEARS OF PROGRESS

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The beauty and horticultural value of the Australian flora was first recognized by Joseph Banks (1743–1820), the botanist who accompanied Lieutenant James Cook on his voyage of circumnavigation of the world in 1768–1771. Banks and his assistants shipped large collections of seeds, living plants in tubs, and dried specimens to England. Many, of course, failed to survive but a surprising number did.

Banks, on his return to England became Director of the Royal Botanic Gardens at Kew and continued his efforts to introduce Australian plants, particularly with the assistance of collectors. A greenhouse known as the Botany Bay House was built to accommodate the living collections. Collectors such as Caley, the superintendent of the new Botanic Gardens at Parramatta gathered plants from the western parts of the Cumberland Plain and the Blue Mountains. Other notable collectors included Brown, Cunningham, and von Mueller in the east of Australia and Baxter, Drummond, and Molloy in the west. Wealthy noblemen and women often owned extensive collections of exotic plants, cultivating them in greenhouses because of the extreme English winter climate. Experienced horticulturists were in strong demand. Gardening journals such as Curtis's Botanical Magazine, first issued in 1787, recorded the early cultivation of Australian plants together with superb colour prints. The catalogues of several large English nurseries listed interesting selections of Australian plants, many of which are now lost. In 1870 James Veitch and Sons of Chelsea, offered various-sized *Blandfordia cunninghamii* for prices in the range 3s 6d to 31s 6d. In 1886 the list of William Bull, also of Chelsea, included *Davidsonia pruriens, Elaeocarpus angustifolius* [syn. *E. grandis*], and a double-flowered *Epacris* sp.

Australian plants also found their way into private collections

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and public gardens in Europe. *Lechenaultia formosa* and *L. biloba* were highly prized in France and Germany in the early 1880's as were everlasting daisies. In Mediterranean countries *Acacia dealbata* became commonly known as mimosa—a cut flower heralding spring and still enormously popular.

Early settlers in Australia failed to appreciate the horticultural merit of the native flora, preferring to bring from Great Britain plants with which they were familiar. So while Europeans struggled to grow Australian plants, Australian colonists struggled with temperate species. Many temperate species did thrive despite poor soils and the comparatively hot, dry climate.

One of the earliest nurseries in Australia was run by the Macarthurs at Camden Park. Their catalogue of cultivated plants published in 1857 listed numerous Australian epiphytic orchids, three species and one variety of *Calostemma*, and several native species of *Crinum*. Approximately 30 species of Australian trees and shrubs were listed among the thousand exotic species. Macarthur was probably the first Australian to create a hybrid involving an indigenous plant: *Crinum pedunculatum* crossed with the African species, *C. scabrum*. Another early nursery in Sydney, Darlings Nursery, was established by Thomas Shepherd at Darlington. He encouraged the cultivation of native plants from N.S.W. by propagating them and lecturing about their use. Notes from his lectures were published in the Sydney Morning Herald in 1834.

During the next eighty years there remained minimal interest in the cultivation of native plants and only popular lines such as *Acacia baileyana, Boronia megastigma,* and *Grevillea rosmarinifolia* were supplied by nurseries. In 1913 the Parry family, particularly Percy and Olive Parry, commenced cultivating Australian plants for cut flowers. They sold these (together with exotics) from Gosford railway station and in the Haymarket. Their cultivated and bush-picked flowers often adorned the international offices of Qantas Empire Airways and were displayed in Australia House, London, and at Royal functions.

Species included Christmas bush (*Ceratopetalum gummiferum*), waratah (*Telopea speciosissima*), native rose (*Boronia serrulata*), *Helichrysum* spp., and *Helipterum* spp. and Geraldton wax flower (*Chamelaucium uncinatum*). Their nursery, "Floralands", was probably Australia's first specialist native nursery and today the Parrys offer a wide selection of plants.

In 1950, James Audus, former botanist at the National Herbarium lamented the lack of interest in the cultivation of native plants. Seven years later A. J. Swaby, a writer on Australian plants for "Your Garden" founded the Society for Growing Australian Plants (SGAP) in Melbourne. Other states followed suit and in December 1959 the first volume of "Australian Plants" was pub-

lished, providing a forum for the exchange of information on the cultivation of native plants. The active promotion of native plants through their theme "Preservation by Cultivation" led to a great deal of interest. Amateurs and nurserymen collected widely, specialist native nurseries began to appear, and general nurseries broadened their range of species. Bill Cane in 1964 wrote of the need to propagate superior selections of natives from cuttings and actively discouraged the propagation of certain natives, such as *Callistemon* from seed. At the same time nursery technology was experiencing great changes—soil-less potting media, root-promoting hormones, mist propagation, polythene pots, etc.

Botanic Gardens have also played an active role in the cultivation of native plants. The Botanic Gardens at Kings Park, Perth was first established in 1962 to specialize in the cultivation of West Australian flora; 1970 saw the opening of the National Botanic Gardens in Canberra, also devoted to the Australian flora. Both gardens have offered some outstanding selections of the flora to the nursery industry.

Apart from some early hybrids of *Epacris* spp. produced in England in the 19th century, the macadamia nut was the first Australian plant to receive attention from plant breeders. The two species, *Macadamia integrifolia* and *M. tetraphylla* were introduced into Hawaii a century ago where superior cultivars were selected and investigations made pertaining to their culture. It wasn't until the 1960's onwards, when ornamental native plants became popular, that selection and hybridization took place. In the 1970's there were numerous cultivars of grevillea introduced to the nursery trade. The majority of these inter-specific hybrids arose from chance cross-pollination in gardens. There appeared to be little selection carried out and many of the hybrids either did not perform well or were inferior to their supposed parents. Some, however, were outstanding and have been successfully cultivated throughout Australian and in the warmer temperate or subtropical parts of the world, e.g. *Grevillea* 'Robyn Gordon', 'Sandra Gordon', 'Honey Gem'. These amply demonstrate the potential that exists for a well-directed breeding program in the genus *Grevillea*.

Kangaroo paws (*Anigozanthos* spp.) have received much attention from plant breeders since the 1960's. Keith Oliver and Stephen Hopper in W.A. and the late Merv Turner in Victoria deserve credit in this regard. Although the aims of these individuals differed (the Hopper hybrids arose from an academic study of breeding relationships), the basic objectives of the other two was to develop cultivars with the vigour and disease tolerance of *A. flavidus* combined with the outstanding colours of the others species (*A. rufus, A. pulcherrimus, A. humilis, A. manglesii* etc.). Some cultivars from all three programs have been immensely successful for both landscaping and cut flower production. Others, particularly non-*A.*

flavidus hybrids are still prone to ink disease and have given a disappointing performance in the eastern states. Obviously there is still considerable challenge in achieving the objective of disease tolerance.

Australia is currently experiencing a rapid expansion in the cultivation of its native flora for the domestic and export cut flower markets. Plants grown include waratah, banksia, dryandra, Geraldton wax, boronia, kangaroo paw and small-flowered myrtles. We are still, however, dependent on wild sources for numerous favoured flowers, especially verticordia, stirlingia and the many smoke bushes. Research is urgently needed into their propagation and cultivation.

We must also be prepared to undertake long-term breeding and selection programs to develop a range of superior cultivars. Such will not be an easy task because many of these plants are woody with protracted generation times, in contrast with the annual/herbaceous perennials that constitute the bulk of popular cut flowers.

During the last three years the N.S.W. Department of Agriculture has been engaged in a breeding program with one of the most successful cut flowers, Geraldton wax. In addition to assembling current cultivars an immense effort has been made to collect from the wild, species and forms hitherto not cultivated. The use of tissue culture techniques for germinating young hybrid embryos or seed and for rapid multiplication has significantly increased the chance of success and shortened the generation time in breeding wax flowers. This program is now in the early stages of cultivar evaluation. These techniques have also been successfully used at Gosford in breeding *Lechenaultia*.

Commercial row-cropping of Australian plants is occurring with success in other countries. New Zealand has mastered the culture of waratahs and researchers have selected some highly desirable cultivars. In the northern hemisphere Israel grows a range of Australian Proteaceae, kangaroo paw and Geraldton wax and in southern California there is much interest in Geraldton wax, kangaroo paw, banksias, and the numerous small-flowered myrtles.

Various reports have suggested that Australian plants have potential on the international market as flowering or foliage plants. The kentia palm is, in fact, a success story and the Lord Howe Island Nursery expects to export more than $2 million worth of seedlings this year. Market research is essential, however, to determine what opportunities (if any) exist for other plants. Whilst some species do have desirable characteristics such as tolerance under indoor conditions, showy flowers, easily propagated etc., much effort is required into their breeding and/or culture in order to "tailor make" them for particular uses.

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REVIEW OF STOCK PLANT ETIOLATION—A "NEW" METHOD OF PROPAGATION

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Workers on stock plant etiolation at Cornell University in the United States have had outstanding success in improving rooting of many traditionally difficult-to-strike species. However, the practice of withholding light to improve propagation is an ancient one. Some of the most common cloning methods; layering, stooling and cuttings, involve keeping light from that part of the plant that propagators hope will form roots.

However ancient the practice, recent refinements are indicating that the technique will have realistic commercial viability. Etiolation is simply the growing of plants in the partial or total absence of light. Stock plant etiolation as a pretreatment to cutting propagation, generally refers to the initiation of new stock plant growth in the dark. These shoots are pale and succulent and they produce roots much more easily than do their counterparts grown in the light.

Banding is a pretreatment adjunct to etiolation, which excludes light from a zone of the cutting base. An opaque adhesive band (e.g. "Velcro") may be applied to the etiolated shoots, which subsequently are allowed to develop normally in the light, and thereby

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Banding is a pretreatment adjunct to etiolation, which excludes light from a zone of the cutting base. An opaque adhesive band (e.g. "Velcro") may be applied to the etiolated shoots, which subsequently are allowed to develop normally in the light, and thereby

retaining the future cutting base in its etiolated base.

The band may also be applied to developing light-grown shoots which are still in the softwood stage, in which case the band is said to "blanch" the underlying tissue.

The goal is to develop this procedure to a technique by which propagators can take plants which they think are of value and get them into production on their own roots sooner than they can currently.

COMMERCIAL APPLICATION TO THE NURSERY INDUSTRY

Stock plant etiolation seems a viable alternative to other more expensive and labour intensive propagation techniques, such as grafting. The technique of etiolation and banding may be applied on any one of a number of scales, from single branches to entire hedges and even small potted trees. Furthermore, cost calculations suggest the process should only add 5 to 10 cents (U.S.) to the price of the rooted cutting. (2)

If this technique is to become commercially viable, it must be compared with current propagation practices. At Cornell University, trials are being run in cooperation with nurseries seeking to compare production schedules, costs, and plant quality of budded and etiolated plants in a commercial nursery.

Initial comparison of production schedules show that etiolation may be as fast or faster at producing the same sized plant as budding.

Table 1 summarizes a comparison in production schedules. It is produced in America but the seasons can be adapted for southern hemisphere conditions.

Table 1. Comparing production time schedules for budding with field and greenhouse etiolation.

Technique	Time of year—Seasons (U.S.A.—Winter, Spring, Summer, Autumn)							
	1987				1988			
	W,	S,	S,	A,	W,	S,	S,	A
Budding	———				———			
Field Etiolation	———				———			
Greenhouse Etiolation	———							

Adapted from (2)

Greenhouse etiolation considerably lessens the time it takes to produce a plant of comparable size. In winter dormant stock plants can be potted up and forced in the greenhouse, thereby producing rooted cuttings by spring or early summer of that same year. These can then be grown on in the same growing season to produce a finished plant by the end of the year.

Budded and field etiolated plants can be produced in size and

quality in approximately the same time as one another. Budded plants are first planted out as seedling understock in spring, budded in the summer, and cut back the following spring to produce a finished plant in autumn of the second year. In the fields stock plants are etiolated in the spring, cuttings are taken from them in summer and rooted; these can then be planted out or put into a greenhouse for growing on. If placed out in the field they are grown on for another season and are ready in autumn of the second year.

The cost of production in these time periods is summarized in Table 2.

Table 2. Summary of production costs (in U.S. Currency)

Method	Total Cost Per Plant/Cutting
Field etiolation	$ 0.43
Greenhouse etiolation	$ 0.48
Budding	$ 0.80

Adapted from (2)

The cost, in both field and greenhouse etiolated cuttings, is well below that of budded stock and when related to its production time the etiolated methods compare favourably.

It potentially results in increased productivity, freedom from root transmitted diseases and pests, no grafting and budding costs, or incompatibility problems. Further work is underway refining the commercial viability of this technique.

ETIOLATION AND BANDING IN AUSTRALIAN NURSERIES

The connection is a clear one. Firstly, the technique can readily be applied to many of those species that have been trialed successfully and are used frequently in Australia.

It is the range of difficult-to-root plant species that this method could be potentially used for; that is its greatest asset, especially if the lower costs and shortened production schedules are any indication.

There is no reason why these factors should not apply here in Australia. For example, *Eucalyptus ficifolia*, the red flowering form, is a good example of a species with potential application for this technique. Its cost and demand warrant its trial. In fact there are many Australian native species that are subject to variation from seed that could potentially be propagated by this technique.

The expertise needed to apply this technique is minimal, and no more demanding than those already employed in Australian production nurseries. The principles of etiolation are well established and accepted, so its application in this form to plant propagation should not be considered suspect.

Nurseries can use existing facilities such as field and growing-

on areas and greenhouses for production. There are no large outlays in capital and expenses that would be associated with other "new" techniques of plant propagation, i.e. tissue culture.

HISTORICAL ASPECTS OF TREATMENT

Etiolation as a stock plant pretreatment has been used successfully on woody plants since as early as the 1920's. However, the procedures of stock plant etiolation and banding which have revived recent interest has essentially remained unchanged since work by Gardner in 1936 (3).

Several research groups in the 1960's and 70's looked into the anatomical and physiological changes that occur in an etiolated shoot. Although observing increases in rooting potential they were still unsure as to why it was occurring. (5, 6, 7).

Although results from this group were inconclusive, Howard and co-workers at the East Malling Research Station, Kent, U.K., refined the technique of etiolation and banding and perhaps made the greatest contribution to our understanding of etiolation as a practical pretreatment to cutting propagation (4).

Their work, using *Malus* (M9 apple), *Tilia*, and other difficult-to-root woody species, examined the optimum timing and duration of etiolation and banding as well as the influence of temperature and humidity in the promotion of rooting by etiolation. (1, 6, 7)

Bassuk and co-workers at Cornell picked up from Howard and recently have been investigating the usefulness of etiolation and banding techniques in a wide range of difficult-to-root woody plants. In the course of their work they developed the use of "Velcro" for the banding technique.

REVIEW OF BASIC TECHNIQUE

Stock plants for etiolation can be maintained in a greenhouse where, in winter, they have several months lead time to produce rooted cuttings. They can also grow outside in the field or growing area where bud break occurs at normal pace.

After bud swell, when shoots began to break, either entire plants, or individual branches, are placed into darkness.

Etiolation may be done in the greenhouse covered by black cloth, or in a frame built over a hedge or single stock plant. Even a single branch may be covered with black cloth.

With shading there is some leeway. Research has shown that shade greater than 70% is the best. This allows for two things. Firstly, it provides for ventilation and secondly, it permits one to check on the progress of shoot extension every two to three days. This does not appear to compromise the benefits of etiolation. (2, 6, 7)

The structure is left in place until the shoots have elongated enough that they are suitable for cutting propagation (5 to 15 cm).

At the time that etiolation is completed the banding material is applied to the base of the etiolated growth. Caution must be exercised at this point because etiolated shoots, lacking protective pigmentation, are susceptible to sun scorching.

The practice should be to apply the banding material and then replace the shading cover partially. This allows for the entry of a small amount of light. Over the course of a week, the cover should be gradually rolled back bit by bit, allowing shoots to green up. After one week or so the shoots should tolerate exposure to full sunlight; however the speed at which shoots adjust to higher light levels varies among species. Some common sense should be all that is needed to avoid disaster at this point.

HORMONES

Hormones, especially powdered forms, may also be applied with the "Velcro" band at the time that the shoot is banded. Bassuk and co-workers found that hormones helped get rooting underway while the rest of the shoot turned green. Cuttings can be treated with IBA in talc (3,000 to 8,000 mg/kg) and put into a rooting medium. (1, 5, 6, 7).

Generally the bands are left on for four weeks, although they can be left on anywhere between 2 to 6 weeks. When a green shoot with an etiolated base is obtained the cutting is made by severing the shoot from the stock plant just below the band making the etiolated zone the base of the cutting. See Figure 1 below.

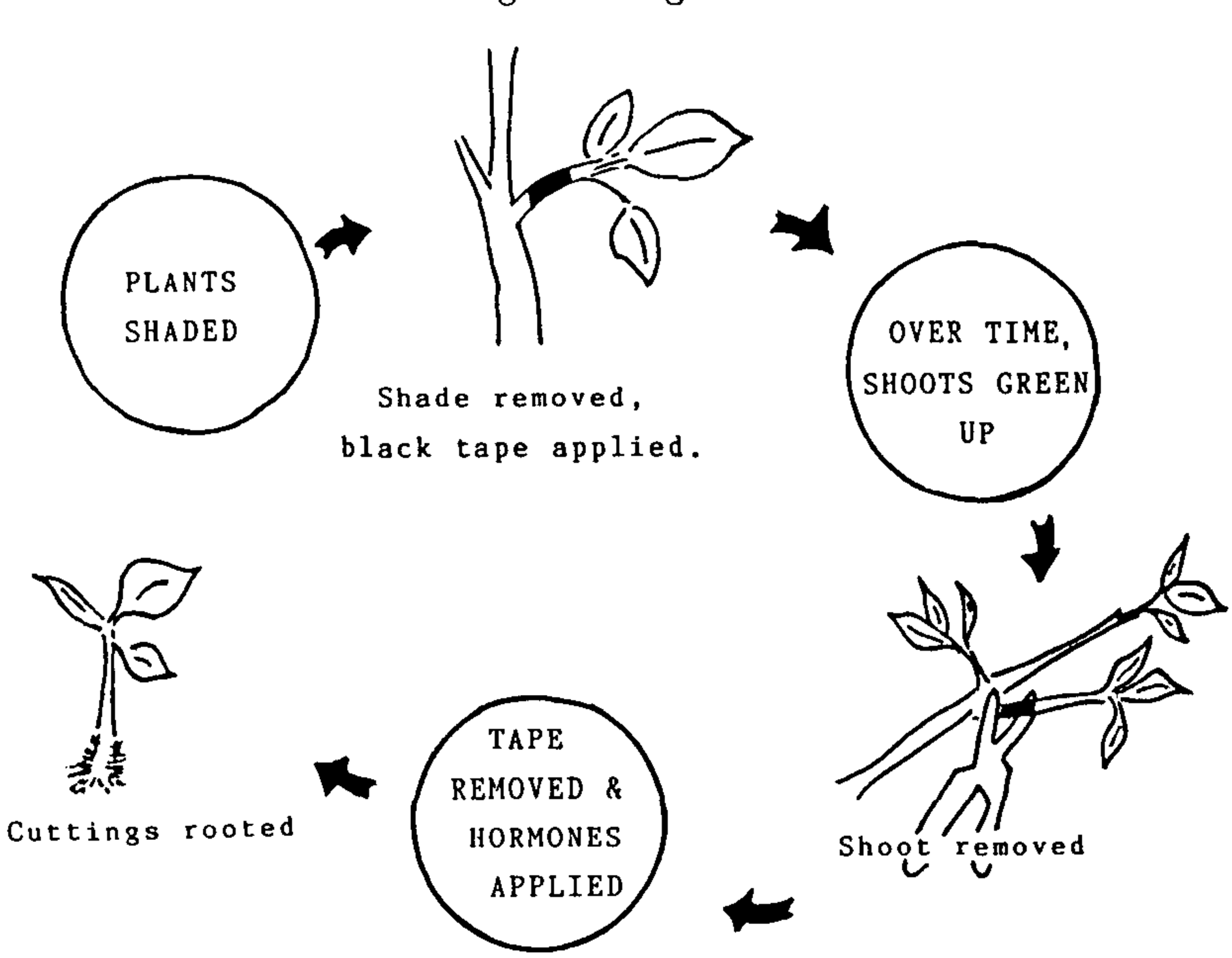

Figure 1. A graphic representation of the stockplant etiolation method. Adapted from (1).

SUCCESS OF ETIOLATION AND BANDING

Actual data for plants rooting response to these techniques has been promising indeed. In the Cornell trials the treated plants rooted significantly more than did the untreated controls.

The Cornell workers have also found that the use of hormones is not always necessary. It is advisable that at first, all treatments including a control, should be chosen for each species. For example, *Castanea mollissima* (Chinese chestnut) was found to have a 100% rooting success when etiolated, banded, and with a hormone application. It showed 44% success when only etiolated and not banded. It did not root at all when light grown, even when banded. (5)

The techniques used at Cornell include either etiolation and banding by themselves or a combination of both. When "Velcro" plus hormones were used, in nearly every case the area under the band was swollen by the time the bands were removed after 4 weeks. In fact in two of the species tested, *Betula papyrifera* and *Carpinus betulus*, visible root primordia formed under the band on the stock plant. Cuttings made from these pre-rooted shoots rapidly developed root systems. (5)

The majority of the taxa tested are known to be particularly difficult to root. Included were *Castanea mollissima*, *Quercus palustris*, *Quercus robur*, *Corylus americana*, a number of *Syringa vulgaris* cultivars, *Pinus strobus*, *Acer* spp., and *Taxus* × *media*. (1, 2, 5, 7)

The results obtained with several of these species represent, to the best of the researcher's knowledge, the best rooting responses yet achieved. Notable examples were *Carpinus betulus* (96%), *Castanea mollissima* (100%), *Quercus coccinea* (46%), *Quercus palustris* (50%) and *Quercus rubra* (30%) (5). The age of the plant material varied. There appears to be no strict rule as they have used 1 yr old seedling stock to 30 yr old hedges and mature trees.

The results have only just begun to show that traditionally difficult-to-root plants can be successfully propagated with this technique.

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VEGETABLE PRODUCTION IN AUSTRALIA WITH EMPHASIS ON THE POTATO

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To describe the Australian vegetable industry of 1988 in a short treatise is almost impossible. I consider there are four key elements that make up the industry. They are marketing, technology, the environment, and industry organization.

Marketing. There is no doubt the vegetable industry is consumer driven and the sooner that is fully realized, the better. Buyers are no longer prepared to take what growers or agents think they want. Vegetables are competing with a whole range of other foodstuffs and as difficult as it may be to change vegetable products, it must be done. The customer is always right.

The marketing of vegetables starts when a grower first decides what type of vegetable to grow and the cultivar and the production system he will use. These all influence the product he finally sells. In Australia many growers make these decisions on what they did last year or perhaps what their agents or neighbours tell them. In Sydney we have Flemington Markets, one of the largest wholesale markets in the world. The agent/merchant system has an enormous influence on what is produced. A lot of produce that is sold in these markets comes from interstate and these growers rely heavily on their agents for advice. The development of rapid road transport has meant vegetables from anywhere in Australia can be economically marketed in Sydney. The increase in the export market has probably been the most significant change in vegetable marketing in the past five years. This market has grown from $15 m in 1981/82 to $60 m in 1986/87.

Technology. Whilst the industry is market-driven the technology must be available to produce the product. Basic vegetable research and development in Australia is limited compared to the size of the industry. Production system development has largely come from taking overseas technology and developing it to our local

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environment. To the credit of individual growers, they have been as expert as anybody at this. Some of the key areas in technology that influence vegetable production are cultivars, pest and disease and weed control, nutrition, irrigation, mechanization, and post-harvest.

The Environment. The Australian continent stretches across a wide range of environments, from the tropics in the north to the temperate regions of the south. As stated before, the development of rapid transport put all these regions within an economic distance of the major population centres. For consumers it means most products are available fresh all year round. Tomatoes, potatoes, and cucurbits are prime examples of this. For the industry it has meant a redistribution of growing areas and, a continuous year round supply of major vegetable types.

Industry Organization. For a commodity the population is so dependent on for its survival, I have always found somewhat disturbing the lack of an adequately funded central organization of producers. The decision to grow or not to grow is largely based on supply and demand which quite often results in large fluctuations in supply. The lack of effective organizations means the Government does not have representative groups to consult with when making important policy decisions. For instance, it has meant a lack of funds for research, the likes of which have helped other industries prosper and develop. If the Australian vegetable industry is to develop further, it must have an adequately funded central organization with skilled executive staff, not the current situation where it relies heavily on the charity of its members to perform industry functions.

POTATOES

I would now like to address the actual propagation of vegetable crops in Australia. However, to discuss the propagation of all vegetable crops in the allocated time would be impossible. So I have decided to concentrate on the major vegetable crop in the world and Australia, that is, of course, potatoes.

Potato Propagation in Australia. As potatoes are vegetatively propagated they pose special problems in breeding, cultivar evaluation and development and, of course, commercial "seed" multiplication. In Australia the problems of viral, fungal, and bacterial disease transmission in potato production have been addressed for many years. The maintenance of clean, true-to-type "seed" lines in highland "seed" producing areas has been conducted since the mid to late 1800s. Much of this development started after the gold rush of the 1850s which, of course, was concentrated in some of the current "seed" growing areas of the central highlands of Victoria and the central tablelands of NSW. These areas, because of their altitude and relative isolation, have low aphid population, the princi-

pal vectors of the major virus diseases.

"Seed" potato growers, as in so many other horticultural industries, maintained their own "seed" lines by a system called "Stud plotting". The growers made their own clonal selections and multiplied these up. Stud plots were carefully rogued for diseased and off-type plants, so that each year a stud plot big enough to produce sufficient tubers to plant the growers commercial "seed" crop was grown. This form of "seed" production became somewhat of an art form with quite a lot of folklore and mystique surrounding it. It probably reached its peak of skills and dedication during the 1930s–60s. In NSW and indeed other States the growers organized themselves into co-operatives to run certification schemes, with inspection and certification of crops done by the State Departments of Agriculture.

At its peak this system of "seed" production and certification proved to be very effective. But, as in all industries, change seemed to be inevitable. The economic pressure for higher yields of specialist end use potatoes saw demands placed on these schemes that they couldn't meet. This came particularly from the processing industries. With each grower producing his own line of "seed", potential yield between "seed" lines was very variable, both genetically and disease wise. Also, because of slow multiplication using whole tubers as the propagule, the industry was slow to adopt and multiply new cultivars.

Potato "Seed" Production Today. The system of potato propagation and "seed" production being used in Australia today has come about for several reasons. Some I have already mentioned above.

—Industry requires "seed" uniform and true to type.
—Tuber transmitted diseases must be kept to an absolute minimum.
—New cultivars must be brought into commercial production as rapidly as possible.
—Total amount of "seed" required could not be catered for under the "stud plot" system.
—Containing the cost of commercial certified "seed" potatoes.

During the 1960s it was found the potato was particularly suited to aseptic micropropagation. This led scientists and practical horticulturists to a whole new concept of potato propagation and multiplication.

Micropropagation of Potatoes. Aseptic micropropagation was not the first change in potato multiplication. It was in fact preceded by a system using stem cuttings that was developed in Australia by Dr. Peter Goodwin of the Sydney University. The system involved taking stem cuttings from virus-indexed mother plants and growing them in aphid-proof screenhouses in sterile potting mix. The stem cuttings, of course, produced mini tubers. As growing plants became large enough, more stem cuttings were

taken and quite rapid plant multiplication resulted. Whilst this system was quite effective, it was never adopted because of the development of aseptic micropropagation. This was a logical development that used the same concepts but gave even more rapid multiplication and reduced the risk of disease infection even further. The system involves establishing a nuclear plantlet that is apparently free of pathogens. Nodal cuttings are taken from this plantlet and as plantlets grow further propagation takes place. Once enough plantlets are multiplied they are then planted out into sterile potting mixture in aphid-proof screenhouses to produce mini tubers. Depending on the cultivar, the average number of mini tubers produced per plant varies from 3 to 6. These mini tubers are then taken to producing areas for field multiplication. Depending on the scheme, this can take from 3 to 6 generations before commercial "seed" is available. These field generations grow under strict hygiene and isolation from other generations. Monitoring for disease status is also carried out. The advantage of this method is large numbers of mini tubers can be produced in controlled conditions free of disease vectors. Whilst the plantlets are in the screenhouses, disease status is closely monitored using such techniques as ELISA.

The Future. It is difficult to pontificate on the future techniques for potato propagation in Australia. One thing is for certain, potatoes will remain as our number one vegetable and a staple of the Australian diet. In terms of propagation techniques there are at least two systems that should be given small scale commercial testing. However, the real restriction on the future is the "seed" production industry itself. On past performance the "seed" growers have been unwilling to accept change. The schemes described above have been heavily subsidized by Government and still the scheme in NSW is in danger of collapse due to lack of grower support. This is in spite of strong pressure from end users for "seed" of limited generation origin. As propagators you are, no doubt, interested in the new techniques available.

The two techniques that I believe have prospects for the future are true potato seed (TPS) and micro tubers.

True Potato Seed. True potato seed (TPS) has long been considered as an alternative method for potato multiplication. However, serious research and development only really started in the mid 70s at the International Potato Centre (CIP) in Peru. Under certain conditions all potatoes will set berries from the flowers. It is from these berries that seed is collected and, after a period of dormancy, can be planted and a tuber-bearing potato plant will result. At this stage TPS is mainly being researched for farmers in the developing countries where it has several advantages. However, most of these advantages could be extrapolated to Australia. Some of them are:

—Reduced cost of planting material.
—Minimizes spread of tuber-transmitted diseases.
—Releases for human consumption the large volume of potatoes previously used for "seed."
—Simplifies "seed" storage and makes high quality planting material available at optimal planting times.
—Reduces cost of planting material in certain circumstances.

The production of TPS is not easy and involves the manipulation of the growing environment through plant density, irrigation, nutrition, and the use of growth regulators. Some cultivars are more prolific seed producers than others and these cultivars may not suit sophisticated end use patterns.

Once the seed is produced and ready for planting, it can be used in two ways. It can either be planted into a nursery and seedling tubers produced for further planting in the field, or, container grown seedlings produced and planted direct into the field. In some instance seed has been directly sown into the field, but with mixed results. When all aspects of production are suitable, up to 45 tonnes/ha are produced using TPS.

Micro Tuber Production. A major disadvantage of the micropropagation now being used in Australian seed schemes is the transplanting phase from test tubes to potting mixture in the open environment. This is the most delicate stage and also the most expensive part of the multiplication process. To overcome this problem, the technique of producing micro tubers in tissue culture has been developed.

Micro tubers like the mini tubers are really only a smaller version of ordinary tubers. Average size is about 8 to 10 mm in diameter. By manipulating the growing environment through nutrition, daylength, and growth regulators, in-vitro plantlets can be induced to set tubers.

The major advantage of micro tubers is that they are more robust than plantlets and can be planted directly into nursery beds or carefully controlled field conditions for further multiplication.

Container Grown Seedlings. This involves the production of micropropagated plantlets that are then grown in seedling containers for hardening off and then direct transplanting into the field. This system is being successfully used in Australia for initial rapid multiplication. It avoids the production of mini tubers in sterile potting mixtures in insect-proof screenhouses. However, it does have problems. In the short time (10 to 14 days) the plantlets are in the cell, only a very weak root system is developed. This has been somewhat overcome by the use of degradable paper pots.

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A "FOG" PROPAGATION SYSTEM USED AT PLANT GROWERS AUSTRALIA

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At Plant Growers Australia (PGA) propagation was previously carried out using conventional misting in polythene houses and, as is usually experienced, both media and foliage were alternately too wet or too dry. The effects were particularly noticeable in summer when foliage became leached of nutrients and then prone to fungal attack. The possibility of creating high relative humidity using fog and consequently reducing leaf transpiration seemed a very suitable alternative to misting.

Two such systems were investigated:

1) pressurized water fog,
2) pressurized air/water fog.

The second system was selected for the following reasons:

1) High pressure water lines used in the first system had been known to burst and could be dangerous in human terms. At that time, operating water pressures were quoted at around 900 psi (6200 kpa). In the air/water system, air pressures were quoted at around 60 psi (413 kpa) and water at about 5 psi (35 kpa), thus much safer. The lower pressures also allowed use of hydraulic plastic tubing instead of metal piping.
2) Many more nozzles were needed in the first system, and much finer nozzle orifices were required. Fine apertures had been found more prone to blockages even when using sophisticated filters and good quality water. Some blockages were caused by small metal particles flaking off the inside of the high pressure water lines, although this should not happen with the stainless steel or pvc piping used today.

   The air/water fog system uses only 3 nozzles per 15 m × 6 m house and the mode of operation of the system allows for much larger nozzle orifices which are consequently less prone to blockage.
3) Finer fog particles are available from the air/water system giving better humidification. The interior of the nozzle is designed so that the air under pressure sets up a sonic wave which breaks water into particles of diameters from 3μ upwards, depending whether a "dry" fog (fine particles) or a "wet" fog (coarse particles) is required. I understand that the

high pressure water system gives particle sizes from about 10μ upwards, thus giving a "wetter" fog. A "dry" fog is more suitable for many of the plants we propagate.

4) The air/water system introduces fresh air into closed polyhouses; the water fog system does not. This is also important, as plants in photosynthesis need CO_2 replacement in closed houses.

We have installed an air compressor of capacity sufficient to give us 8 ft^3 of air at 87 psi (600 kpa) stored in a metal receiver tank. Air passes from this tank through an oil filter to give clean air at about 60 psi (413 kpa) which is carried into the house in hydraulic plastic tubing to the upper inlet in each nozzle. Water at 5 psi (35 kpa) enters the lower inlet and is broken into fog particles inside the nozzle. The lines and nozzles run along the centre of the house about 20 cm below the apex of the roof.

Fogging is controlled by an electronic humidity-sensing device which is placed near the plant material. The sensor is connected to a control unit which activates fogging when the relative humidity drops below the set level. At the end of a fogging cycle, water is automatically cut-off while the air flows for a further 2 minutes to clear remaining water out of the water line, thus reducing mineral and algal build-up in the nozzle orifices.

In summer, houses are covered with white shadecloth to reduce both light and heat transmission. The minimum shade necessary to control heat build-up inside the houses is used to keep transmission at optimal levels for the cutting material contained in the polyhouse.

Using this system, we have found many advantages over conventional mist propagation:

1) fungal infections are reduced because plant material is in a less stressed condition.
2) cuttings root faster and more evenly,
3) difficult plant material strikes more readily,
4) tissue culture transfers (of plants as diverse as *Gypsophila* and *Grevillea*) can be made with virtually 100% success,
5) uncovered fine seed germinates more readily.

However, some precautions must be taken with plant material leaving a "fog" house. Plant material is much softer when grown in such ideal conditions and needs additional weaning in dry, hot weather. We overcome this problem by weaning trays of rooted cuttings in a non-"fog" house before tubing-up and by avoiding tubing cuttings on very hot, dry days.

Although there are new management techniques to be learned for successful use of fog houses, the benefits in propagation far outweigh any problems which may be encountered.

FOGGING SYSTEMS FOR PROPAGATION

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Fog has a number of important applications in agriculture and horticulture:

(a) temperature reduction;
(b) humidity control;
(c) frost protection;
(d) application of pesticides.

The plant propagator is primarily concerned with the control of the humidity in the propagation environment. Temperature reduction through the evaporative cooling effect of fog droplets can be a secondary advantage of fog in propagation.

A clear distinction must be made between fog and mist in plant propagation. Intermittent mist is used to provide a film of moisture over the leaves of cuttings and other evaporating surfaces in the propagation house. Fog provides the means to directly increase the relative humidity of the greenhouse atmosphere with little or no free water application to the leaves of the cuttings. The absence of this free water from the leaves of the cuttings provides a number of advantages to the plant propagator:

(a) reduced leaching of nutrients from leaves;
(b) improved aeration of propagation media;
(c) improved management of foliage diseases.

The principal agricultural application of fog to date has been in the cooling of poultry sheds. The primary aim in this situation is temperature reduction. In enclosed buildings with relatively low light transmission significant temperature reduction can be achieved by the introduction of fog into the internal atmosphere.

Fogging for humidity control in the propagation greenhouse presents a different problem due to the high levels of light which are transmitted into greenhouses. As the light level increases in the greenhouse it becomes increasingly difficult to maintain a stable humidity.

Shading of the greenhouse structure is of great importance in evening out humidity fluctuations due to rapid dispersal of the fog. Shading may be achieved by the application of paints or shading compounds to the greenhouse covering material or by the use of external or internal blinds or screens. The potential benefits of fog in the reduction of internal greenhouse temperatures may be substantially reduced in an unshaded greenhouse.

In most propagation situations where fog would be advantageous, such as cutting propagation and in greenhouse establishment of tissue-cultured material, reduction in light transmission to reduce moisture stress is often a standard procedure so propagators should not be concerned at the need for shade to maintain a stable fog.

It must be stressed strongly that fogging systems are not irrigation systems. The fog is being placed in the greenhouse atmosphere to regulate the humidity and it is unlikely that the fogging system will provide sufficient moisture to keep the propagation media uniformly moist. Regular monitoring of moisture levels in the propagation media will be necessary and routine watering may be required.

TYPES OF FOGGING SYSTEMS

The three types of fogging systems commercially available were summarized in a paper presented at the joint New Zealand/Australian Region IPPS Conference in Tauranga in 1987 (1).

(a) Ventilated Fog.
(b) Pressurized Water Fog.
(c) Pressurized Air/Water Fog.

Ventilated fog is not used to any extent in Australia.

Pressurized Water Fog—An installation at the Queensland Agricultural College. An experimental pressurized water fogging system was installed in the Plant Nursery Unit at the Queensland Agricultural College (Q.A.C.) in February of 1988 for evaluation under southeast Queensland conditions.

The unit is installed in a 15 × 6 metre greenhouse and consists of two lines of high pressure PVC pipes mounted at two metres height running the length of the greenhouse. The delivery lines are uniformly offset from the centre of the structure and are fitted with stainless steel micro-nozzles spaced 1 metre apart. The nozzles are inserted into the lines at a 30° inward facing angle. A self-draining valve is fitted to the end of the delivery line to ensure that water does not remain in the delivery line. This prevents possible blockage of nozzles due to mineral accumulation caused by evaporation of water from the nozzle orifice.

Water quality is of great importance with fogging systems and rainwater is used at QAC. A high quality rope-wound filter is used as a pre-treatment to remove solid matter which could cause blockages. Further pre-treatment to remove minerals or salts may be necessary with some suspect water supplies.

A 1.5 h.p. piston pump capable of delivering 8 litres per minute and set to operate at 600 p.s.i. provides the necessary power to generate a fine fog. These small high pressure pumps are very noisy and this may be a limitation to their use in some situations.

Control of the operation of the fog is via a humidistat sensor, although a number of cheaper control systems can be used. The humidistat sensor is located in the crop zone of the greenhouse and constantly senses humidity directly in the zone of the greenhouse where the crop is located. The sensor is connected to a digital control unit which enables programming of minimum and maximum

humidity settings. Once these settings are programmed, the fog will automatically be activated as needed to maintain the required greenhouse humidity.

Shading of the greenhouse structure is provided by the use of white fiberglass on the roof of the structure combined with a white shadecloth lining on the inside of the roof. The level of shade provided means that fluctuations in humidity due to rapid fog dispersal in bright sunshine are minimized.

Experience to date with the high pressure fogging system is that the control of humidity in the greenhouse is much more accurate than was possible with intermittent mist or polythene tents. A series of trials using cuttings of *Chamelaucium axillare* indicate the following results:

Percentage rooting under high pressure fogging system	61%
Percentage rooting under polythene tent and mist	0% (to date)
Percentage rooting under polythene tent only	31%

Cuttings propagated under fog were able to be potted up ten days earlier than those propagated under the tent and, to date, none of the cuttings under mist have rooted.

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BENCH TOP-WORKING OF ORNAMENTAL TREES, SHRUBS, AND CONIFERS

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A definition of top-working can be expressed as a specialized method of grafting in which the scion, either as a stem with multiple buds or as a single bud, is normally worked onto the rootstock 0.3 to 1.8 m (1 to 6 ft.) above soil level. The genera and species for top-working are varied, ranging from evergreen and deciduous shrubs, conifers, roses, and trees to ground covers.

The scope of bench top-working can be appreciated by summarizing the reasons why propagators use this method:

1. It is particularly useful for producing unusual and novel plant material. Examples of novel bench grafting combinations include *Cotoneaster horizontalis* on *C. frigidus*, *Hedera helix* 'Pixie' on × *Fatshedera lizei*, *Euonymus fortunei* 'Emerald 'n' Gold' on *E. europaea*, *Juniperus chinensis* var. *procumbens* 'Nana' on *J. virginiana* and *Betula pendula* 'Trost's Dwarf' on *B. pendula*.

2. Novelties can also be described as "custom-built" trees—for example, using interstems of the attractive peeling bark of *Prunus serrula*. The *P. serrula* is grafted onto *P. avium* Mazzard 'F12/1' and then one of the Japanese hybrid cherries (such as *P. serrulata* 'Shirotae', or, for the smaller garden, *P.* 'Okame') is grafted onto the stem of *P. serrula* at the desired height. Another good example of custom-built trees is the container production of espalier fruit trees where 3 pairs of buds are chip-budded at 38 to 45 cm (15 to 18 in) intervals up the stem. The growth resulting from each pair of buds is espaliered to produce a saleable product for retail sales after one growing season.

3. Some trees normally grow as shrubs unless top-worked onto a rootstock stem—particularly those which have a natural weeping effect. Highlighting these plants on a stem can give them a very different visual effect. Examples include, *Salix caprea* 'Pendula' on *S.* × *smithiana*, *Piptanthus nepalensis* [syn. P. *laburnifolius*] on *Laburnum anagyroides*, *Acer pseudoplatanus* 'Brilliantissimum' on *A. pseudoplatanus*, and *Juniperus horizontalis* 'Blue Chip' on *J. virginiana* 'Skyrocket'.

4. With certain species, it provides the propagator with the ability to produce a saleable product within a shorter period of time.

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[1] Director

For example, the slow-growing *Chamaecyparis obtusa* 'Nana Gracilis' can have numerous scions grafted onto *C. lawsoniana* or *Thuja occidentalis*. This concept can be used to change cultivars of *Acer palmatum*. A five-gallon crop of *Acer palmatum* cvs. which have not sold can be changed to a more saleable cultivar by stick budding up to twenty buds to framework the rootstock.

5. It is an effective method for inducing vigorous early growth in weak species that fail with bottom-working—for example, *Quercus robur* 'Concordia'.

6. Bench top-working allows the propagator to re-work certain species that are surplus to requirements. There are often open-ground trees which require lifting and transferring into a greenhouse for top-working. For example, the weeping *Cotoneaster* × *watereri* 'Pendulus' may be conveniently top-worked onto other cultivars within the Watereri group such as *C.* 'Cornubia' and *C.* 'St. Monica', and *Laburnum anagyroides* 'Pendulum' and *Cytisus battandieri* can be conveniently top-worked onto unsold stems of *L. anagyroides*.

TOP-WORKING GRAFTING IN BRITISH COLUMBIA

As part of the Plant Introduction Scheme of the University of British Columbia, we are currently evaluating new and unusual scion/rootstock combinations to produce plants for retail sales. Currently being researched is a very good pink form of the low-growing *Prunus prostrata*. To date, the rootstock with which it is compatible is Myrobalan B, but we have yet to ascertain whether this vigorous rootstock has disadvantages in producing trees for small gardens and patios. Through the research work of Agriculture Canada, two of our clones of *P. glandulosa* are in the final phases of being made virus-free. We will be assessing the suitability of these two clones for top-working.

With the emphasis on retail sales, Geoff Schwyn of Westham Island Nurseries, Delta, B.C., has developed a unique product where demand has exceeded supply. First-grade layers of the apple rootstock 'M.26' or 'Quince A' are potted directly into 27 cm (10½ in.) diameter containers. Then two or three pairs of scion buds are chip-budded at about 38 cm (15 in.) intervals up the stem in late July to early August. The pairs of buds are either three distinct cultivars or just one cultivar. Budding in pairs can prove difficult as the buds may fall out from the chip before or during the tying-in procedure, but this can be prevented by placing a short length of sticky tape across the front of the bud shield and adjoining rootstock following the matching of the chip bud. This allows the propagator to tie in both buds with a strip of polyethylene tape. The following February after budding, the rootstock is headed back to just above the top pair

of buds. A pre-fabricated wooden trellis is slotted into the container adjacent to the inner wall and the subsequent lateral growth is espaliered and tied onto this trellis. The espaliered trees are sold in the following fall or spring with a colored tag label and cultural booklet attached to the wooden trellis.

Top-working of ornamental *Prunus* has been a very successful retail product for Rick Sorenson, Homestead Nurseries, Clayburn, B.C. First-grade layers of *Prunus avium* Mazzard 'F12/1' are purchased and then heeled outdoors in sawdust. The rootstocks are lifted from the holding area during January and bare-root whip, or basal root grafted and tied in with rubber grafting ties. Following waxing of the union and scion, the grafts are tied into bundles of 15 and the roots plunged into peat moss or sawdust in an unheated greenhouse. A polyethylene bag can be placed over the scion and tied in beneath the union if there is a need to increase the humidity around the union. In February, some six weeks after grafting, the rootstocks can be potted into 27 cm (10½ in.) containers and kept within the polyethylene greenhouse before being transferred to the outdoor container site. The top-worked trees are ready for sale by the following fall. The leaders and side shoots are pruned up to three times during the year in order to produce trees with full heads. Cultivars produced satisfactorily so far include *Prunus* 'Accolade', *P.* 'Okame', *P.* 'Pink Perfection', *P. serrulata* 'Shirotae' and *P. subhirtella* 'Autumnalis'.

The encouraging thing about this propagation schedule is that staff with a minimum amount of training have achieved excellent results. Criteria for success with novice staff, besides good instruction, is to ensure that only fully dormant scion wood is used by collecting it early at the turn of the year and that tying-in is tight and secure. Firm tying-in and good matching between scion and rootstock very often can compensate for uneven cut surfaces on the different grafting techniques used. A disadvantage of top-working *Prunus* is that the union can become unsightly at eye level in subsequent years.

Miniature standard conifers are becoming increasingly popular. The graft is sited some 30 to 45 cm (12 to 18 in.) above the rim of the pot. A side veneer or side wedge graft is used. Graft combinations include *Juniperus horizontalis* 'Blue Chip' and *J. horizontalis* 'Emerald Spreader' onto *J. virginiana* 'Skyrocket', *Picea pungens* 'Globosa' on *P. abies*, *Pinus mugo* 'Prostrata' on *P. sylvestris*, and *Pinus strobus* 'Nana' on *P. strobus*.

Through the understanding of growth habits and graft compatibility, bench-top grafting provides the opportunity for the propagator to use his or her ingenuity. This paper provides some of the principles involved and some specific examples being used in British Columbia. The appendix to this paper provides a selection of effective scion/rootstock combinations for top-working.

A SELECTED LIST OF SCION/ROOTSTOCK COMBINATIONS FOR ORNAMENTAL DECIDUOUS AND EVERGREEN BROAD-LEAVED TREES, SHRUBS, AND CONIFERS SUCCESSFULLY PROPAGATED BY TOP-WORKING

NOTE:—The grafting times in this list have been taken as an optimum range for both North America and Europe. The geographical location of a nursery may mean that grafting is carried out before (or after) the times listed here.

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
Cedrus atlantica 'Glauca Pendula' (weeping blue Atlas cedar)	*C. deodara* (Himalayan cedar)	late July–Aug or Jan–Feb	P.G.	Side
Chamaecyparis obtusa 'Nana Gracilis' (dwarf Hinoki cypress)	*C. lawsoniana* (Lawson cypress) *C. pisifera* (Sawara cypress)	Jan–Feb	P.G.	Side
Juniperus horizontalis 'Blue Chip'	*J. virginiana* 'Skyrocket' (skyrocket juniper)	Jan–Feb	P.G.	Side
J. horizontalis 'Emerald Spreader' (creeping juniper cvs.)	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side
J. horizontalis 'Wiltonii' (Wilton carpet or blue rug juniper)	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side
J. procumbens 'Nana' (Dwarf Japan garden juniper)	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side
J. sabina 'Buffalo'	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side
J. sabina 'Calgary Carpet' (savin juniper cvs.)	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side
J. scopulorum 'Tolleson's Blue Weeping' (Rocky Mountain juniper cv.)	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side
J. squamata 'Blue Star'	*J. virginiana* 'Skyrocket'	Jan–Feb	P.G.	Side

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
(Single-seed or scaly-leaved Nepal juniper cv.)				
Larix decidua 'Pendula' (weeping European larch)	*L. decidua* (European larch) *L. kaempferi* (Japanese larch)	Jan–Feb	P.G.	Side
L. kaempferi 'Pendula' (weeping Japanese larch)	*L. decidua* *L. kaempferi*	Jan–Feb	P.G.	Side
Picea abies 'Inversa' (drooping Norway or drooping spruce)	*P. abies* (Norway spruce)	late July–Aug or Dec–Feb	P.G.	Side
P. pungens 'Globosa' (globe Colorado blue spruce)	*P. abies*	late July–Aug or Dec–Feb	P.G.	Side
Pinus mugo 'Prostrata Wells' (Wells' prostrate mugo pine)	*P. sylvestris* (Scots pine)	Nov–Jan	P.G.	Side
P. strobus 'Nana' (dwarf white pine)	*P. strobus* (eastern white pine)	Nov–Jan	P.G.	Side
P. sylvestris 'Glauca Nana' (dwarf blue scots pine)	*P. sylvestris*	Nov–Jan	P.G.	Side
Acer palmatum 'Burgundy Lace' *A. palmatum* 'Dissectum' and similar cvs. (Japanese maple cvs.)	*A. palmatum* (Japanese maple)	July–Aug or Jan–Feb	P.G.	Side
A. platanoides 'Globosum' (globe Norway maple)	*A. platanoides* (Norway maple)	Jan–Feb	P.G. or root-balled	Side
A. pseudoplatanus 'Brilliantissimum' *A. pseudoplatanus* 'Prinz Handjery' (sycamore maple cvs.)	*A. pseudoplatanus* (sycamore maple)	Jan–Feb	P.G. or root-balled	Side or Whip
Aesculus × *carnea* 'Briotii' (ruby horse-chestnut)	*A. hippocastanum* (common horse-chestnut)	Jan–Feb	P.G. or root-balled	Side or Whip

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
A. pavia 'Koehnei' (red buckeye cv.)	*A. hippocastanum* *A. pavia* (red buckeye)	Jan–Feb	P.G. or root-balled	Side or Whip
Betula nana (dwarf birch)	*B. pendula* (European white or common silver birch)	Jan–Feb	P.G.	Side
B. pendula 'Youngii' (Young's weeping birch)	*B. pendula*	Jan–Feb	P.G.	Side
B. pendula 'Trost's dwarf'	*B. pendula*	Jan–Feb.	P.G.	Side
Caragana arborescens 'Pendula' (weeping Siberian pea shrub)	*C. arborescens* (Siberian pea shrub)	Jan–Feb	P.G.	Whip
C. arborescens 'Walker' (Walker Siberian pea shrub)	*C. arborescens*	Jan–Feb	P.G.	Whip
C. frutex 'Globosa' (Russian pea shrub cv.)	*C. arborescens*	Jan–Feb	P.G.	Whip
Catalpa bignonioides 'Aurea' (golden Indian bean)	*C. bignonioides* (Indian bean) *C. speciosa* (western catalpa)	Jan–Feb	Balled & burlapped	Whip
C. bignonioides 'Nana' (umbrella catalpa)	*C. bignonioides* *C. speciosa*	Jan–Feb	Balled & burlapped	Whip
Corylus avellana 'Contorta' (Harry Lauder's walking stick)	*C. colurna* (Turkish Filbert)	Jan–Mar	B.R.	Whip
C. avellana 'Pendula' (weeping European filbert or hazelnut)	*C. colurna*	Jan–Mar	B.R.	Whip
C. maxima 'Purpurea' (purple giant filbert)	*C. colurna*	Jan–Mar	B.R.	Whip
Cotoneaster adpressus var. *praecox*	*C. bullatus* (hollyberry cotoneaster)	Jan–Feb	P.G.	Whip

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
(early cotoneaster)	*C. frigidus* (Himalayan cotoneaster) *C.* × *watereri* cvs. (Waterer cotoneaster)			
C. horizontalis (rock cotoneaster, rockspray)	*C. bullatus* *C. frigidus* *C.* × *watereri* cvs.	Jan–Feb	P.G.	Whip
C. × *watereri* 'Pendulus' [syn. *C.* 'Hybridus Pendulus']	*C. bullatus* *C. frigidus* *C.* × *watereri* cvs.	Jan–Feb	P.G.	Whip
Crataegus laevigata 'Gireoudii' (English hawthorn cv.)	*C. laevigata* 'Paulii' (Paul's scarlet hawthorn)	Jan–Mar	B.R.	Whip
C. monogyna 'Flexuosa' (common hawthorn cv.)	*C. laevigata* 'Paulii'	Jan–Mar	B.R.	Whip
Cytisus battandieri (Atlas or Moroccan broom)	*Laburnum anagyroides* (Common Laburnum)	Jan–Feb	P.G.	Inlay or Whip
C. scoparius cvs. (Scotch broom)	*Laburnum anagyroides*	Jan–Feb	P.G.	Inlay or Whip
Elaeagnus pungens 'Maculata' (golden elaeagnus)	*E. umbellata*	Jan–Mar	P.G.	Side
Euonymus fortunei 'Emerald 'n' Gold' (winter creeper euonymus cv.)	*E. europaeus* (European spindle tree)	Jan–Feb	P.G.	Side
Fagus sylvatica 'Purpurea Pendula' (weeping copper beech)	*F. sylvatica* (European beech)	Jan–Feb	P.G.	Side
Fraxinus excelsior 'Pendula' (weeping European ash)	*F. excelsior* (European ash)	Jan–Feb	P.G.	Whip

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
Hedera helix 'Pixie' *H. helix* 'Silverdust' (English ivy cvs.)	× *Fatshedera lizei* (botanical-wonder)	Aug Oct–Nov	P.G.	Side
Hibiscus syriacus 'Hamabo' (rose-of-Sharon cv.)	*H. syriacus* (Rose-of-Sharon)	Jan–Feb	P.G.	Whip, Wedge
Laburnum alpinum 'Pendulum' (weeping golden-chain or Scotch laburnum)	*L.* × *watereri* 'Vossii' (Voss' Long-cluster golden-chain tree)	Jan–Mar	B.R.	Whip
Malus prunifolia 'Pendula' (weeping plum-leaved apple)	M.M. 106 *M.* 'Bittenfelder'	Jan–Mar	P.G. or B.R.	Whip, Whip & Tongue
M. 'Royal Beauty'	*M. sylvestris* (crab apple, French crab)	Jan–Mar	P.G. or B.R.	Whip, Whip & Tongue
Morus alba 'Chaparral' *M. alba* 'Pendula' (weeping mulberry) *M. alba* 'Venosa' (white mulberry cvs.)	*M. alba* var. *tatarica* (Russian mulberry)	Jan–Mar	B.R.	Side
M. bombycis 'Issai'	*M. alba* var. *tatarica*	Jan–Mar	B.R.	Side
M. latifolia 'Spirata'	*M. alba* var. *tatarica*	Jan–Mar	B.R.	Side
Piptanthus nepalensis (evergreen laburnum) [syn. *P. laburnifolius*]	*Laburnum anagyroides* (common laburnum)	Jan–Mar	B.R.	Whip
Prunus × *cistena* (purple-leaf sand cherry)	*P. c.* 'Myrobalan B' (Myrobalan plum) *P. c.* 'Myrobalan B' *P. mahaleb* (Mahaleb cherry)	Jan–Feb	P.G., B.R.	Whip
P. fruticosa 'Globosa' (European cherry or ground cherry cv.)	*P. avium* (mazzard, gean cherry)	Jan–Mar	B.R.	Whip

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
P. 'Okame'	*P. avium* Mazzard 'F12/1'	Jan–Feb	P.G., B.R.	Whip
P. serrulata 'Shirofugen'	*P. avium* *P. avium* Mazzard 'F12/1'	Jan–Mar	B.R.	Whip
P. subhirtella 'Pendula Plena Rosea' (double weeping rosebud cherry)	*P. avium*	Jan–Mar	B.R.	Whip
P. triloba 'Multiplex' (flowering almond cv.)	*Prunus cerasifera* Myrobalan 'B' *P. cerasifera* St. Julien 'A', 'Brompton'	Jan–Feb	B.R.	Whip
Rhododendron 'Elisabeth Hobbie'	R. 'Anna Rose Whitney'	Jan–Mar	P.G. or root-balled	Side
Robinia hispida var. *macrophylla* (smooth rose acacia)	*R. pseudoacacia* (black locust)	Jan–Feb	P.G.	Whip, Whip & Tongue
R. pseudoacacia 'Umbraculifera' (mop-head acacia)	*R. pseudoacacia*	Jan–Feb	P.G.	Whip, Whip & Tongue
Rosa 'Dorothy Perkins'	*R. canina* 'Pfander' (dog rose cv.)	Jan–Feb	P.G. or B.R.	Whip, Rind
R. 'Little Buckaroo'	*R. multiflora* (baby or Japanese rose) *R. canina* 'Inermis' (dog rose cv.)	Jan–Feb	P.G. or B.R.	Whip, Rind
R. moyesii (Moyes' Rose)	*R. canina* 'Pfander'	Jan–Feb	P.G. or B.R.	Whip, Rind
Salix caprea 'Pendula' (Kilmarnock willow)	*S.* × *smithiana*	Jan–Mar	B.R.	Whip
S. hastata 'Wehrhahnii' (halberd-leaved willow cv.)	*S.* × *smithiana*	Jan–Mar	B.R.	Whip
S. helvetica (Swiss willow)	*S.* × *smithiana*	Jan–Mar	B.R.	Whip
S. purpurea 'Pendula' (weeping purple	*S.* × *smithiana*	Jan–Mar	B.R.	Whip

Scion	Rootstock	Time of Year	Bare-Root (B.R.) or Pot-Grown (P.G.)	Type of Graft
willow)				
Sophora japonica 'Pendula' (weeping Japanese pagoda tree)	*S. japonica* (Japanese pagoda tree)	Jan–Feb	P.G.	Side
Ulmus × *elegantissima* 'Jacqueline Hillier'	*U. glabra* (Scotch or Wych elm)	Jan–Feb	P.G.	Whip, Whip & Tongue
U. × *glabra* 'Camperdownii' (Camperdown elm)	*U. glabra*	Jan–Feb	P.G,	Whip, Whip & Tongue
U. glabra 'Crispa' (fern-leaf elm)	*U. glabra*	Jan–Feb	P.G.	Whip, Whip & Tongue
U. glabra 'Nana' (Scotch elm cv.)	*U. glabra*	Jan–Feb	P.G.	Whip, Whip & Tongue
U. parvifolia 'Geisha' (Chinese elm cv.)	*U. glabra*	Jan–Feb	P.G.	Whip, Whip & Tongue
Wisteria venusta (silky wisteria)	*W. sinensis* (Chinese wisteria)	Jan–Feb	P.G.	Side

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SUCCESSFULLY INTRODUCING PLANTS FROM BOTANICAL COLLECTIONS INTO THE NURSERY AND LANDSCAPE INDUSTRIES

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The Plant Introduction Scheme of the University of British Columbia Botanical Garden (PISBG) was initiated in 1980 by the Garden's previous Director, Dr. Roy L. Taylor[2], and nine plants have been released to date into the B.C. nursery trade for subsequent wholesale, retail, and landscape sales. Descriptions of the material released, propagation methods, and the procedures for evaluation and introduction of plants are documented in the references listed at the end of this paper. Plants released through the PISBG programme that are registered with the Canadian Ornamental Plant Foundation (COPF) are *Anagallis monelli* 'Pacific Blue', *Arctostaphylos uva-ursi* 'Vancouver Jade', *Genista pilosa* 'Vancouver Gold', *Ribes* sanguineum 'White Icicle', *Rubus calycinoides* 'Emerald Carpet' and *Viburnum plicatum* 'Summer Snowflake'. Recommended but non-registered plants are *Diascia rigescens, Microbiota decussata* and *Teucrium scorodonia* 'Crispum'.

The role of this paper is to relate our experiences as a basis for recommendations to a botanical garden, or similar institution, wishing to successfully introduce their plant material. In our opinion, botanical gardens are generally far too conservative in the use of, and introductions from, their plant collections. There is often a tendency for gardens to collect material with no apparent overall objective and to consider the plants collected merely as "collectors items", with little consideration as to how they can be made available to the nursery trade, urban landscape, and home gardener. Our recommendations can be listed under eight headings.

INDUSTRY INVOLVEMENT

The primary users of the plant material must be involved and consulted from the very start. The key players are the wholesale and nursery growers, landscape architects and contractors, together with parks boards. The nurseries involved should be chosen from growers selling both locally and across the country, as well as having the ability to export their product. During this phase, it is

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vital to have thorough consultation with the industry so that they are fully aware of the programme's objectives.

COMMITTEE STRUCTURE AND FUNDING

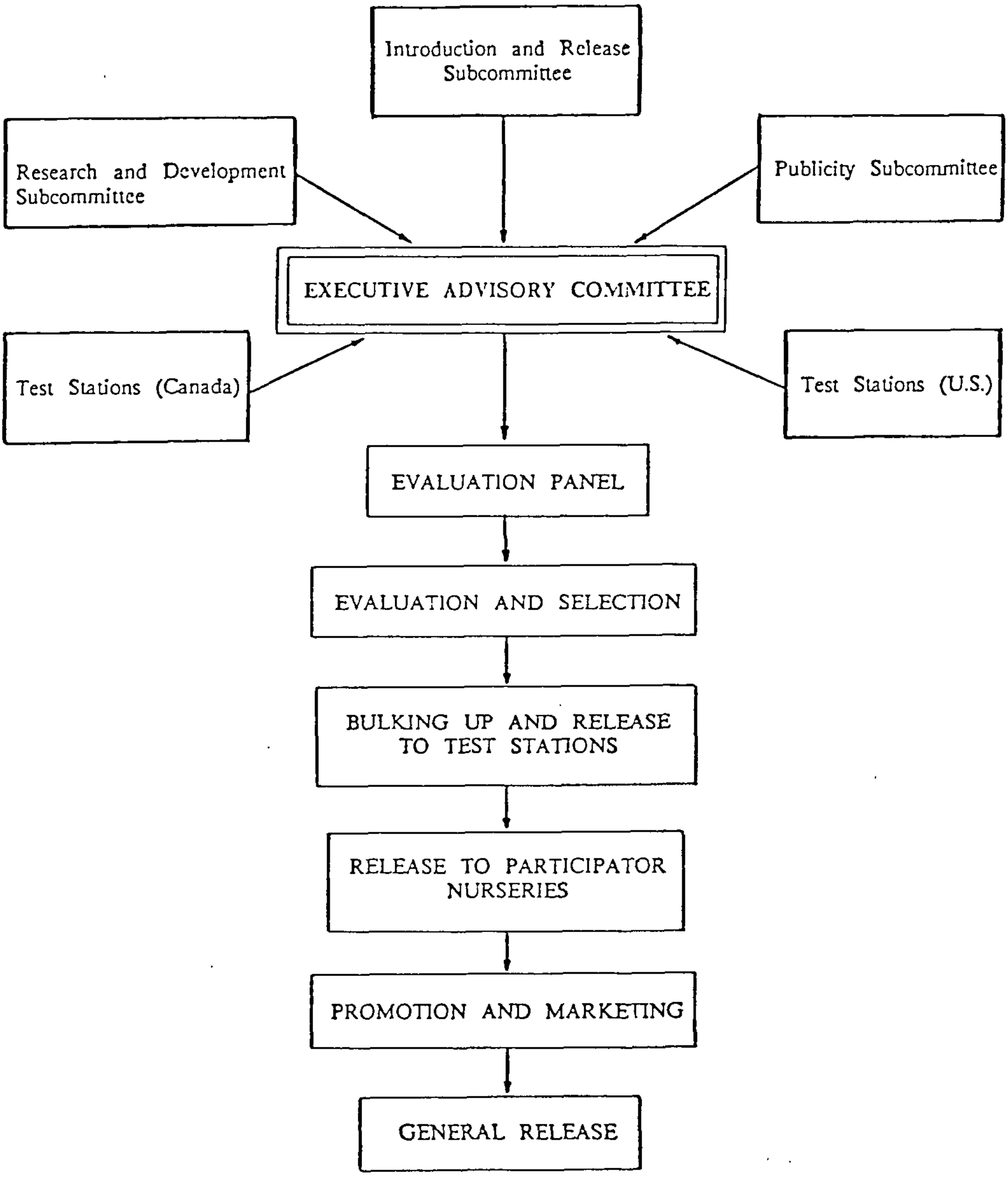
It is imperative to select the executive committee members from people who will contribute both positively and constructively. Our advice is to keep the committee to no more than ten individuals representing key sectors of the industry. One of our early goals was to evaluate the reasons why other institutional and commercial introduction programmes had or had not been successful. As a result of this evaluation, several criteria were set for the PISBG. It is very important to meet regularly, particularly initially, so that industry can see that action is being taken. Too many good programmes lose their impetus by excessive committee work with slow and inconclusive results.

Once the executive committee has resolved the objectives, we have found that a series of sub-committees with a membership of four to five members is an effective way for the programme to proceed. The three sub-committees of the PISBG programme are for *publicity, research,* and *introduction and release*—the latter being the "core committee" that makes the final choice of plants to be released, sets royalties, and is used by the Garden to provide advice on "trouble-shooting" to the programme. The following diagramatic representation reflects the organizational structure of the PISBG programme.

Ideally, a new programme requires some "seed-funding." Considerable effort was made to recruit and lobby for outside funding for the PISBG. This was subsequently achieved by funding from the Science Council of British Columbia—an organization that supports joint research and industry programmes—and the Devonian Group of Charitable Foundations in Calgary, which supports diverse horticultural projects in Western Canada. Funding is more easily attracted when the goals and procedures have been formulated before approaching groups—this shows the potential agency that the necessary homework has been carried out and that the program is viable.

A number of botanical gardens may have insufficient nursery resources of their own to support an introduction programme. With this in mind, we placed considerable emphasis on upgrading and expanding our facilities. The nursery should be the "core" of any botanical garden because inaccurate accessioning and/or production and planting of poor quality plants has uneconomic long-term consequences.

DIAGRAMMATIC REPRESENTATION OF THE P.I.S.B.G. PROGRAM



REVENUE FROM THE PROGRAMME

It is vital that one fundamental principle is understood—both industry and the botanical garden must receive revenue from the plants selected and sold. The PISBG programme receives revenues from three main sources—royalties, sales of cuttings, and sale of mother (stock) plants. Currently, these account for revenue received in the region of $30,000 Cdn.—we anticipate this will increase in the region of 10 to 15% per annum. A new plant introduced into the market will provide new sales but may also partially or fully substitute an existing product. For example, in British Columbia, *Arctostaphylos uva-ursi* 'Vancouver Jade', a local selection of the important native ground cover, has increased new sales, particularly for export, but it has also replaced sales of the type species and existing cultivars due to its superior qualities.

Participator nurseries in British Columbia have been excellent in making royalty payments, but we have missed out on royalty payments from other countries. Our most immediate concern is to resolve this problem either by using nurseries to patent new plants on our behalf in their respective countries or by formulating a contract between the University and a particular nursery.

A direct economic benefit has been provided to the nursery industry of British Columbia such that an independent economist, hired by the Science Council of British Columbia, estimated that sales to wholesale nurseries from participator nurseries was $1.9 million cdn. in 1987.

EVALUATION PANEL FOR PLANT SELECTION

There are over 13,000 different plants in the Garden's collections in Vancouver and therefore criteria have to be formulated as to the choice of individual plants to be selected for introduction. Maximum impact is achieved by inviting an evaluation panel selected from different sectors of industry to attend annually, or more frequently as the necessity requires, to thoroughly assess each plant for possible selection. We view up to a maximum of 14 plants in one day. Each member of the panel completes a detailed evaluation form for each plant to determine its uses, market outlet, economic impact, and positive and negative characteristics, together with its over-all suitability for introduction. After analysis of the forms, the possible selections are narrowed down to three plants by the introduction and release sub-committee.

To ensure that the programme makes a quick impact, we recommend that ground covers, perennials, or easy-to-propagate shrubs are chosen initially. This produces material for sale in a relatively short space of time and also allows for royalties to be returned to the programme at an early phase.

One important note is that the botanical garden should use its

expertise to ensure that a plant is correctly named and that any new cultivar is correctly registered. It is vital to make comparisons with existing clones, and outside expertise should be sought to verify that it is correct for a particular plant to be given a cultivar name. The choice of cultivar name is important for its public success.

PRODUCTION OF MOTHER PLANTS, AND RELEASE TO PARTICIPATOR NURSERIES

After selection of the plant for introduction, there are essentially two ways by which the bulking-up of material for release can proceed. *Firstly,* a designated nursery can undertake this—this, however, could innocently lead to the accusation of some bias. *Secondly,* the botanical garden or institution can produce the mother (stock) plants—we use the latter method. Some 500 to 1000 mother plants are produced and sold in minimum lots of 50 at a premium price to participator nurseries. When distributed, it is essential that a contract be signed to determine the date of public release, royalty payment, and the number of plants to be made available at the time of release. Our experience has shown that the latter is the most unpredictable. The PISBG programme began with nine participator nurseries and today there are 26.

Two-way communication between the garden and nurseries during the phase from release to the participator nurseries until the date of public release is vital to ensure that they adhere to the recommended production schedules. It is also very important that the garden takes notice of, and amends from, the industry experience. The botanical garden can advise on propagation and production methods from its own research and development, but a considerable amount of information results from the commercial situation. If an important problem arises during the research phase, release of the mother plants is delayed until trials on a commercial site.

TESTING AND EVALUATION IN THE PUBLIC LANDSCAPE

Each plant selected for the programme has usually been growing in the Garden for a minimum of six to seven years. The varying climatic conditions of North America meant that seven test sites in Canada and six in the United States were arranged at different institutions. Average winter temperatures range from −44°C through to +4°C, according to site. This resource information has been invaluable. However, a test site is only as good as the care that the plants are given. The liaison provided by the botanical garden is important to ensure that knowledge gained from the test sites is made available to industry. On a number of test sites, summer temperatures and humidity have been a greater factor for successful growth of the plants than winter hardiness.

We have a clause included in the programme that allows pre-release of plants for a high-profile public landscape site. However, more recently we have been working with the provincial Department of Highways for testing plants in different areas of British Columbia. It is strongly recommended that the Department of Highways be involved with the programme because of the potential number of plants involved.

PUBLICITY AND PROMOTION

Our experience has shown that funding for, and time spent on, publicity and promotion is well rewarded. This phase of the programme has been directed to:—

(i) Production of a special stick (for liner pots) and tag label (for one gallon and upward) so that the potential buyer at a retail outlet knows that the plant has come through the PISBG programme. The participator wholesale nursery is responsible for ensuring that the labels are placed on the plants.

(ii) Promotional brochures, posters, and weatherproof garden centre display labels.

(iii) Media involvement through contacting garden clubs, press, radio and television. One press release about the 1988 introduction of *Ribes sanguineum* 'White Icicle' resulted in five interviews being given to newspapers across Canada and in three radio interviews.

(iv) Providing seminars for retail garden centre staff. Direct contact with those employees actually selling the plant is necessary for a plant to be successful.

(v) Production of coloured information sheets on each plant for distribution to landscape architects and potential buyers of the material. These sheets contain photographs, descriptions, and culture of the plants; propagation and production information are also summarized.

(vi) Participation in trade shows with the major nursery trades associations. The PISBG plants have been a feature of the exhibits in shows in British Columbia and Ontario. We are currently investigating the production of a video presentation on the PISBG programme.

RESEARCH AND DEVELOPMENT FOR POTENTIAL PLANTS

It is relatively straightforward to select the initial "winning plants" from the botanical collections. Long-term success of the programme is ensured by having plants at various stages of development so that introductions can be provided on an annual basis. We

shall be proceeding with the following goals in order to achieve this:—

(i) Wild field collections of British Columbia native plants to select natural variants for habit, hardiness, flowering, etc.

(ii) Joint research with experts already at this University into micropropagation to regenerate species which are difficult by conventional means.

(iii) Commence plant breeding programmes, particularly with native perennials and deciduous and broad-leaved evergreen shrubs.

With these goals in mind, a Foundation has been set up in the name of Henry M. Eddie, one of the province's pioneer nurserymen and plant breeders. The Foundation has a board of trustees with strong industry representation and will set up an endowment fund to support the future research and development of the PISBG programme. The plan is to raise $1.0 million Cdn. over five years.

In conclusion, I have tried to summarize the past, present and future of our programme to encourage botanical gardens in both Australia and New Zealand to formulate similar joint programmes with their nursery and landscape industries. Five institutions in North America are in the process of modelling the PISBG programme, which has given us considerable encouragement. Plant collections can be described as "living museums", but botanical gardens have an important use in ensuring that the very best of their plants are selected for ultimate use in private gardens and the public landscape.

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PROPAGATION OF GREVILLEA HYBRIDS

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We grow about ten kinds of *Grevillea* in our nursery, and they include 'Robyn Gordon', 'Sandra Gordon', × *gaudichaudii,* and 'Royal Mantle'.

The methods used to grow these plants in our nursery have resulted from many trials focusing on different aspects of their propagation. These include stock plants, types of cuttings, hygiene, hormones, rooting media, potting up procedures, environmental conditions, and nutrition of the cuttings.

We are constantly looking to improve the growing conditions for the cuttings, and to fine tune the whole propagation process.

The propagation factors to be considered are:—

Stockplants. Stockplant gardens were established at the nursery to ensure good quality cutting material, free from disease and insects. These gardens supply about 80% of our cutting material, and the remaining 20% is gained from private gardens and nursery container stock. Cutting material can be taken from the stock garden throughout the year, although there is little growth during the winter as there are many frosts. Because of the frosts we like to have all the cutting material taken off the plants in autumn. Any cutting material needed during winter comes from container stock or garden plants which are not affected by frosts.

It is most important to have all stock plants free from disease, especially fungal disease and insect pests.

Cuttings. Cuttings taken from the stockplants are immediately taken into the propagation shed, where they are thoroughly washed in a sodium hypochlorite solution. They are then rinsed in running water and placed on the propagation bench.

Cuttings are made up in two ways. The first is with a node at the bottom, scarred, and a node with one bud and one leaf at the top. The second is with one node at the bottom, and two nodes, two buds and two leaves at the top. Half the leaf blade is removed as the leaves can be quite large.

Once the cuttings have been made, they are kept moist by covering with wet paper while they are on the bench. At no time should they be put under any excess stress from drying out or heat. On very hot or windy days we take smaller batches of cutting material throughout the day to ensure they can be processed and put under the mist quickly to avoid stress damage. If any cuttings are left at the end of the day they are held over night in the cold room or refrigerator.

Hygiene. We cannot stress too highly the importance of good hygiene practices and comfortable conditions in the propagation

area. The entire propagation shed is washed with sodium hypochlorite and the benches are washed and the rubbish from making the cuttings and general work is removed each day. The propagation shed is fully lined to help protect the cuttings on hot and cold days, also for staff comfort. The floor is concrete and fully drained to the outside of the building. Soil used for striking cuttings and for tubing is kept separate from the benches used for making cuttings.

Hormones. Hormone powder is applied to the base of the cuttings, and the strength varies from 3g of IBA per kg to 20g of IBA per kg, but more work has to be done to determine the optimum strength.

Media. The cuttings are dibbled into single cell containers. There are 48 cells in a large sheet which fits into a standard 30 cm × 26 cm seedling tray. The medium used is a mixture of three parts clean coarse sand and one part peatmoss.

Environmental conditions. Glasshouse conditions for striking the cuttings are tuned to those which avoid stressing the cuttings. Misting is kept quite high until callusing has occurred, and then they are gradually weaned off the mist. This process can be quite tricky as too much moisture causes the cuttings to decay, and not enough causes growth to stop and can even cause death.

The propagation benches have bottom heat, using hot water circulating in pipes in the sand on the benches. This is the only form of heating in the houses and works quite satisfactorily even when the outside temperatures drop as low as −2 to −3°C on some nights. Using this method, high bottom heat can be applied to achieve speedy root growth.

Ventilation and air circulation are essential aspects of our growing house management. Because the air in the house is not heated we can afford to have a higher roof and this helps greatly in cooling and ventilation.

To avoid fungal infection in the house we have a preventative spraying program, using a combination of two fungicides to give a broad spectrum control. All water used in the nursery is chlorinated using chlorine gas.

Fertilizing. After the cuttings have callused well and the misting is off a program of liquid feeding is commenced. The cuttings are fertilized while still on the bottom heat until they have produced roots. They are then moved to a shadehouse with 50% shade until they have developed enough to be potted-on. The liquid fertilizing is continued during this time as well.

In the summer months the cuttings take approximately 4 to 8 weeks to get to the potting-on stage. The strike rate for most of the grevilleas is between 70% and 80%, depending on the cultivar being grown. In the cooler months the cuttings take longer—from 8 to 12 weeks depending on the season.

SINGLE NODE VS. DOUBLE NODE CUTTINGS FOR THE PROPAGATION OF *PYROSTEGIA VENUSTA, HARDENBERGIA VIOLACEA* 'HAPPY WANDERER' AND *CLYTOSTOMA CALLISTEGIOIDES*

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Training and experience show that there is greater root development around a node than there is along the stem so it is a general practice to propagate cuttings with a minimum of two nodes, one below, in the medium, the other above it.

This is a practice that research and long usage has proven effective. However, there are disadvantages with some species. These are:

a. when the internodal length is exceptionally long, the cuttings are difficult to handle and become unwieldy when placed in a community tray.

b. if the plant material is badly tangled (as often happens with climbers) it is difficult and time consuming to extract "two node" cutting material. There is also a risk of plant tissue damage.

c. There are obvious arithmetical disadvantages if each cutting has to have two nodes should there be a shortage of plant material.

Whilst over time there must have been research into root production on single-node (leaf-bud) cuttings, a brief search of the literature revealed little information and, in particular, nothing on the three species mentioned in this paper.

It is not easy for a commercial grower to conduct rigorous plant trials (and record the results), while still operating on an economic basis. It was decided therefore that initial trials would only be brief, unreplicated, and limited in size.

The objective was simply to assess whether there was a satisfactory strike rate from cuttings with only one node. Three kinds of plants were selected:

a. *Pyrostegia venusta* [syn. *P. ignea*] (orange trumpet creeper). An evergreen, vigorous climber with brilliant scarlet-orange flowers in great profusion. Grows well, but does not flower well, if at all, in southern Victoria.

b. *Clytostoma callistegioides (Bignonia lindleyi' Tecoma lindleyana).* The Argentine trumpet-vine. An evergreen, large climber bearing in spring and summer, large trumpet flowers of lilac, marked with yellow and purple.

c. *Hardenbergia violacea* 'Happy Wanderer' (purple coral pea). Evergreen, this cultivar is a vigorous climber with masses of purple pea shaped flowers from July to October; other colours are pink and white.

Each trial consisted simply of a control and the treatment. The nursery's standard propagating techniques were used.

The propagation medium consisted of 85% sharp sand and 15% peat moss. Propagating trays (350 mm × 300 mm × 50 mm) were filled to the top with the medium. Pre-watered it was left to drain before the cuttings were inserted in rows at approximately 25 mm centres, giving 150 to 200 cuttings per tray. The cuttings were dipped in a 1% Benlate solution before sticking.

The two-node cuttings averaged 70 to 100 mm long and the tips were removed if they were unduly soft. The basal cut was made immediately below the node and was horizontal, (there may be more than two nodes if the internodal length was short). The bottom leaves were removed and the remaining leaves were trimmed if too large. The top cut, if any, was made immediately above a node.

With the single node cuttings, the top cut was made just above a node and the bottom cut (horizontal) approximately 50 to 70 mm below the same node.

All the trial cuttings were treated with an IBA powder, which was a commercial 12,000 ppm IBA reduced to required strength with talc on a daily basis depending on the specific needs. The propagation trays of cuttings were placed on sand bottom-heated benches in a fibre glasshouse with solid walls. The bed temperature was set at 21°C and the mist frequency was adjusted daily to suit the ambient conditions. Fungicides were applied as required.

Rooting results are given in Table 1.

Table 1. Rooting obtained with either single or two node cuttings of *Pyrostegia venusta*, *Hardenbergia violaceae* 'Happy Wanderer', and *Clytostoma callistegioides*.

Trial 1. Pyrostegia venusta

Propagated	Number of Cuttings	Type	IBA	Tubed	Number Struck	% rooted	Comment
27-11-87	111	Single Node	4	11-1-88	48	43	Cuttings from 2 yr old 1.2 m high plant in 20 cm container in igloo.
27-11-87	85	2 Node	4	11-1-88	65	76	Cuttings from 5 month tubes held in igloo.
27-11-87	85	Single Node	4	22-2-88	29	34	Cuttings from 5 month tubes held in igloo.

Trial 2. Hardenbergia violacea 'Happy Wanderer'.

Propagated	Number of Cuttings	Type	IBA	Tubed	Number Struck	% rooted	Comment
26-2-88	520	2 Node	5	8-4-88	357	68.8	150 cuttings (28.7%) restruck 13 cuttings (2.5%) dead.
26-2-88	1205	Single Node	5	8-4-88	612	50.7	150 cuttings (12.4%) restruck 248 cuttings (20.7%) dead.

Trial 3. Clytostoma callistegioides

Propagated	Number of Cuttings	Type	IBA	Tubed	Number Struck	% rooted	Comment
16-2-88	90	2 Node	4	30-3-88	84	93	Dead 6
16-2-88	165	Single	4	30-3-88	160	97	Restruck 5

DISCUSSION

As with most trials the results raised more questions than answers. As always one would have wished for more replications, larger numbers and the elimination of more variables.

However from the results it would appear that single node cuttings were justified for *C. callistegioides;* of doubtful value for *H. violacea* 'Happy Wanderer'; and not justified for *P. venusta*.

Further research is required however, and until then there must be reservations about the results. In this trial the samples were small and the results were not statistically analyzed; no allowance was made for seasonal variation in cutting wood. For example, whilst poor results were obtained with *P. venusta* using young or juvenile wood, we normally propagate this species from older hardwood and, as a general rule, achieve higher strike rates.

The very high death rate of the *H. violacea* single node cuttings looks most discouraging. However, this was semi-hard mid-season wood (February). It may be that single node cuttings might strike more readily in late spring (November–December). Alternatively the incorrect hormone rooting powder may have been selected. It may also be that cuttings propagated in sub-tropical climates (south-east Queensland) will provide a higher number of adventitious roots.

The good results for *C. callistegioides* single node cuttings may not be replicated with cuttings taken at other times or at other stages of plant growth. Nonetheless we do know that cuttings propagated

in January from lush container-grown material will strike readily whether cuttings have one or two nodes.

Not enough attention was paid in this trial to where the roots developed and in what densities along the cutting. It is known that two node cuttings of *H. violacea* produced roots from the basal node only, but the root development patterns of the single node cuttings were not closely observed.

It is not known how the struck cuttings will develop as they grow in the tubes, and whether the effect of different root production patterns will affect subsequent growth patterns.

Finally, in conjunction with the results and these reservations any economic benefits must also be evaluated. There are many climbers where the cutting material is so tangled that a degree of loss is acceptable if single node cuttings permit faster production rates, albeit with a correspondingly higher non-strike rate. Offset, of course, by the extra cost of labour, nutrients, space and time. It becomes a bottom line decision.

KANGAROO PAW BREEDING—THE "BUSH GEMS" CULTIVARS

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Parkes St
West Ryde 2114

I would like to dedicate this paper to my late friend and mentor, Mervyn Turner, who during the last decade of his life dedicated himself almost entirely to breeding kangaroo paws (*Anigozanthos* spp.). His breeding program gave rise to the "Bush Gems" range of hybrid cultivars. Merv had a vision for breeding not just kangaroo paws, but also a whole range of other Australian native plants, such as Christmas bells (*Blandfordia* spp.), pimeleas (*Pimelea* spp.) and numerous others.

As a tribute to Merv Turner I would like to review the results to date of the "Bush Gems" breeding program. I hope that the experience gained with kangaroo paws will be of assistance to those interested in the genetic improvement of Australian plants.

The genus *Anigozanthos* contains species with a spectacular range of colours and flower forms and often within a species a range of colour forms exists. The large range of colours and colour combinations available to the breeder has only been partially exploited to date.

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The greatest limitation to the horticultural development of

kangaroo paws has undoubtedly been the condition known as "ink spot". After extensive experience it is my view that "ink spot" is caused by a variety of factors. One cause has been isolated as a fungal leaf pathogen in the genus *Alternaria* (2); however, I have observed several environmental factors which cause leaf blackening ("ink spot"). These include frost, snail damage, chemical spray damage, and nutritional stress. It appears that leaf blackening results from pigments released following cell death, and I believe this makes the goal of breeding ink spot tolerant cultivars extremely difficult.

The only kangaroo paw species which has been consistently reliable in cultivation has been *A. flavidus*. This species has been widely planted as an ornamental landscaping subject, and its success in cultivation appears to derive from its distinctive tough, leathery strap-like leaves. Although the commonly grown forms of *A. flavidus* are unspectacular, this species has proven to be the key parent for breeding hardy cultivars. Almost all of the commercially successful "Bush Gems" cultivars have *A. flavidus* in their parentage.

Thus, the *A. flavidus* hybrids have proven to be the most successful part of the kangaroo paw breeding story. In particular, hybrids between the two metre tall, *A. flavidus* and the smaller species such as *A. humilis* and *A. bicolor,* have yielded a range of hardy, long-flowering dwarf cultivars including 'Bush Baby' and 'Bush Ranger'. These cultivars have established a niche for kangaroo paws as flowering pot plants and have been a great success.

Some of the taller *A. flavidus* hybrids with species such as *A. rufus, A. pulcherrimus,* and *A. manglesii* have also been successful. These plants are equally useful as landscape specimens or for cut flower production. The cultivars 'Bush Dawn', 'Bush Noon' (both *A. pulcherrimus* × *flavidus*) and 'Bush Sunset' are hardy, productive and relatively free of ink spot.

The versatility of the range of "Bush Gems" cultivars has greatly enhanced their commercial appeal, and any prospective breeders of Australian plants would do well to choose genera which have potential for multiple uses.

The strengths of the "Bush Gems" kangaroo paws could be summarized as:

- Improved vigour and hardiness.
- An improved colour range.
- Longer flowering season.
- An increased range of heights, from dwarf to tall.
- An improved range of plants for cut flower production.
- The attraction of nectar-seeking birds to landscape plantings.

Whilst the "Bush Gems" cultivars have been well accepted

there have been problems with other hybrid kangaroo paws. I am sure that Merv would wish that others could learn from both the good and bad experiences with kangaroo paws.

Perhaps the biggest problem has been in relation to "ink spot," and one of his main aims was to select cultivars with a high degree of tolerance to this condition. However, in hindsight the environmental factors which are a primary cause are ultimately beyond the control of the breeder. Thus, even the best cultivars will develop leaf blackening if grown under sub-optimal conditions such as heavy shading or poor drainage. It is my current feeling that rather than stress that cultivars be bred for tolerance to "ink spot," a better approach would be to emphasize how to avoid it by appropriate cultural practices. There can be no doubt, however, that the best of the "Bush Gems" cultivars show greatly increased tolerance to ink spot. A number of potential cultivars were, however, rejected because of their susceptibility.

Another problem confronted was the practical difficulty in adequately trialling promising hybrids. In this regard, I was extremely interested in Bruce Macdonald's paper outlining the Plant Introduction Scheme in Vancouver, Canada. Australia, with its vast range of climatic types would do well to adopt a scheme such as this which would allow new cultivars to be evaluated on an objective basis over a wide range of geographical areas. Introduction of new cultivars in Australia at present is, at best, a rather hit and miss affair. It would be a fitting gesture if such a scheme could be initiated in our Bicentenial year.

In conclusion, I would like to make some observations about the future of genetic improvement of Australian plants generally. Biotechnology, such as genetic engineering, has captured the imagination of many people and a great deal of money is being invested by entrepreneurs and governments. Greg Lamont's use of plant tissue culture techniques, such as ovule and embryo culture, to facilitate the breeding of *Chamelaucium* hybrids provides an excellent example of how the new biotechnology techniques can be used effectively. However, I believe that these new techniques should be kept in perspective, particularly in relation to the breeding of Australian plants.

A great deal has been said and written about the untapped potential of the Australian flora. It should be remembered that this untapped potential exists because the Australian flora has not yet received the sustained attention from plant breeders that genera such as roses, carnations and chrysanthemums have had. For many Australian genera, new taxa are constantly being discovered and most genera have had little or no systematic breeding. Thus, I feel it is imperative that the limited private and public resources available for breeding Australian plants are used in the most cost-effective way. Our first priority, as propagators, should be to continue the

task of clonal selection from wild sources. This wild genetic resource represents our greatest tangible advantage over competitors from overseas who are working with our flora. Rapid advances in domestication of our flora have been made by the judicious integration of conventional breeding and the new biotechnology techniques. Merv Turner's work with *Anigozanthos* (1), and Greg Lamont's work with *Chamelaucium* provide outstanding models of how this can be achieved.

Finally, it is my hope that this presentation of the late Merv Turner's work will serve as a model and an inspiration to those interested in the horticultural development of our wonderful flora.

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1. Stewart, A. 1987. Some commercial applications for plant tissue culture in Australia. *Search* 18, 130–132.
2. Watkins, P. A. 1983. Kangaroo Paws. *Australian Horticulture* 81(8), 27–30.

STOCK PLANT MANAGEMENT

TONY CUPITT

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Glenorie, New South Wales 2157

My experience as a production manager in a large container nursery showed me the need for an area to be put aside for stock plants to be managed efficiently for large scale cutting production.

The main reasons for having stock plants are to:

a. Obtain an increased strike rate in less time.
b. Obtain large quantities of favourable wood.
c. Increase efficiency in the ease and speed of collecting cuttings.
d. Improve convenience and cut down travelling time.
e. Ensure the early introduction of new cultivars thus discarding inferior forms.
f. Ensure accurate labelling of plants from which cuttings are taken—cuttings are always taken from accurately labelled plants.

If stock plants are regularly replaced with stock which have been hygienically grown and have good vigour and juvenility, high strike rates will follow.

Stock plants should be controlled and managed by the propa-

task of clonal selection from wild sources. This wild genetic resource represents our greatest tangible advantage over competitors from overseas who are working with our flora. Rapid advances in domestication of our flora have been made by the judicious integration of conventional breeding and the new biotechnology techniques. Merv Turner's work with *Anigozanthos* (1), and Greg Lamont's work with *Chamelaucium* provide outstanding models of how this can be achieved.

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Stock plants should be controlled and managed by the propa-

gator, who can appoint one person to be responsible for the cultural needs of the plants.

There are four main methods of obtaining cutting material.

1. *Cuttings from container or open ground production crops.* The "growing on" stages can provide an excellent source of young cutting material. The cultural practices of watering, pruning, and spraying are regularly carried out on the production crop. No extra space is required in another area of the nursery. Good supervision of staff taking cuttings is vital to avoid mixing species and cultivars with similar foliage. Clear and permanent marking of crops is essential. It is very important to prevent the recycling of pests and diseases through the propagation stages if they have not been properly controlled in the stock plants. Care must be taken when taking cuttings and pruning these plants as inexperience in this area can ruin a crop for sale if sufficient growth cannot be refurnished in time.

The maintenance of a specimen plant of each line grown is a good idea to ensure that clonal integrity is maintained, and, if changes are noticed, to replace stock plants with the original type of cultivar.

2. *Cuttings obtained from permanent stock plants in the open ground without overhead protection.* This is the best system as the major source of cuttings, provided sufficient land is available; however extra labour is required to manage these plants. The advantages of this system are:

a. Greater opportunity to keep the plants correctly named as the propagator can return to the initial clonal material when cuttings are required.
b. Unskilled labour, properly supervised, can often be used to collect the cutting material.
c. The uniform growth of cutting material is encouraged as systematic pruning, fertilizing, pesticide application and removal of cutting material can be predicted. Uniform cuttings mean less grading before sticking, more even rooting, and an improved quality plant for sale.

It is relatively easy to "manipulate" the plants to improve the number of cuttings at the desired stage of growth by using specific pruning methods. These include:

a. Stooling of all shoots to ground level to obtain long canes for standards, or thick wood for hardwood cuttings or just to rejuvenate the old plant.
b. Heavy annual pruning to a foundation framework.
c. Tip pruning—annual winter, spring or summer pruning of all shoots to half their length. Sometimes two or three prunings are carried out to control growth and form multi-branched cutting material.
d. Replacement procedures which involve shoots from the base of

the plant being removed every three to four years allowing younger shoots to act as replacements.

e. Shearing of growth to remove all shoots just below the previous season's growth. This is useful for plants which produce large numbers of annual shoots, e.g. *Berberis, Photinia, Cotoneaster,* and some conifers grown as hedges.

There are some fundamental practices that need to be carried out whichever method is used:—

- Removal of all diseased and dead material. The crown of stool plants and the framework of heavily pruned plants must be checked for canker and stem decay.
- Removal of stems with foliage that have reverted from true variegation. e.g. *Elaeagnus pungens* 'Maculata'. This will discourage clonal variability.
- Removal of flower buds on plants such as *Polygala* to encourage vegetative growth.
- Removal of all prunings from the vicinity of plants to discourage infection of the stock plants from disease.

Open ground stock plant production requires the keeping of accurate records on the performance of the stock plants and helps in the determination of when their replacement is required.

Much thought needs to be given to the detailed planning of the open ground stockbeds. These must include:—

a. The number of stock plants needed to fulfill your cutting requirements, a plan of the bed, and location of species, plus the source of your clonal material and the date it was obtained.

b. Careful site preparation which must ensure that the site is not a frost pocket. Vermin, such as rabbits, must be excluded by adequate fencing. Windbreaks must be established if the plants need to be protected from damaging winds. Irrigation may be necessary to provide water and fertilizer. Sub-soil ploughing may be beneficial to break up hard soils, and organic matter can be added to improve soil structure; pH should be checked to ensure that it is correct for the plants being grown.

c. The design and layout of the stock plant area. Rows should be north/south to improve light distribution to all plants. Plants of similar growth habits should be grouped together, but adequate spacings should be allowed for all plants.
e.g. Vigorous plants—1.8–2.0m
Medium plants —0.9–1.2m
Slow plants —0.7–0.9m

Sufficient space should be allowed between different cultivars in a row so that labels can be clearly seen when collecting cuttings.

Cultivars of similar foliage should be separated by plants of different colour or habit where applicable.

Other cultural practices are necessary to ensure healthy stock

plants. These include:

a. *Weed control.* This can be achieved by cultivation using a rotary hoe, or by hand tools; chemical means using weedicides such as Roundup or Tryquat; or by the use of black plastic or other weed mats.
b. *Pest and disease control.* Soil fumigation prior to planting can reduce weed and disease problems initially. A commercial company specializing in large scale fumigation should be used if disease problems are to be controlled by this method. Routine spraying should be conducted on a regular basis to control pests and diseases. Regular inspections of plants with a ×10 hand lens should be carried out to determine the presence of some smaller pests. When there is a sudden build up of localized pests such as aphids or red spider mite "trouble-shooting" spraying should be used.

3. *Cuttings obtained from permanent stockplants in the open ground with overhead protection.* An effective method for establishing stock plants is to house them in a glasshouse, polythene structure, or shadehouse. This gives protection to soft foliage in summer and winter. These structures can lengthen the growing season and produce more growth for cuttings, especially for climbers and semi-hardy shrubs.

4. *Container-grown stockplants under protection.* This method provides more flexibility to a smaller nursery growing a wide range of plants. It is much easier to discard old and diseased plants. This method can act as a "back up" to open ground stock plants if there are problems with irrigation or pests and diseases. It can provide a source of cuttings four to six weeks earlier than open ground plants, e.g. azaleas, camellias, and clematis. During our very hot summer I have noted improved strike rates with *Grevillea* 'Robyn Gordon' and daphne when grown under shade. Direct sunshine can sometimes lead to desiccation of tissues, damage, and disease leading to a reduced strike rate.

AUSTRALIAN ENDANGERED SPECIES

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It is now 200 years since the first white settlement in Australia and in recent years we have been taking stock of our natural resources, and starting to wonder what will be left for the next two hundred years.

The Australian landscape has been radically altered over the years, and now in many regions there is very little surviving of the original vegetation. Some of the major events which have affected the environment include the establishment of the sheep industry, massive development in wheat farming, economic depressions, drought, and the introduction of the rabbit (1). More recent events include harvesting forests for wood chips, strip mining, and the destruction of rainforests.

Since the mid-1970's Botanic Gardens have become aware of the need to be involved in the conservation of species. The International Union for Conservation of Natural Resources was responsible for early initiatives in this area producing the red data books, which list rare, vulnerable, and endangered species.

In Australia there are now 3317 species listed on the rare or threatened list (2) this is made up of:

222 Endangered species
853 Vulnerable species
1371 Rare species
811 Poorly known species now suspected of being threatened

There are also 131 species that are presumed to have become extinct in the wild.

The Australian National Botanic Gardens has concentrated its main effort on conserving those species in the Endangered category. These are the species at the highest risk and are likely to become extinct during the next 1 to 2 decades (1). The aim is to maintain viable collections of Endangered species and to do this we attempt to grow 5 clones of each species. Where there is more than one population of a species an attempt is made to grow 5 clones from each population. To ensure that individual clones are not lost, at least 3 replicates of each clone are grown.

The collection and cultivation of Endangered species is expensive as it requires considerable time and effort and our funding for field work is limited. As a result efforts so far have been confined to those species that are in the southeastern part of Australia.

Some of the species worked on over the past 2 years are:—

(1). *Acacia pubescens* (Vent.) R. Br., a bushy shrub 1 to 3 meters high, formerly known to occur in small populations to the west of

Sydney and in the lower Blue Mountains. Many of its original sites are now covered by houses—a freeway was recently built through what was thought to be one of the last stands of this species. Our field work however, has shown that this species still occurs in at least two other areas with over 1000 plants in each area. This species has soft blue-green leaves and is a most attractive garden plant.

Propagation: It is easily propagated from seed treated with boiling water. Seed is not always available, as seed set may be erratic. It can also be propagated from cuttings using 4000 ppm IBA as a liquid dip. As this species often suckers profusely it is possible that division could also be used as a propagation method.

(2). *Grevillea iaspicula* McGillivray is a spreading rounded shrub 1.5 to 3 m high with red and white pendulous flowers. This species was initially known to consist of 15 plants confined to three small limestone outcrops in the Wee Jasper area of southern NSW. Further searches have located two other populations containing nearly 500 plants. In all cases the species is confined to limestone soils.

Despite doing best on alkaline soils, plants adapt readily to a range of soil types. With some light pruning this species performs well and is useful for attracting honeyeating birds to the garden.

Propagation: It is readily grown from cuttings taken in late summer and autumn. 2000 ppm IBA applied as a liquid dip gives excellent results.

(3) *Haloragodendron lucasii* (Maid. & Betche) Orchard. This small shrub was thought to be extinct, as it had not been seen for nearly 60 years. A chance find located a small population of 200 plants growing on sandstone in the Ku-ring-gai area near Sydney. This species is of limited horticultural appeal and is likely to be grown only by native plant enthusiasts.

Propagation: Plants of this species have been observed to layer naturally. It is also very easy to strike from cuttings.

(4). *Phyllota humifusa* A. Cunn. ex Benth, is a prostrate shrub 15 cm high by 2 m across with orange/red pea shaped flowers. While this species is common at the two known localities it may never have been very widespread. It occurs on deep yellow sands in the Penrose-Mittagong area 100 km from Sydney. This attractive species has the potential to be a very useful ground cover.

Propagation: It can be grown from cuttings using 500/500 ppm IBA/NAA as a liquid dip. It is expected that seed would also germinate readily, but to date no seed collections have been made.

(5) *Pimelia spicata* R. Br. is a small spreading shrub to 50 cm high with white flowers. Although formerly quite widespread, it now appears to be very restricted, with only two small populations at Narellan and Shellharbour. There are approximately 200 plants in one location, 15 in the other. Interestingly, these two habitats

differ markedly in soil and vegetation types and distance from the sea. This species thrives in cultivation and performs well as a pot plant. It has a persistent carrot-like tap root which is unusual for this genus.

Propagation: It can be grown from cuttings using 500/500 ppm IBA/NAA as a liquid dip.

(6). *Pomaderris brunnea* Wakefield, is an erect shrub to 3 m tall that occurs in the Picton area. The small known populations were thought to be endangered by mining operations but further searches have found over 700 plants growing in a sanctuary. As with many species of *Pomaderris, P. brunnea* is of limited horticultural appeal.

Propagation: This is a very difficult species to grow from cuttings. Our best results have been a 5% strike using 500/500 ppm IBA/NAA as a liquid dip. Propagation from seed has not yet been attempted.

(7) *Prostanthera stricta* R. T. Bak., is a bushy shrub 1 to 2 m high with mauve/violet flowers. Previously only known from one locality at Ilford and last collected in the early 1950's, this species has been relocated at Ilford in reasonable quantities. It grows mainly along the edge of cliff lines in this area. This desirable species, along with most of the *Prostanthera* genus, is susceptible to root rot and requires well drained soil or grafting onto resistant rootstocks for best results.

Propagation: It grows very easily from cuttings using 1000/300 ppm IBA/NAA as a liquid dip.

(8). *Swainsona recta* A. T. Lee is a small perennial herb that grows from 15 to 30 cm high and has very attractive purple pea-shaped flowers. Two widespread populations of this species were previously known, one in Canberra (5 plants) and the other at Wellington (approx. 50 plants). A further 200 plants have since been found growing along a railway line close to Canberra. It is rather whispy and inconspicuous when not in flower and may die back to a perennial rootstock during winter. Slugs and snails find this species very palatable in the nursery and grazing by livestock is thought to be the main reason for decline in the wild.

Propagation: It grows well from seed but is difficult to maintain in cultivation.

(9). *Syzgium paniculatum* Gaertn., is a medium tree to 15 to 20 m with ornamental magenta coloured fruit. Although it is frequently seen in the nursery trade it is quite rare in the wild. A number of small populations are known, one near Kurnell (20 trees) and the other at Jervis Bay (14 trees). This species is quite fast growing in mild climates and looks quite attractive when in fruit.

Propagation: It can be grown from either seed or cuttings. Seed should be sown soon after harvest for best results. Insect larvae often cause severe damage in wild collected seed.

While not all threatened species are horticultural subjects it is hoped that all can be saved from extinction. Some difficult-to-grow species may only be conserved in their natural habitats, others can be easily maintained in cultivation.

It is important that every effort be made to save these plants as most have not been assessed for their potential. Some may be important sources of pharmaceuticals. Others closely related to crop plants may be useful for breeding purposes. Once gone, however, they cannot be replaced.

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INTEGRATED PEST MANAGEMENT WITH REFERENCE TO PLANT PROPAGATION

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INTRODUCTION

Since the large scale production of synthetic pesticides following World War II, the most common approach to pest control in agriculture and horticulture has been prophylactic application of chemicals, based on potential insect and disease threats. Recent increased awareness of the limitations and side effects of pesticides is causing this attitude to be rethought. Problems associated with pesticide use include widespread resistance in insect and mite pests and pathogens, elevation of organisms to pest status through elimination of natural suppressive agents, major environmental damage from some pesticides, and human health and safety concerns (in particular mutagenic effects of pesticides). With a number of crop plants, phytotoxic injury from pesticides is a major problem, and there is evidence that regular pesticide use may suppress plant growth (15). In addition, while the presence of pests constitutes barriers to international trade, so do unacceptable levels of pesticide residues.

The rate at which new pesticides are being developed is not able to keep pace with their removal from the market place. Two recent Australian examples are the withdrawal of the fungicide Captan, and the miticide Cyhexatin. Pesticide companies realize that a more

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The rate at which new pesticides are being developed is not able to keep pace with their removal from the market place. Two recent Australian examples are the withdrawal of the fungicide Captan, and the miticide Cyhexatin. Pesticide companies realize that a more

rational use is essential to ensure longevity of other currently registered pesticides.

The response to the above is a shift from a chemical basis of pest control to a biological one, where emphasis is placed on management of pests by integrating a number of control methods. Integrated pest management (IPM) is defined by FAO as a "system that, in the context of the associated environment and population dynamics of the pest species, utilizes all suitable techniques in a compatible manner, and maintains the pest populations at levels below those causing economic injury" (14). Such an approach is dynamic, and involves continuous monitoring and evaluation, intervening with pesticides only when necessary. In practice, most successful IPM schemes have been developed in perennial plantation crops (e.g. fruit trees), because of their long term ecological stability. However, excellent results have also been obtained in nurseries and protected crops (15).

This paper discusses integrated pest management strategies with potential in nurseries and plant propagation. Limits to widespread adoption of IPM are also discussed.

COMPONENTS OF IPM PROGRAMMES

Insect and Mite Pests

Biological Control. This has been the major alternative strategy to pesticide use for insect control, and has been incorporated into most IPM programmes. Biological control encourages or augments natural organisms such as predators, parasites, pathogens and competitors to suppress pest populations or their activity. With ornamental and nursery plants, the most effective method has been the introduction of mass produced biological control agents. European and North American programmes have been directed at glasshouse pests with high reproductive rates, such as spider mites, white flies, aphids, thrips and scale insects.

The most spectacular and widespread programme has been control of spider mites, *Tetranychus* spp., by the phytoseiid predatory mite *Phytoseiulus persimilis* (15). Research in Australia by C.S.I.R.O., several state Departments of Agriculture, and private companies has led to commercial production of this agent, which is now available from HAWKAID INTEGRATED PEST MANAGEMENT SERVICE, RICHMOND, N.S.W. and BIO-CONTROL PTY. LTD., WARWICK, QUEENSLAND. The former company is working closely with the N.S.W. Department of Agriculture, and additionally provides a monitoring and technical service to participants in the programme (27). One important area of ongoing research is the testing of pesticides for compatibility with predatory mite use in protected structures (Goodwin, S., personal communication).

Other successful biological control campaigns in overseas

glasshouse crops, using commercially available predators and parasites, are:

- Whitefly, *Trialeurodes vaporariorum,* by the parasite *Encarsia formosa* (29).
- Leafminers, *Liriomyza* spp., by the parasites, *Opius pallipes, Dacnusa* spp. and *Diglyphus isgea* (21).
- Aphids, particularly *Myzus persicae* and *Aphis gossypii,* by parasites of the families *Aphidiidae* and *Aphelinidae* (25).
- Thrips, *T. tabaci,* by the predatory mites, *Amblyseius mackenziei* and *A. cucumeris* (22).
- Mealybugs, *Pseudococcidae,* with the predatory ladybird, *Cryptolaemus montrouzieri,* and the parasite, *Leptomastix dactylopii* (7, 8).
- California redscale, *Aonidiella aurantii,* by the parasites *Aphytis melinus* and *A. lingnanensis* (9).

A number of insect pathogens have been tested for biological control, but few have been commercialized. The most widespread is the spore-forming bacterium, *Bacillus thuringiensis,* the common strain of which is specific for control of lepidopterous pests. Other strains with different specificity are being developed. The commercial use of strains of the fungus *Verticillium lecanii* for aphids, whitefly, and thrips control in European glasshouses (12), has been limited by conditions of temperature and relative humidity required for its success (Scopes, personal communication). Insect viruses have also had limited commercial success. Nuclear polyhedrosis virus for budworm, *Heliothis* spp., control is registered in Australia and U.S.A.

Insect nematodes have been successfully trialled in Australia and elsewhere in horticultural crops. Examples include use of *Steinernema bibionis* to control currant borer, *Synanthedon tipuliformis,* in blackcurrant cuttings, *Heterorhabditis heliothidis* to control black vine weevil, *Otiorhynchus sulcatus,* in potted plants in commercial nurseries in Tasmania (3) and California (30) and control of citrus root weevil in Cuban nurseries by *Neoaplectana* P2M (20).

Lures and Traps. Lures and traps (including food lures, sticky traps, coloured traps, light traps, and pheromones) have been used for many years in insect pest control with limited success. Their chief benefit has been their ability to monitor pest populations to enable accurate decision-making (24). The incorporation of pesticides into food lures (such as insect, mollusc, and rodent baits) has been more effective in direct pest control.

The recent successful use of pheromones to reduce pest damage by disrupting mating in oriental fruit moth, *Cydia molesta* (17), gives a model for further development of this technique.

Resistant/Tolerant Cultivars. This method has not been greatly explored for insect control. The two most significant examples are

woolly aphid resistant apple cultivars and the use of American grape rootstocks in Europe and Australia for *Phylloxera* aphid (14). The economic viability of further developments in this area relies on ease of incorporation of resistant genes by genetic engineering.

Pathogens

Biological Control. Biological control has not received the same degree of attention for control of diseases as it has for insects or weeds. Recent interest centres around control of soil- and media-borne diseases (4). The aim is to reduce pathogen numbers or their ability to produce disease by antibiosis and competition (2, 18). This is achieved by maintaining or encouraging natural bacterial and fungal antagonists through cultural practices such as manipulating media composition, composting and pasteurizing or by the addition of specific organisms into the media or on to plant tissues.

Media in which peatmoss is the only organic component are generally not suppressive, and are therefore conducive to pathogen colonization and spread (13). Composted plant materials, particularly hardwoods, are more suppressive for damping-off diseases such as *Pythium*, *Rhizoctonia*, and *Fusarium* (32). Hoitink and Fahy (13) indicate compost quality may be the key factor in determining success in suppression of soil-borne diseases.

Inoculation of previously-treated soil or media with specific organisms has shown some spectacular results. Broadbent et al. (5), using *Bacillus* spp., and Chang et al. (6), using *Trichoderma harzianum*, both reported increase in growth rate in a range of bedding plants.

Plant surface inoculation with the antagonistic organism *Agrobacterium radiobacter* has been commercially successful in controlling crown gall, *A. tumefaciens*, in plants of the family *Rosaceae* (11, 19). Other examples include inoculation of fresh cut surfaces of carnation with *B. subtilis* to prevent disease caused by *Fusarium roseum* (1), control of *Fusarium oxysporium* by inoculating with *F. solani* on cut sweet potato, and biological control of rusts (28) and fire blight, *Erwinia amylovora* (16) on ornamentals.

Cross-protection is the ability of mild strains of a disease to prevent the deleterious effects of more severe strains. It has been used successfully for control of several virus diseases. With citrus tristeza virus, inoculating with mild isolates imparts a high degree of resistance. This technique, initiated in Brazil is now used worldwide. Other examples include woodiness virus in passionfruit, pawpaw ringspot in Hawaii and Taiwan, sun blotch in avocado (26) and stone and pome fruit viruses, especially in U.S.A. There is evidence that cross protection may break down with time (31), and while cross protection may be suited to specific crops, use of disease-resistant annual plants, such as TMV resistant tomatoes, is more economic.

Resistant cultivars. The majority of modern plant breeding pro-

grammes include selection for resistance to diseases, particularly air-borne fungi, viruses, and soil-borne pathogens. The use of disease-resistant rootstocks for controlling soil-borne diseases in perennial crops such as citrus, stone fruit, and avocado is widespread.

Modification of Environment. Many bacteria and fungi thrive under the high humidity conditions found in poorly ventilated nursery structures. Improved design of protective structures should significantly reduce disease incidence, thereby reducing the need for other control measures. Modification of the soil/media environment to reduce disease outbreaks has been discussed previously.

Cultural Procedures. Sanitation procedures, such as disinfestation of structures, equipment and media by chemicals, heat, or irradiation are likely to reduce carry-over of pests. Other operations include roguing and destruction of plants with disease symptoms, quarantining of new plant material, restricting entry of personnel, chlorination of water supply, rotation of plant species, and timing of cultural practices to avoid pests. When incorporated into IPM programmes, these further reduce the need for other control methods.

Use of Pesticides

Intervention with pesticides is an integral part of many IPM programmes. This may be done with reduced rates of application when it is desired to temporarily redress the pest/biological control agent imbalance.

The selection of pesticides which minimally disrupt other strategies, particularly biological control, is critical. More research is needed to determine non-toxic effects of pesticides on biological control agents (such as reduced fecundity), and also on pesticide residue activity in protected environments.

DEVELOPMENT OF IPM PROGRAMMES IN PROPAGATED CROPS

Integrated pest management programmes may be considered to be "all things to all men" (23), where each programme developed can be unique to that industry or enterprise. All, however, adhere to the same philosophy of understanding pest-plant-environment interactions and continuous data gathering and decision making, based on an awareness of alternative strategies and their consequences. Inherent in all programmes is a pest or damage threshold above which intervention is economically warranted. In practice, however, these economic thresholds are imprecise, often based on past experience or "gut-reaction" (33).

There are a number of factors which limit the development of IPM programmes in propagated or ornamental plants. The first is the low tolerance of pest damage. Classical biological control, for

example, is not immediate in its effects, and reduces, but does not eliminate pest incidence. A second factor is the requirement for continuous monitoring by trained staff. In large enterprises, this could be the specific personnel responsible for plant protection. Alternatively, contract monitoring by private companies may be more appropriate. In either case, the technique of monitoring based on removal of plant leaves for later examination is not feasible in ornamental plants. Another limit to IPM development is the rapid turnover and, hence, short term nature of propagated plants. Thirdly, diversity of plants in a confined area also complicates development of successful programmes.

In conclusion, the scenario of reduced pesticide availability and effectiveness will continue and, despite the limits outlined above, the need to move to integrated management of pests will become more obvious.

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PRESIDENT DENNIS CONNOR: A few years ago we met here in British Columbia and I have always thought there would be no way to top that meeting. But Bruce Macdonald has been working his very best to make it even better for us. I have always been amazed at the friendliness of the British Columbia people and how well everyone here cooperates to make us feel so welcome. Now, we are ready to start our first session of speakers:

EFFECT OF 10-HOUR PHOTOPERIOD ON *IN VITRO* ROOTING OF A DIFFICULT-TO-ROOT CROP—*PISUM SATIVUM*

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The rooting of pea cuttings has been the subject of intensive physiological research to determine the factors associated with successful rooting (1, 2). Rooting has also been a problem with tissue culture propagation of peas. Filippone (3) reported up to 82% *in vitro* rooting of peas derived from explanted shoot tips of 7-day-old seedlings. The successful medium consisted of the following constituents: Linsmaier Skoog (4) half-strength, 10% sucrose, 2 g/liter activated charcoal, and 220 mg/liter $CaCl_2$. Both activated charcoal and $CaCl_2$ were required for a high rooting percentage.

Research in our laboratory determined planting out of *in vitro* peas directly from multiplication medium was not practical because of nearly 100% mortality. Therefore, *in vitro* rooting was essential for a complete vegetative propagation system. *In vitro* rooting experiments were nonresponsive when testing varying rates of auxins, ancymidol, inorganic salts, and activated charcoal. Placing the cultures in darkness had no positive effect on rooting either. The base line of about 10% of the cultures rooting in 3 to 4 weeks remained constant with all treatments.

Our experiments verified Filippone's that the addition of Ca ion

improved the color and vigor of the shoots. We used $CaSO_4$ rather than $CACl_2$ to supply the additional calcium ions to both multiplication and rooting media. However, addition of both $CaSO_4$ and activated charcoal to the rooting medium had no effect on rooting in our pea cultures.

Additional information became available to us through several experiments. We had no problem in rooting cultures from excised pea embryos and from cultures recently explanted from young seedlings. This made us aware that juvenility was, indeed, an important factor in rooting our established pea cultures. These cultures had been explanted from 4 to 5 week-old seedlings and had been continuously cultured for over a year. In addition, these cultures had started flowering after several recultures. We were able to reduce the flowering problem by excising shoot tips and increasing the frequency of reculturing to 3-week intervals. Our standard culture room conditions were set at a 16 hours light, 8 hours dark per day. The light source was from cool white fluorescent bulbs providing a light intensity of 20 μmol/m^2/s. The culture room temperature was maintained at a constant 20°C.

An experiment was set up with a photoperiod with 10-hours light and 14-hours dark and was compared to the standard 16-hours light and 8-hours dark. The stock cultures were preconditioned for each photoperiod by increasing them for 2 recultures in their respective photoperiod environments before the rooting experiment was initiated. The rooting medium consisted of ⅓ strength Linsmaier-Skoog (4), 30% sucrose, 90 mg/liter $CaSO_4$, 2.5 mg/liter IBA, and 0.8 mg/liter NAA. The pH was adjusted to 5.7 before addition of 8 g/liter Bactoagar. The 10-hour photoperiod treatment resulted in a rooting of 80% compared to 10% in the 16-hour photoperiod.

Not only did the shorter photoperiod become essential for rooting peas, it resulted in 37% less energy requirement for lighting and also reduced energy costs for air conditioning. Some crops respond favorably to the 10-hour photoperiod for both shoot multiplication and rooting. A general growth response of cultures was longer shoots.

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BRITISH COLUMBIA'S ALPINE AND SUBALPINE FLORA WITH GARDEN POTENTIAL

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The alpine and subalpine zones of British Columbia offer not only some of the most spectacular scenery in the world, but a wide range of plants with garden potential. Many of these are known in cultivation only to the avid alpine plant enthusiasts and are not generally available commercially.

A wide range of growing conditions in these zones, depending on aspect, soil and rock types, exposure and elevation, create microhabitats for a variety of plant species. Many of these habitats can be successfully recreated at lower elevations in the Pacific Northwest, even on the wet coast. The potential for using native plants for the drier interior of the Pacific Northwest has not been realized.

The plants discussed in this paper include those true alpines as well as some from lower elevations in montane meadows. Although British Columbia's flora will be stressed, a number of plants from the Pacific Northwest or Western North America are also included. Some of the more familiar alpine plants, at least to the alpine enthusiasts, such as *Silene acaulis, Anemone* (or *Pulsatilla*) *occidentalis* and *Lewisia* species, especially *Lewisia tweedyi,* will not be discussed further, although it could be argued that even these need to be promoted to a wider market. The plants that will be discussed, alphabetically, will be those possibly less familiar to even the enthusiasts and those with some commercial potential.

The genus *Arnica* contains some of the most common species of montane and alpine plants in Western North America, where the center of distribution of the genus occurs. *Arnica cordifolia* is the most widespread species, found from montane forests to high alpine slopes. It is a rhizomatous species and thus somewhat invasive in the garden, but the bright yellow flowers heads are showy in spring and it does well in cultivation throughout the Pacific Northwest. The small var. *pumila* from high elevations is better as a garden plant for small alpine gardens, because it is less rhizomatous and of smaller stature. *Arnica gracilis* (treated in some floras as a variety of the widespread *Arnica latifolia,* but generally accepted by experts in the genus as being a good species) is a non-rhizomatous, tufted plant of scree slopes and high, rocky alpine meadows. It varies greatly in nature, with some plants or populations being much more floriferous than others. It is not difficult to maintain in

gardens in a well-drained, sunny location. Two of the other smaller arnicas which are rarely, if ever, cultivated are *Arnica louiseana* and *Arnica rydbergii*. Both of these have relatively large flowers on low plants and are ideal for rock gardens. The flower heads of the Lake Louise arnica are nodding with pale yellow ray florets. *Arnica rydbergii*, sometimes called the orange arnica has distinctly darker orange-yellow rays than other *Arnica* species, with several flowers per stem. The plants are tufted or short rhizomatous. It is difficult to maintain on the wet coast, but easier in the drier interior. The greatest problem with growing arnicas in gardens is probably a general dislike of yellow "daisies" by many gardeners.

Coptis asplenifolia is a member of the buttercup family (Ranunculaceae) with very dark green, shiny, dissected leaves. The species name comes from the leaves looking like an *Asplenium* (one of the common genera of ferns). The leaves are at least partially evergreen, forming a good ground cover in very shaded situations. Small flowers are green and usually go unnoticed. It is found in peaty soil along the coast, often in subalpine areas. It is rarely, if ever, cultivated in gardens and is not commercially available, but has great potential as a ground cover or an accent plant in shade, where the glossy leaves appear to brighten dark places in the garden.

Forming low, dense mats on high, exposed alpine slopes is *Douglasia laevigata*, a member of the Primulaceae. When the shocking pink flowers are fully out, the mats of plants are visible at great distances. It is variable in size, colour and general growth habit in nature, offering possibilities for selection of individual wild plants for cultivation. It needs a sunny, very well-drained situation on the wet coast.

Dryas species are very widespread in arctic, subarctic, and alpine situation in the Northern Hemisphere. The plumed, wind-borne achenes (single-seeded fruits) make them ideal subjects for colonizing roadsides and barren areas. The potential for most of the species for sunny, dry situations is great. The leaves, flowers, and seed heads are all attractive and the plants are extremely cold-tolerant.

The *Eriogonum* species, usually known as a group as wild buckwheats, are common at high elevations and in the drier parts of most of Western North America. The range of variation among the species and within species and individuals in a single population is great. Flower color varies from nearly pure white to cream, yellow, orange and pink on plants that may be very low carpets to taller shrubs. *Eriogonum umbellatum* is one of the most widespread species in the western mountains and, not unexpectedly, the most variable species. It is uncommon in cultivation and is a plant with great potential for drier interior gardens. *Eriogonum compositum*, growing naturally from Washington to California, has bright yellow

flowers held above large gray leaves on low sub-shrubs, making it one of the showiest species in the genus. It needs a well-drained, dry, sunny location and is too large for all but the largest rock gardens. It is probably best used in a shrub border or as a specimen plant in the landscape.

Much work has been done in cultivation, selection, and breeding of the European herbaceous perennial geraniums, but little has been done with our North American species. Most our geraniums are not truly alpine plants, but more often a common component of mountain meadows. At least three species, *Geranium erianthum*, *G. richardsonii* and *G. viscosissimum*, have great garden potential if good forms are selected from the wild or are bred in cultivation. *Geranium erianthum* has good foliage texture and colour as well as good blues in the flowers. *Geranium richardsonii* has good pure white flowers and *G. viscosissimum* has large bright pink-purple flowers, on quite variable-sized plants. Shorter forms with large flowers of the latter species need to be selected in the wild. All three of these species are now being cultivated and some hybridization is being done in the UBC Botanical Garden. Spontaneous hybrids between the latter two species have occurred in the Garden.

Hesperochiron pumilus is a very attractive little plant in the Hydrophyllaceae. It is found in the edges of vernal pools or other areas with winter and spring moisture, but areas that become completely dry in summer. The stemless plants produce a small rosette of spoon-shaped leaves surrounding several showy flowers with yellow centers and white petals veined with purple. The plants are not easy to grow in cultivation, but are worth the effort to keep them growing. An alpine house or bulb frame is probably the best way to grow them successfully. The fleshy underground parts decay easily if grown in summer-wet conditions.

Iliamna rivularis is a plant of moist mountain meadows below the subalpine zone. It is almost unknown in cultivation and deserves to be grown in our perennial gardens. It looks like a small hollyhock, with palmately lobed leaves and pink flowers on spikes up to 2 meters (6 feet) tall. Plant height, size of leaves, color of petals and size of flowers is variable and the most desirable of these characteristics could be selected for in nature.

Most of the montias are not of any particular value for gardens, but the creeping *Montia parvifolia* [syn. *Claytonia parvifolia*] forms attractive mats of green or often coppery foliage that is almost covered with pink flowers in late spring. It likes moist soil in a sunny or slightly shaded situation. Although it is not evergreen, the plant has potential as a ground cover for the wild garden.

The genus *Penstemon* is a very large one, especially abundant in Western North America, growing in a wide variety of habitats from high mountain and alpine meadows to dry sagebrush hillsides.

The genus contains some of our most colorful of wild flowers and a great deal of selection and breeding of some of the species, especially those from desert regions, has already been done. However, very little has been done with selection and breeding of the Pacific Northwest species. *Penstemon fruticosus, P. davidsonii* and *P. procerus* are among the variable species with garden potential that are little-known in cultivation.

Most of the *Oenothera* species in cultivation are the yellow-flowered biennial species, commonly known as evening primroses. Two Western North American species, *O. pallida* and *O. caespitosa* are white-flowered perennial species. They are difficult to grow on the wet coast, but have great potential for dry interior gardens. *Oenothera caespitosa* is stemless with a basal rosette of gray-green leaves and large, white, evening-opening flowers. *Oenothera pallida* has definite stems and the flowers are smaller.

The genus *Phlox* also contains a large number of species and hybrids that are already in cultivation, but the native, caespitose species are not often grown in our gardens. *Phlox caespitosa* is one of the common species that has flower color varying from pure white through shades of pinks, mauves and blues.

Although the great majority of the Western North American members of the large genus *Potentilla* are herbaceous perennials, only the shrubby *Potentilla fruticosa* is common in cultivation. There are many herbaceous species with great garden potential, especially *P. flabellifolia,* a plant of peaty subalpine and alpine meadows.

Silene hookeri is a delightful little herbaceous plant of dry slopes in southwestern Oregon and northern California. It is usually found in heavy clay soils derived from serpentine rocks. It is among the choicest but most difficult plants to keep in alpine gardens. The petals are variably dissected and range in color from pure white through dark pink. The roots are very slender and thread-like, with few root hairs, which is likely the reason that plants cannot be transplanted easily. Starting them from seed is the best means of propagation, but keeping the plants going is a problem. Dry summer conditions are essential for success in the garden. Seeds available from various sources listed as this plant often prove to be one of the taller European species.

Sphaeralcea is a genus of variable plants in the Malvaceae. They are often a common component of dry sagebrush hillsides and roadsides. The gray-green, lobed or dissected leaves are an attractive foil for the orange-red or pink-red flowers. Dwarfer forms are good for dry gardens, but the plants are difficult to keep growing on the wet coast.

Several shrubby members of the alpine or subalpine communities are difficult to propagate or maintain in gardens at lower elevations. Four members of the Ericaceae deserve further study to

successfully work out the propagation and cultural techniques. *Rhododendron albiflorum,* although not as showy as many of the other species or hybrids in the genus, has a subtle charm, with its white flowers late in the season in subalpine meadows and edges of high mountain forests. Usually growing with this *Rhodendron* is *Cladothamnnus pyroliflorus,* the copper bush, a variable, deciduous shrub with five-petalled, coppery-colored flowers. It has been only rarely cultivated in gardens, and like the *Rhododendron* isn't spectacular, but of interest to those gardeners who want something different. Large flowered individuals need to be selected and propagated. *Cassiope mertensiana* (white mountain heather) and *Phyllodoce empetriformis* (red mountain heather), which are superficially similar, grow together in acid, subalpine to alpine meadows and boggy areas. Although they are both available commercially to a limited extent, there is still much to be learned about propagation and culture of these two attractive native sub-shrubs.

Saving the most difficult to the last, the semi-parasitic Indian paintbrushes (*Castilleja* species) are considered difficult, if not impossible, to propagate and maintain in the garden. This is unfortunate, as they are among the showiest of our Western North American plants and a common feature in our natural landscapes, from dry sagebrush country to mountain meadows and alpine slopes. If someone can find out how to successfully cultivate them, they will be popular garden plants. Some degree of success has been achieved in the UBC Botanical Garden Native Garden, when they are transplanted with the host plant or, if seed is sown directly around known host plants. *Castilleja miniata,* the most common species, has been brought in with the host, *Heuchera cylindrica*. After a few years the paintbrushes have now naturalized and become fairly common in the garden, growing on a number of host plants.

This list of potential plants could go on. Anyone else familiar with native plants of the Pacific Northwest could come up with a list of other species, equally as long. There still remains much work to be done on selective collecting, cultivation, and breeding of native alpine and subalpine plants for our gardens.

NATIVE HERBACEOUS PERENNIALS OF THE PACIFIC NORTHWEST WORTHY OF COMMERCIAL PRODUCTION

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An estimated 3,000 native herbaceous perennial species grow in the Pacific Northwest, from Oregon into British Columbia. They grow from sea level to alpine peaks. Among them is a great diversity of form, size, color, habitat, and adaptability.

This presentation will not include plants growing at higher elevations, nor the grasses (Poaceae or Graminae), sedges (Cyperaceae), rushes (Juncaceae), the many families of water plants, nor some of the lower plant families, such as club-mosses (*Lycopodiaceae*), and selaginella (*Selaginellaceae*). But even without them, the number of Northwest native herbaceous perennials is enormous, and the potential for their use is substantial.

Relatively little use is currently made of these plants. Competition of plants from other parts of the world, especially from Eastern North America, Europe, China, and Japan, and traditional use habits are among reasons for the tardy recognition of Northwest natives. Limited interest has delayed much needed selection, breeding, and propagation of superior clones and hybrids.

Most interest in commercial production of native materials has been for the woody species. Few nursery propagation and production practices are developed for Northwest herbaceous perennials. Seeding is the best known and mostly widely practiced of propagation techniques, as discussed by a number of authors (1, 2, 4, 5, 7).

Vegetative propagation will become more important with selection of improved clones, cultivars, and hybrids. Research, experience, and information is limited on propagation of Northwest herbaceous perennials by cuttings, tissue culture, grafting, and other vegetative techniques. Division is a more common method. Few have written on vegetative propagation of these perennials (1, 5, 6, 7).

Following is a listing of a few Northwest native herbaceous perennials which merit consideration for commercial production. The multitude of species and varieties in nature suggests the possibilities to be far greater. Careful selection of better performing clones is suggested for most species. Nomenclature is according to Hitchcock and Cronquist (3), with family in parenthesis.

Anemone deltoidea Hook., western white anemone (Ranunculaceae). A nice groundcover for moist woodlands; good spring bloom of white flowers.

Aquilegia formosa Fisch., red columbine (Ranunculaceae). An adaptable red flowering columbine, unique in form; blooms best in sun with good moisture, in partial shade in warmer areas; readily self-sows and crosses with other species.

Aruncus sylvester Kostel., = *A. dioicus* (Walt.) Fern., sylvan goatsbeard (Rosaceae).

Attractive foliage and billowy floral plumes, 3 to 7 ft tall in bloom; for moist woodland or shade garden; native range extends beyond Northwest, across North America, and into Europe.

Dicentra formosa (Andr.) Walp., Pacific bleedingheart (Fumariaceae). A 12 to 18 in. high groundcover or border plant for moist shaded areas; a vigorous, attractive plant with finely cut foliage and pink to purple, or bluish lavender to white, flowers.

Disporum smithii (Hook.) Piper, fairy lantern (Liliaceae). A 1½ to 2 ft high groundcover or border plant for shaded areas, best in moist soil with added organic matter; white hanging flowers in spring, red fruits in fall.

Erigeron speciosus (Lindl.) DC., showy fleabane (Compositae). Blue to bluish lavender flowers at top of clustered 10 to 30 in. stems during several weeks in late spring and summer; good foliage, easy to grow in full sun to light shade, not invasive.

Eriophyllum lanatum (Pursh) Forbes, woolly sunflower (Compositae). Dense yellow flowers, May to August, gray tomentose foliage, 4 in. to 2 ft according to variety; best in sun, well-drained soil.

Fragaria chiloensis (L.) Duchesne, coastal strawberry (Rosaceae). Evergreen maritime groundcover only a few inches high, white flowers in spring, handsome foliage; for sunny or partially shaded moist areas.

Galium boreale L., northern bedstraw (Rubiaceae). Showy panicles of fragrant white flowers in late spring, leafy plant 10 to 30 in. tall; sun to light shade with ample moisture; native across North America.

Lupinus polyphyllus Lindl., bigleaf lupine (Leguminosae). Largest and most lush Northwest lupine, to 3 to 4 ft tall, 6 to 24 in. spikes of blue, violet, or reddish flowers; does best in open, moist areas.

Oxalis oregana Nutt., Oregon oxalis or redwood sorrel (Oxalidaceae). An aggressive groundcover for moist shaded areas, handsome foliage, white flowers in spring; botanical forma *smalliana* (Knuth) Munz, with deep rose-purple flowers and patterned leaves, is especially attractive.

Smilacina racemosa (L.) Desf., false Solomon's seal (Liliaceae). Arching stems to 3 ft tall, with panicles of often fragrant white flowers, red berries in fall; a beautiful, bold garden plant for light to rather deep shade with moisture.

Thalictrum occidentale Gray, western meadow rue (Ranunculaceae). Delicately beautiful foliaged plant, finer textured than most meadow rues, 2½ to 4 ft tall in flower; for open woodland or semi-shaded border plantings.

Vancouveria hexandra (Hook.) Morr. & Dec., inside-out flower (Berberidaceae). A foot high plant of moist shady woods, dull green hexagonal leaflets make it a most attractive plant, lacy panicles of sparse ¼ in. white flowers in spring; vigorous, can be invasive if not contained; excellent groundcover under trees, around ericaceous and other shrubs.

Many other Pacific Northwest herbaceous perennials are also worthy of consideration and should be tried. Following is a partial list.

Achlys triphylla (Smith) DC., vanillaleaf (Berberidaceae)
Actaea rubra (Ait.) Willd., western red baneberry (Ranunculaceae)
Anemone multifida Poir. var. *multifida*, Pacific anemone (Ranunculaceae)
Angelica arguta Nutt. ex T. & G., *A. canbyi* Coult. & Rose, angelica (Umbelliferae)
Armeria maritima (Mill.) Willd., thrift or sea pink (Plumbaginaceae)
Arnica cordifolia Hook., heartleaf arnica (Compositae)
Artemisia tilesii Ledeb. var. *unalascensis* Bess., Aleutian mugwort (Compositae)
Asarum caudatum Lindl., wild ginger (Aristolochiaceae)
Aster L. *spp.*, *aster (Compositae)*
Boykinia elata (Nutt.) Greene, slender boykinia (Saxifragaceae)
Cynoglossum grande Dougl., Pacific hound's tongue (Boraginaceae)
Delphinium spp., larkspur (Ranunculaceae), many forms, blue to white

Erigeron glaucus Ker-Gaul, seaside daisy (Compositae)
Eschscholzia californica Cham., California poppy (Papaveraceae)
Gaillardia aristata Pursh, gaillardia (Compositae)
Geranium oreganum Howell, western geranium (Geraniaceae)
G. viscosissimum F. & M., sticky purple geranium (Geraniaceae)
Geum triflorum Pursh var. *ciliatum* (Pursh) Fassett, prairie smoke avens (Rosaceae)
Helenium autumnale L., sneezeweed (Compositae)
Heuchera micrantha Dougl. ex Lindl., smallflowered alumroot (Saxifragaceae)
Lupinus spp., lupine (Leguminosae)
Mertensia paniculata (Ait.) G. Don var. *borealis* (Macbr.) Williams, tall bluebells (Boraginaceae)
Mimulus spp., monkeyflower (Scrophulariaceae) yellow and red forms
Montia cordifolia (Wats.) Pax & K. Hoffm., broadleaved montia (Portulacaceae)
Nothochelone nemorosa (Dougl. ex Lindl.) Straw, woodland beardtongue (Scrophulariaceae)
Oxalis suksdorfii Trel., western yellow oxalis (Oxalidaceae)
Peltiphyllum peltatum (Torr.) Engl. = *Darmera peltata* (Torr.) Voss, umbrella plant (Saxifragaceae)
Penstemon spp., penstemon (Scrophulariaceae)
Petasites frigidus Fries var. *palmatus* (Ait.) Cronq. = *P. palmatus* (Ait.) Gray, sweet coltsfoot (Compositae)
Polemonium occidentale Greene = *P. caeruleum* L. subsp. *amygdalinum* (Wherry) Munz, western polemonium (Polemoniaceae)
Potentilla gracilis Dougl. ex Hook., slender cinquefoil (Rosaceae)
P. villosa Pall. ex Pursh, villous cinquefoil (Rosaceae)
Sidalcea spp., checker mallow (Malvaceae)
Solidago spathulata DC. var. *neomexicana* (Gray) Cronq., dune goldenrod (Compositae)
Streptopus amplexifolius (L.) DC., clasping-leaved twisted-stalk (Liliaceae)
S. roseus Michx. var. *curvipes* (Vail) Fassett, rosy twisted-stalk (Liliaceae)
Tellima grandiflora (Pursh) Dougl., fringecup (Saxifragaceae)
Tolmiea menziesii (Pursh) T. & G., piggy-back plant (Saxifragaceae)
Trautvetteria carolinensis (Walt.) Vail, false bugbane (Ranunculaceae)
Trientalis latifolia Hook., western starflower (Primulaceae)
Valeriana sitchensis Bong., Sitka valerian (Valerianaceae)
Veratrum spp., false hellebore (Liliaceae)

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CALIFORNIA NATIVE PLANTS OF HORTICULTURAL VALUE

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INTRODUCTION

California is the third largest state in area in the United States, covering over 150,000 square miles. The state's topography is diverse, ranging from 276 ft. below sea level in Death Valley to 14,494 ft. above sea level at the peak of Mt. Whitney—the lowest and highest elevations in the contiguous United States.

The Sierra Nevada mountains to the east and the Pacific Ocean to the west form the natural boundaries which isolate the native flora. Plants cut off from the relatives of their family or genus evolve and adapt to different environmental conditions. The genetic make-up changes when free pollination among the taxa of the continent does not take place to homogenize the species.

California is a Mediterranean climate zone of winter rainfall, summer drought. This weather pattern creates xeriphytic plants; that is, plants that live in moist conditions while, at the same time, have physiological mechanisms to protect themselves from stress during long, dry periods, an important consideration during a time of dwindling water supply and rising water costs.

California is made up of five biotic provinces. Within the biotic provinces there are 23 plant communities according to the system of Munz and Keck. The 23 plant communities contain 5,000 taxa, 2,000 are endemic to California. Sadly, 93 are Federally listed as threatened, rare, or endangered.

The combination of numerous square miles over diverse and isolated terrain produces a plant palette of great variety. From this plant palette I have selected 15 genera of particular horticultural value. The following plants are relatively easy to propagate and tolerate a wide range of garden conditions. Most of the genera are either commercially available or, in my opinion, would be a welcome addition to any nursery's catalog.

SELECTED NATIVE PLANTS

1. *Cercis occidentalis* — Western Red Bud
   20 × 15 ft.
   Pink flowers, April
   Rocky soil, full sun. Deciduous
   Dry slopes and canyons in foothills below 3500 ft. from northern to southern California
2. *Heteromeles arbutifolia* — Toyon
   20 × 20 ft.
   Red berries, Dec.–Feb. Cream flowers, summer

Well-drained soil but adaptable
Full sun, evergreen. Can be sheared
Semi-dry brushy slopes below 4000 ft. Humboldt Co. to southern California

3. *Arctostaphylos* spp. Manzanita
   20 × 15 to 1 × 6 ft.
   White, blush-pink, pink flowers. Dec.–Feb.
   Rocky, well-drained soil, full sun
   Evergreen
   Wide spread; 117 taxa
4. *Ceanothus* spp. Wild Lilac
   20 × 20 down to 14 ft.
   Cobalt-blue flowers to pure white. March–May
   Well-drained soil, full sun
   Evergreen
   Wide-spread; 130 taxa
5. *Romneya coulteri* 'White Cloud'. Matilija Poppies
   6 × 8 ft. or more
   White flowers, May–June
   Any soil, full sun
   Cut back to ground in fall
   Rocky slopes in Southern California, coastal
6. *Baccharis pilularis* Coyote Brush
   1 to 3 × 6 ft.
   Well-drained rocky soil, full sun
   Evergreen
   Windswept dunes and headlands, coastal Monterey county to Sonoma county
7. *Fragaria* spp. ground cover Wild Strawberry
   6 in. to wide spreading
   White flowers in spring, followed by red berries
   Full sun to full shade
   Evergreen coastal and woodland
8. *Penstemon* spp. Beard Tongue
   1 to 3 × 1 to 3 ft.
   Pink, blue, lavender, red flowers, spring and summer
   Rocky well-drained soil
   Full sun, wide-spread
   Evergreen—cut back in summer
9. *Diplacus* spp. Monkey Flowers
   2 to 3 × 2 to 3 ft.
   Red, yellow, pink, white, rust, burgundy flowers
   Throughout spring
   Well-drained, rocky soil; full sun/part shade
   Evergreen. Cut back in summer
10. *Monardella macrantha* red Penny Royal
    16 × 4 in.
    Red flowers, June–Aug.
    Well-drained/high humus soil
    Full sun/part shade
    Evergreen
    Species dry slopes, 2500 to 6000 ft. from Monterey county to Baja, California mountain ranges
11. *Quercus* spp. Oak
    Deciduous and evergreen
    Large trees
    Wide-spread
12. *Heuchera* hybrids. Coral Bells

Pale pink to deep pink flowers, Jan. to May
High humus soil, dappled shade
Evergreen

13. *Aquilegia formosa* — Columbine
Yellow and salmon-pink flowers between Jan. and May
High humus, dappled shade
Evergreen. Cut off spent flowers

14. *Salvia spathacea* — Hummingbird Sage
2 × 3 ft.
Red flowers Jan. to March
High humus soil, dappled shade
Evergreen; cut off spent flowers
Grassy shaded slopes. Southern to central California

15. *Lilium humboldtii* var. *ocellatum* — Humboldt Lily
3 ft. in flower
Orange flowers, spring
Well-drained soil, light shade
Southern California

CONCLUSIONS

The native flora of California has a wealth of plant material to capture and domesticate. Native plants have a variety of textures and colors which can enhance the home garden. In addition, these plants are adapted to the special weather patterns of their areas.

It is for us to integrate the ecosystems outside our city walls with the landscape therein. We need to broaden our knowledge of cultivation of native plants so we can offer them through our nurseries. As horticulturists, let us use the vast resources from our meadows and hillsides to create landscapes unique to our regions.

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VOICE: Many of these rare species that we collect are on the endangered list. Should we be collecting, reproducing, then selling these endangered species plants?

GERALD STRALEY: You should first check with the local authorities, such as the Agricultural Extension Service for lists of endangered plants. If you can get in ahead of the bulldozers or loggers then take the plant. Use your best judgement. We can do a great service by propagating and maintaining rare plants that would otherwise become extinct. We now have a certain plant in Canada in

cultivation that doesn't exist in the wild anymore.

LINDA ABERBOM: You can also check with the Botanic Gardens. They are continually collecting information on the status of endangered species.

WILBUR BLUHM: In the Pacific Northwest the Botanic Gardens are much involved in this problem. Your question is an excellent one. I think there is an ethic here we must all subscribe to when we are working with endangered species to make sure we are not part of the problem.

MECHANICAL AND HAND METHODS FOR PROCESSING SEED

SUSAN SCHAFF

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Carpinteria, California 93013

Seed processing is a vital part of making available high quality seed. A good seed processing job can assure growers of maximum germination and true-to-type seed, plus the seed will store better. The quality of seed is improved during processing by removal of contaminants such as seeds of other crops, weed seed, inert material, etc. and by upgrading or eliminating poor quality seed.

Seed processing is aided by proper collection of material in the field. There are many methods of collecting seed but all generally produce either dry or wet material to process. The seed processor will evaluate the crop to determine the best method or methods of separating the seed from the contaminants.

An important prerequisite for efficient and effective seed cleaning of dry seed is that the seed is completely threshed and as free flowing as possible. This may require removal of awns or beards or breaking up of pods, seed heads, or seed clusters. To minimize losses of good seed, these clusters, heads, or pods must be completely broken up before the lot is cleaned. Often a debearder machine is used to complete threshing and to remove appendages or hulls that interfere with the flow of the seed.

The debearder has both rotating and stationary beater arms that are permanently fixed inside the machine. When the material is fed into the machine, the seed is rubbed by the rotating arms and is rotated toward the discharge gate. Weights can be placed on the gate to control the length of time the seed is in the debearder. Generally brittle seeds, such as *Isomeris arborea* or lupines are run through the

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machine quickly so as to prevent chipping of the seed, while a type like *Achillea tomentosa*, which consists of many fine seeds in a head, may be held in the debearder longer so the head will be thoroughly broken up and the seed released. Following this treatment, most seeds are cleaned on the air screen machine.

The air screen machine is the basic cleaner in most seed processing plants. Almost all dry seed must be cleaned by an air screen cleaner before specific separations can be attempted. Many seed lots can be satisfactorily cleaned by this machine alone. The machine size can vary from small, two screen models to large industrial cleaners with 7 or 8 screens.

As before, in order for seed to be separated, cleaned or processed, the components of the lot must differ in some physical characteristic. The air screen machine is able to make separations on the basis of the differences in both size and shape. This enables the air screen machine to use three cleaning elements:

1. Aspiration: light material is removed from the seed mass by air;

2. Scalping: good seed is dropped through openings in the screens but larger material is carried over the screen to a separate spout;

3. Grading: good seed rides over the openings in the screens and smaller particles fall through.

When the seed processor sets up the air cleaner for a particular crop, he selects the screens to use according to the size and shape of the crop seed. He may measure the seed or do test samples with screens to determine what size holes to use. While running the seed through the machine, adjustments in air are made to provide the best separation.

The seeds to be cleaned are fed from the hopper by the feed roll which can be controlled to regulate the amount of material entering the machine. They first pass through an upper air system which acts as a vacuum to remove light chaff and dust. The seed mass then falls on the top screen which performs rough scalping. The perforations in the top screen are large enough to readily drop all the crop seed but small enough to scalp off large foreign material such as stems, sticks, dirt, or weed seed. The seed that passes through the top screen is caught on the second set of screens which performs a close scalping, removing large foreign material or contaminating seeds that were small enough to pass through the top screen. Good seed that passes through the second set of screens is caught on the third set of grading screens which have perforations which drop out trash, weed seed, and dirt smaller than the crop seed. As the crop seed falls off this final set of screens, it passes through a lower air separation. This final draft of upward moving air removes light seed and trash not removed by the upper air and screens. For efficient cleaning the air draft should be strong enough to blow out a few good seeds.

After running a crop through the air screen machine, further cleaning may still be needed. The seed may be run through the air screen machine again using different screens or another type of machine may be more effective.

Undesirable seed and contaminants are often so similar to good seed in size, shape, and seed coat characteristics that the air screen cleaner cannot make an efficient separation. The undesirables may differ from the good seed in unit weight or specific gravity. For example, insect damaged seeds may retain the same dimensions but are lighter due to the interior destruction of the seed by insects. Deteriorated, moldy, or rotten seed are usually similar in size but have a lower specific gravity and thus are much lighter. Empty or sterile seed often develops normally and looks good in size and shape although the embryo has not developed and is lacking. Empty seed is always much lighter than fertile seed. Sometimes soil particles, gravel and sand are similar in size and still remain after basic cleaning. These contaminants are usually heavier than the crop seed. Contaminating crop or weed seed may be the same general size and shape but heavier or lighter because of differences in structure or composition. Contaminating seed or material differing from crop seed in unit weight or specific gravity can be separated with a specific gravity separator or gravity table.

The gravity table is a basic machine used as a finishing cleaner. It was originally developed by the mining industry to separate and grade ore. The seed industry has adopted the concept of the gravity table to separate seed and contaminants and to grade seed. It will separate seeds of the same size but different densities or seeds of the same densities but different sizes. It will not separate a mixture of sizes and densities.

The seed to be separated flows across an inclined deck mounted on incline toggles which cause an up and down motion and a backward and forward motion to occur at the same time. In addition, the deck is covered with an open mesh material through which filtered air is blown. The air floats seed so it becomes stratified into layers. The light seed rises to the top and the heavier seed settles to the bottom. The up and down motion of the deck pitches the seed up so the stratification is quickly affected. As soon as the seed is stratified, the layers separate and move in the direction dictated by their specific gravity. The back and forth motion causes the heavier seed to travel uphill because those seeds are in contact with the deck surface while the light seed flows downward on a cushion of air. As these layers move in opposite directions, they also move across the deck toward the discharge end. The result is that different grades of seed fall off the discharge end of the deck. The light seed discharges on the lowest side, while the heaviest seed discharges along the highest side. The middle is an intermediate mixture of heavy and light material, which usually contains too many good seeds to

discard so it will be recleaned to salvage the good seed.

Wet seed, such as *Asparagus densiflorus, 'Sprengeri'* or *Nandina domestica* berries are processed in a different way. The seeds need to be removed from the pulp and then further processed to a dry clean seed state. First, large debris such as leaves, sticks and stems are removed so only the berries remain. This may be done with the air screen cleaner, water flotation, fans, screens or, in the case of many palms, hand stripping.

The machine used for depulping the berries is a Dybvig seed cleaner named after the inventor, Melvin Dybvig. The Dybvig, or "Green Machine" as we call it, has a hopper, a cleaning plate, and electric motor with a chain driving variable speed sheaves. The cleaning plate is adjustable for various sizes of seeds. As the cleaning plate whirls the seeds inside the hopper, the seeds rub against each other and the sides of the hopper which removes the pulp. The addition of a stream of water washes away the pulp. Larger depulped seeds are flushed out one side spout while the pulp goes under the plate and out another spout. When smaller seeds, such as *Feijoa sellowiana* are cleaned, the seeds will go out with the pulp mass.

The water sluice is used to further separate the seed from the pulp and any other contaminates such as rocks, dirt, and other types of seeds. Our sluice box is 20 feet long with 5 areas where four wooden boards can be stacked to create dams. The seed and debris or the seed and pulp mixture is put into the sluice box. A dam is created to hold the material then water is added. The water causes the material to stratify in layers. When agitated, the pulp, light seeds and other light debris float to the top, the seeds form the middle layer, and dirt and rocks settle to the bottom. When the top board of the dam is removed, the top layer of light seed, pulp and debris float over the dam and out the sluice box. This material is allowed to flow away to debris holding ponds. The seed processor continues to agitate the material, to add water and adjust gates until the seed is allowed to flow out of the sluice box onto screens. Finally, the dirt and rocks are flushed out to the debris holding ponds. The cleaned seeds are spread on screens to dry. After drying, further processing is often necessary to remove the final bits of debris and contaminating seeds.

We have discussed five machines or methods that are used to process seeds. The nurseryman collecting his own seed may not have access to sophisticated machinery however, except for the gravity table. The principles of cleaning used by these machines can be duplicated by various hand methods.

The debearder breaks up the seed head, pods, and clusters by rubbing them against each other and the rotating arms. Individual screens can also be used to hand rub the seed heads, pods, or clusters to affect the same breaking up action. Other techniques include

stomping of dry material in a barrel or hand threshing in a sack. All methods will cause the seed mass to more easily flow and be separated.

The air screen cleaner uses both air and screens to separate seeds by size and shape. Hand held screens with various size openings can be shaken to separate seed from other material either by scalping—so the good seed falls through the screen and other debris remains on the top—or by grading, so the good seed stays on the top of the screen and the smaller debris falls through. A fan set behind catch trays can be used to aspirate the seed. As the seed mass is steadily shaken in front of the fan, the moving air carries the material. The heavy seed and stones will fall in the tray closest to the fan. The next tray will be a mixture of good seed, light seed, and some heavier debris.

The Dybvig cleaner depulps fruit by rubbing the berries against each other and the cleaner. Fruit can also be depulped by rubbing the berries against a screen or by placing the wet fruit in a container and stomping. We use this method in cases where we feel the Dybvig is too aggressive and will damage the seed.

The water sluice is used to stratify and separate seed from debris and light seed as well as heavy dirt and stones. Putting the seed mass in a container, adding water, stirring, and then rocking the container will cause the same stratification. The components will settle in layers. The light seed and light contaminants will float to the top and can be either scooped or poured off. The seed can be poured onto screens and the sediment discarded.

In conclusion, expert seed processing improves the quality of seed for storage and for the grower. We have discussed only some of the methods and machines available. There are many more that can be used but all are dependent on the skill and knowledge of the seed processor who is constantly challenged by his craft.

PROPAGATION OF *ENSETE VENTRICOSUM* 'MAURELII' AT MONROVIA NURSERY COMPANY

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Ensete ventricosum, or the Abyssinian banana, is a palm-like plant which is actually an evergreen herbaceous perennial—one of the largest. The genus consists of about seven species. The apparent trunk is actually a stalk or pseudostem made up of leaf bases. The true stem begins as an underground "corm" which grows up through the center of the stalk, eventually producing the terminal inflorescense which bears the fruit. The flowers are unisexual with the flower parts of one sex in each bloom being non-functional. The female flowers are located at the base of the inflorescense.

Ensete is a member of the Musaceae family, which also includes *Strelitza*, *Ravonala*, *Heliconia*, and *Musa* (the edible banana). Abyssinian bananas were usually listed with *Musa* until about 30 years ago. They differ from *Musa* in that they do not have rhizomes (produce no natural offsets), have much larger seed (up to 1 in. in diameter), and have some technical differences in their pollen. The fruits of *Ensete* are usually only 2 to 3 in. in length, dry, and inedible. In both *Ensete* and *Musa*, each stem flowers and produces fruit only once; thereafter the stem dies. For most *Ensete*, this takes place after about five years.

Over thirty years ago, David Barry of California Jungle Gardens introduced a red leaf form which he called *Ensete ventricosum* 'Maurelii'. 'Maurelii' is a dramatic looking plant which can be used as a container or landscape specimen anywhere the temperature does not drop below 30°F.

Since *Ensete* does not produce offsets, and since this red form reportedly does not set seed (which may or may not produce red progeny), another means of propagation needed to be devised. It has been reported that the natives had developed a means of forcing shoot growth from the stumps, but I have no further information on this. At Monrovia Nursery, I have traced the propagation of *Ensete ventricosum* 'Maurelii' back to the early 60's when Conrad Skimina began to produce them in much the same manner as I will discuss. What I will describe here is the method we now use to induce and root shoots from stumps of large plants.

We grow stock plants in #15 containers for one year. During December or January, these plants are cut off at about one foot above the soil line. All of the remaining leaf bases are then carefully peeled away exposing the stump ("corm"), which is normally 6 to 8 in. in diameter. The center portion of this stump is then removed

with a knife, eliminating the growing point. The plants are then placed in a warm greenhouse with a 68°F night temperature.

After about five weeks, a ring of callus tissue forms, grows, and eventually produces protocorm-like buds which develop into plantlets or shoots. When these shoots are 5 to 6 in. in height, they can be removed with a knife and rooted directly into 2 in. pots. A small amount of callus tissue is removed with each shoot. The 2 in. pots are placed on a greenhouse bench and hand misted (3 to 4 times per day) until rooting occurs (3 to 4 weeks). No hormone is necessary. This process is repeated as long as the stump continues to produce shoots. We normally can continue removing shoots until about May when the stump finally weakens and dies. Approximately 100 to 150 plantlets may be obtained from each stump.

A similar method was reported in the IPPS Proceedings, Volume 27 by Donal Duthie (1). Her technique involved barerooting the stumps and packing them in containers of sphagnum moss.

The major problem with this method is scheduling. We would like to have the plants saleable in #1's by May; however, these plants do not "make" until about July in #1's and September in #5's. For this reason, we are working on tissue culturing *Ensete ventricosum* 'Maurelii' but are not ready to report on that today, except to say that it looks very promising.

LITERATURE CITED

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PROPAGATING WESTERN CANADIAN NATIVE PLANTS IN POLYETHYLENE GREENHOUSES

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The use of native plants in western Canada has increased dramatically over the last five years. Not only has the number of plants being demanded increased but the species that are being asked for has broadened. The increase in the number of species being sought has caused a reassessment of the cultural conditions under which these plants are grown.

We are presently growing in excess of 100 species of native plants. These plants include alpine perennials, xerophytic plants from the dry lands, and species from West Coast rain forests. The variety of plants demands close assessment and control of the cultural conditions under which they are managed in the nursery.

CULTURAL CONDITIONS

The use of polyethylene greenhouses is the most common method of production of plants in Western Canada. This practice has therefore found its way into the growing of native plant material. Under greenhouse conditions the important cultural conditions to be addressed are: temperature, media, fertilization, water regime, shade requirements, and soil pH.

Temperature Control. Most of the polyethylene greenhouses control temperature by the use of side vents that can be manually rolled up and down. A more expensive method is the use of cooling fans on the end of the houses. Unfortunately, it is usually difficult to top vent poly houses therefore convection cooling is difficult.

Due to the sensitivity of some species of natives to high temperatures it is desirable to use automatic cooling fans whenever economically feasible. An example would be the production of *Cornus canadensis;* this species has very negative responses to excessive temperatures that are often experienced for brief periods during partially sunny days. On these days the manual rolling up and down of side vents in impractical and often house temperatures become excessive. However, if fans are used then moderate temperatures can be maintained.

Species, such as *Gaultheria shallon,* show very little rooting unless the temperature is less than 20°C. It is, therefore, imperative to have the ability to either vent or shade houses for the growth of these plants. There are also a number of western Canadian natives that need relatively high heat to enhance their growth. These species come from the hot, dry interior regions of British Columbia

and respond best to relatively hot and dry conditions. Examples of these are *Amelanchier alnifolia, Pachistima myrsinites, Rosa woodsii,* and many others. These plants need relatively hot temperatures and well drained media to maximize growth.

Soil Media. The customizing of soil media is critical for the production of native plants. Native plants have not been selected for their ability to grow under nursery conditions and they react very quickly to foreign media conditions. Since there is such a wide range of conditions that these plants come from there is a need for a wide number of media mixes. In general the plants can be divided into: wetland plants, dryland plants, and moisture-loving, but needing well-drained mixes.

Within the above media requirements there is variations around soil pH and fertilization regimes, but three general mixes will usually suffice. Depending on the availability of material one can vary the quantity of components, such as peat, pumice, perlite, bark, etc. to obtain the appropriate moisture-holding characteristics.

It has been found that if the medium is not suited to the plants there is elevated occurrences of root fungal diseases in those plants requiring dry or well drained mixes. In particular, we have found that *Cornus canadensis, Gaultheria shallon, Penstemon fruticosus,* and *Paxistima myrsinites* are very prone to root rot.

Fertilization. Most native plants in nature grow in relatively low nutrient conditions compared to the normal horticultural practices. They also have inputs of these nutrients at specific times of the year. For these reasons we have found that many native plants are difficult to grow using slow-release fertilizers incorporated into the mix. Also there are very specific nutrient needs by various species of native plants. For this reason it is recommended that the use of liquid fertilizers be considered and that their application be based on a schedule of monitoring and analyses.

A prime example of this is the production of *Gaultheria shallon*. This species has not responded well to slow-release fertilizers, which tend to release at high temperatures and cause severe root burn. Since this plant has its most significant growth at temperatures less than 20°C, we liquid feed when the temperatures are appropriate.

Shade Requirements. A large number of the most interesting native plants are shade-requiring plants. Examples of these are *Vaccinium ovatum, Vaccinium parvifolium, Mahonia nervosa, Linnaea borealis, Acer circinatum,* and many native ferns. Although these plants will grow under full sun conditions, their growth characteristics and vigor are greatly increased when grown under partial shade. In general one can extrapolate from the natural conditions of shade to the optimum nursery conditions.

Irrigation Requirements. Integrated into all the above discus-

sion is the water requirements of native species. Due to the wide variation in species these requirements are extremely varied. It is, however, critical to integrate the watering, fertilization, and temperature control into a functional system. Due to the wide variation in requirements and in the specificity of soil media, irrigation of natives for optimal development is difficult. Our experience has led to the belief that the use of small greenhouses with each having its own water and temperature regime is the most effective means of controlling this variable.

CONCLUSIONS

The production of native plants under greenhouse conditions does not vary greatly from that of normal horticultural species. The greatest problems are in the lack of good information on the cultural characteristics of many of the species. This is compounded by the fact that there is wide variation, both inter and intra species. Under normal horticultural conditions most of the plants grown have undergone considerable selection procedures that have tended to eliminate most of the variability within species, and most have been selected for some ease of propagation and growth.

With the variation in native plants and rather stringent culture characteristics of many of these plants it is imperative to have very strict control of the greenhouse conditions. In particular, the use of a number of smaller greenhouses each having very specific conditions is recommended. Within each house all plants grown should be in the same soil medium and have the same fertilization, temperature and irrigation requirements.

DON DILLON: A question for Bruce McTavish. You mentioned using a liquid fertilizer. How do you apply it?

BRUCE McTAVISH: We have tried varying the percentages of N P K, depending on the growing season, without getting high quantities of nitrogen late in the season, but increasing the amount of phosphorus. We just have a large bucket we move around in the system to add materials to our movable booms or the overhead sprinklers.

VOICE: There was a question about liverwort control. We found Physan to give good control as a drench. Surflan as an underbed spray will prevent rooting into the gravel.

ROOTED CUTTINGS IN BRITISH COLUMBIA'S TREE IMPROVEMENT PROGRAM

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Rooted cuttings are being increasingly used in tree improvement and reforestation programs in British Columbia. Present uses include: 1) an alternative to grafting for cloning selected parent trees for seed orchards and clone banks; 2) a research tool for nursery and field trials to control genetic variability; 3) an alternative to seedlings for reforestation; 4) a means for bulking-up genetically improved seed; and 5) clonal forestry (testing, selection, and deployment of clones). Projects aimed at developing and using these techniques are established in British Columbia.

Cloning parent tree selections. Rooted cuttings have been used in the establishment of British Columbia's seed orchards and clone banks as an alternative to grafting. Cloning of first generation parent tree selections, which were mostly over 60 years old, was usually done by grafting. However, rooted cuttings were used where grafting techniques had not yet been developed.

Graft incompatability is a serious problem with coastal Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii;* however, rooting of cuttings from old trees is also unreliable (1). Second generation parent tree selections for the coastal Douglas-fir tree improvement program are from 12- to 15-year-old trees and a research project to investigate the use of rooted cuttings from these younger selections is being carried out at the Cowichan Lake Research Station.

Research tool. The use of clones for forest research trials can increase the efficiency of the trial by controlling genetic variability, and increase the precision of genetic information (2). However, before clones can be used for such trials, it is important that reliable cloning techniques are developed in order to minimize within-clone variation due to "c"-effects, and to establish that rooted cuttings exhibit similar growth rate and form as seedlings. Current research projects with Sitka spruce (*Picea sitchensis* (Bong.) Carr.) (7), white spruce (*Picea glauca* (Moench) Voss), coastal Douglas-fir, yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach), and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) (6) are addressing both these requirements. Currently, there are field trials comparing seedlings to rooted cuttings for all of the above species, as well as for interior Douglas-fir (*Pseudostuga menziesii* var. *glauca* (Beissn.) Franco).

A trial comparing seedlings to rooted cuttings of yellow-cedar was established in the field in 1978 (4). After 11 growing seasons,

there is no significant difference in height, diameter, and survival between seedlings and rooted cuttings, as shown in Table 1 (4). These trials will have important ramifications for justifying the use of rooted cuttings as an alternative to seedlings.

Table 1. Eleven year comparative growth and survival of yellow-cedar seedlings and rooted cuttings.

	Seedlings	Rooted cuttings
[1]11-year height (cm)	274	277
[1]11-year diameter (cm)	2.9	3.1
[1]survival (percent)	85%	88%

[1]Differences in height, diameter, and survival between seedlings and rooted cuttings are not significant at P=0.05

Alternative stocktype for reforestation. Rooted cuttings can be used as an alternative to seedlings for reforestation in situations where there are seed shortages, poor seed germination, or difficulties in seedling greenhouse culture. A yellow cedar rooted cutting program was initiated in response to an increase in demand for planting stock which could not be met due to seed shortage and poor germination (3). Since 1975, 50 percent of all the yellow-cedar planted have been rooted cuttings. Over the last two years, 650,000 rooted cuttings have been propagated annually, comprising nearly all of the planting stock for this species.

The main sources of cuttings are hedge orchards and serial propagation. Orchards are hedged to 25 cm in height annually to maintain juvenility. With serial propagation, rooted cuttings are grown up to 10 cm over target height and, prior to lifting and cold-storage, the tops are cut back and used for more cuttings.

Rooting success of yellow-cedar is affected by the age, hedging height, and crown position of the cutting donors such that:

1) rooting percentage decreases as cutting donor age increases;
2) rooting percentage decreases as cutting donor hedging height increases;
3) rooting percentage decreases as cuttings are taken higher in the cutting donor crown;
4) hedging the cutting donor delays maturation.

Hedging cutting donors also affects the growth and form of subsequent rooted cuttings. Table 2 illustrates the influence of cutting donor hedging height on the diameter, stem straightness, and root and shoot dry weight of one-year-old rooted cuttings. All of the traits are significantly improved by hedging cutting donors to a height of 25 or 50 cm.

Bulking-up genetically improved seed. In the early stages of a tree improvement program, genetic information is usually avail-

Table 2. Effect of hedge height of cutting donors on growth and form of one-year-old yellow-cedar rooted cuttings.

	Hedge height (cm)			
	25	50	100	No hedging
[1]Stem straightness	1.24 a[2]	1.35 a	1.91 b	2.61 c
Root collar diameter (mm)	3.88 a	3.77 ab	3.41 b	2.98 c
Shoot dry weight (gm)	2.56 a	2.19 b	1.72 c	1.31 d
Root dry weight (gm)	0.89 a	0.72 b	0.56 c	0.42 c

[1]Stem straightness: 1=upright; 2=45 to < 90 angle from horizontal; 3=0 to < 45 angle from horizontal.
[2]different letters in the same row indicate significant differences at the P=0.05 level according to Duncan's Multiple Range test.

able before seed orchards are producing large quantities of seed. Rooted cuttings can be used as an interim measure for transferring genetic gain to operational plantings. Seeds from superior clones, which are in limited supply, are grown in greenhouses under accelerated conditions and cuttings are rooted from these seedlings to bulk-up the number of plants for reforestation. The technique is illustrated and described for white spruce in Figure 1. This procedure produces a large number of cuttings from each seedling in a short period of time, while maintaining the juvenility of the cutting donor. An operational trial at the Cowichan Lake Research Station uses this procedure to produce white spruce and coastal Douglas-fir, genetically improved, rooted cuttings.

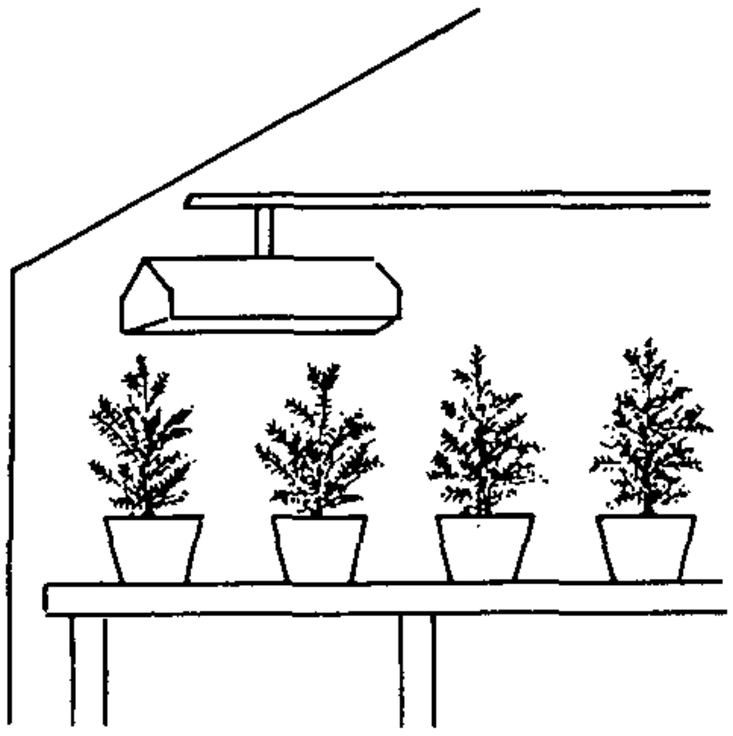
Clonal forestry. The ultimate use for rooted cuttings in forestry is for the deployment of genetically improved, tested clones (5). The major obstacle to practising clonal forestry with conifer species is the problem associated with ageing of the original clones as testing proceeds. Clonal forestry research is currently being conducted within the British Columbia Forest Service to determine the feasibility of this strategy for yellow-cedar, Sitka spruce, and white spruce.

A clonal testing strategy, being developed for yellow-cedar, involves the following steps:

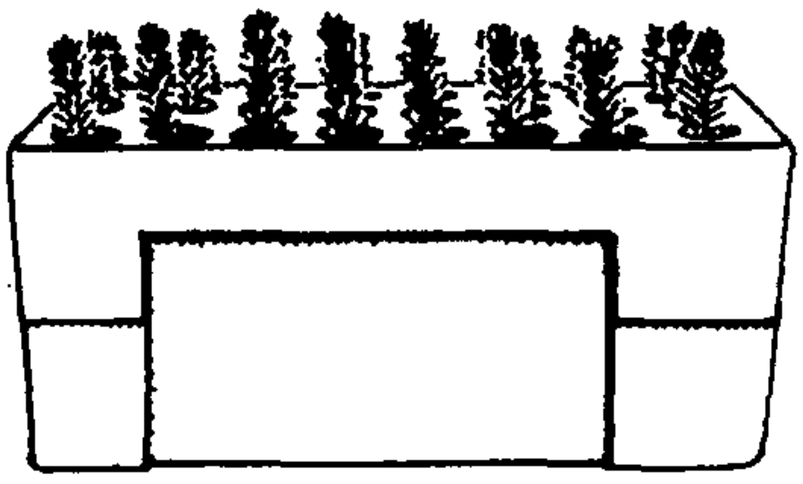
1. Production of full-sib families from container-grown grafts of selected parent trees;
2. Cloning of one-year-old seedlings from the full-sib families;
3. Establishment of nursery-bed clonal trials;
4. Establishment of clonal hedges concurrent with clonal tests;
5. Rogueing poor clones out of the hedge orchard, based on four year growth in clonal trials.

The early selection provides genetic gains which can be transferred to operational use through mass propagation of the better

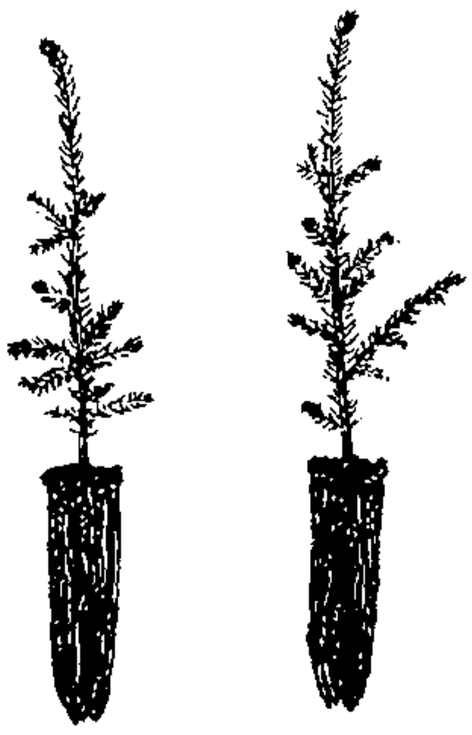
Controlled crossing between genetically superior trees produce improved seed which are used for cutting-donor plants.



Donor plants are grown from seed under 20 hour photoperiod and a light intensity of 10 000-lux. Each plant is pruned 3 times in an 8-month period and produces 70 cuttings on average.



Cuttings are taken from donor plants that have been hardened-off for 2 months and stuck in PSB containers. The containers are placed over bottom heat (20°C) and the air is kept cool and moist.



Cuttings will root in 2 to 3 months with greater than 90% success, and then can be treated as rising 1+0 seedlings.

Figure 1. Production of genetically superior rooted cuttings of spruce.

clones in the hedge orchard. As more reliable techniques for maintaining juvenility of cutting donors are developed, selection of superior clones can be made at an older age with more confidence.

CONCLUSIONS

Rooted cuttings have been an integral part of British Columbia's tree improvement and reforestation program for over 15 years. Selected parent trees that have been cloned by rooted cuttings for seed orchards are now producing genetically improved seed for reforestation. Yellow-cedar rooted cuttings are the primary stocktype currently being used for reforestation. Most of the cuttings are produced by private growers, using the techniques developed at the Cowichan Lake Research Station.

Recent research initiatives within the British Columbia Forest Service have resulted in new techniques, which allow the expanded use of rooted cuttings, including the bulking-up of genetically improved seed, the use of the clone as a research tool, and the testing, selection and deployment of genetically improved clones. Rooted cuttings will remain an integral part of British Columbia's silviculture program for years to come.

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GENETIC CONSIDERATIONS FOR BREEDING *POTENTILLA FRUTICOSA*

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The shrubby potentilla or cinquefoil is a common dwarf shrub that is widely planted in the Northern Hemisphere. There are in excess of 60 cultivars that have been named and released; however, few have remained popular (11).

The basis of any breeding program requires sound knowledge of the taxonomy of the particular plant. When we established the breeding program in *Potentilla* I found that the taxonomy of the species was very confused. It was, therefore, necessary to become involved in a taxonomic study of the plant to help define the complex and identify problem areas. There are up to 10 different species reported in the shrubby group (1, 3, 4, 6, 7, 9). However, there is no overall concensus on which is the best taxonomic approach.

One of the approaches utilized to study the taxonomic status was to establish breeding relationships among the groups. This was accomplished by crossing between the major types reported in the literature. The concept of gene exchange and limits to gene exchange are important in species definition and critical in a breeding program (8). The exercise is also valuable in that one is forced to become familiar with a broad range of plants and the diversity of characteristics present. Eight different plants were selected to represent the major types. These included North American, European, and Asian representatives. Each of these were intercrossed in all possible combinations. The resulting seed set, germination percentages, and subsequent seedling production were recorded. All plants were successfully crossed and viable and fertile seedlings produced. Breeding barriers were relatively minor (Figure 1). It appears that all members of this complex are the same species since gene exchange is possible in all combinations. On the basis of this research and other studies we completed it appears that *Potentilla fruticosa* is the most appropriate name for the complex.

The next phase of the study investigated the inheritance of flower colour and extra petals. These two characteristics are of considerable interest in relation to cultivar development. Knowledge of the inheritance of these should be of importance and help speed the release of new introductions.

To initiate this study, four principal parents were selected to represent important phenotypic classes. These were:

1) UM 8102 ('Snowbird') white ± 15 petals
2) UM 7901 ('Yellowbird') bright yellow ± 10 petals

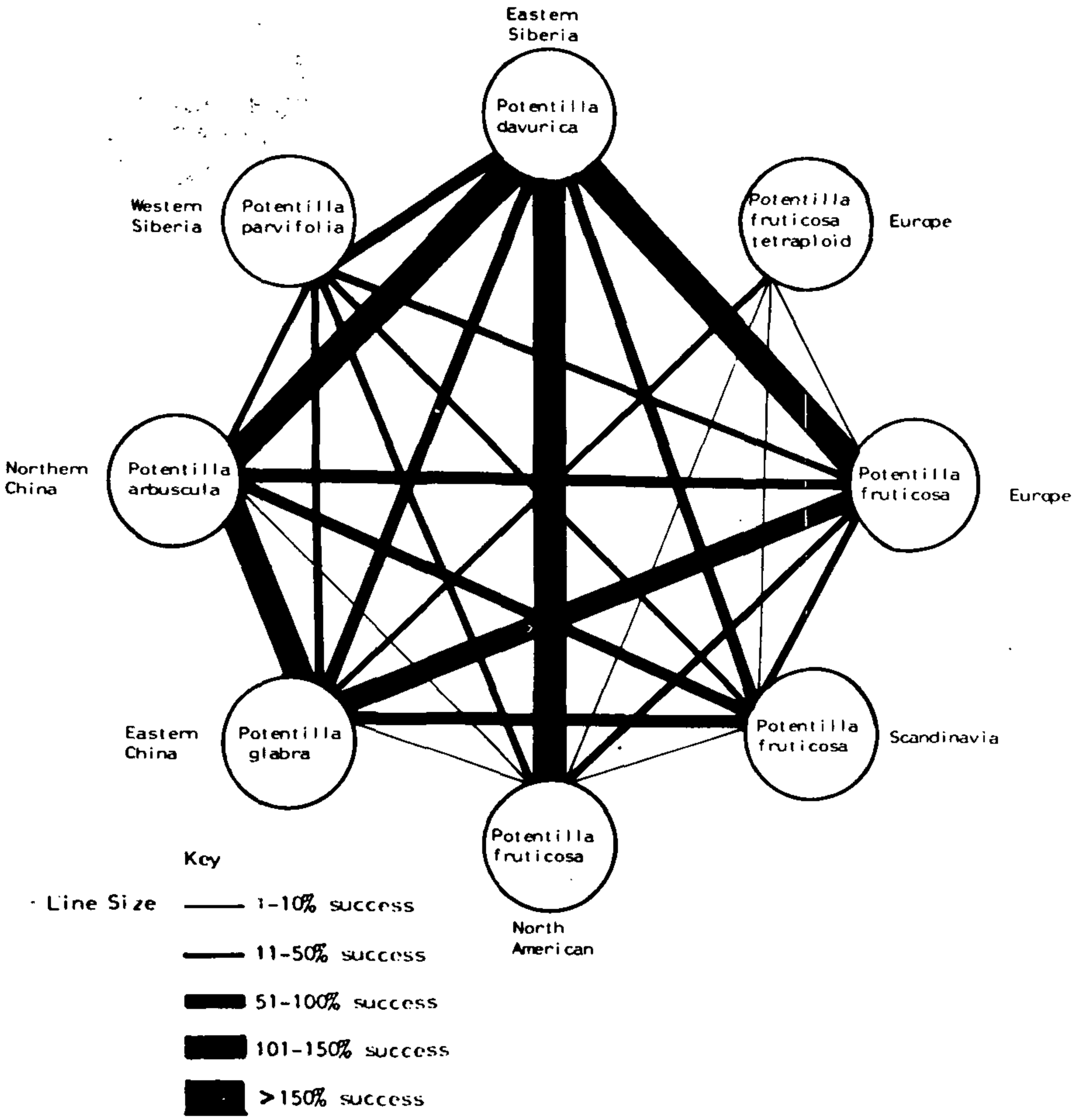

Figure 1. Breeding relationships based on success of seedling production. Success was based on average seedling yield for the cross and reciprocal, divided by the appropriate outcrossed maternal parent value.

3) UM 7911 ('Pin Whisper') creamy white with pink 5(6) petals
4) UM 7904 ('Orange Whisper') creamy yellow with orange 5 petals

These plants were crossed in all combinations to develop populations to study inheritance. Information was also obtained from other controlled crosses. The resulting seedlings were field-planted in a randomized block design. Data were collected from the onset of flowering through to mid-September. Robertson (10) found

that flower colour and extra petals were influenced by the environment. Both characteristics are more predominate under cool moist conditions. Cyanic pigments, those responsible for orange, pink and red, are reduced during periods of high temperatures while droughty conditions often reduce expression of extra petals.

To develop a hypothesis for the inheritance of yellow and white flower colour several assumptions were made (2). There were:

1) Dark yellow, bright yellow, and light bright yellow were treated as one phenotypic class. These colours are quite similar and could possibly be due to environmental variability or the effect of a diluting or bleaching gene(s). Similarly, creamy yellow, light creamy yellow, and creamy white were treated as a second phenotypic class.
2) Bright and creamy yellow colours may be associated with cyanic pigments but the quantities were low and the background colour was visible. These were easily classified in either the bright or creamy yellow colour classes.
3) Any strongly cyanic plants, orange, pink, or salmon colours were removed from the analysis since their background colour was not easily visible. This resulted in the removal of only 6 plants from over 600 seedlings assessed.

On the basis of data collected there appear to be at least four genes involved: two whitening genes and two yellowing ones. In crosses between white and bright yellow there were two groups of bright yellows. In one case, creamy yellow progeny predominated while in the other bright yellow flowers were more prevalent. In both situations 3:1 ratios were observed. The cause of the differences was not due to the white parent since the same white-flowered plant was used as a parent in all crosses.

In crosses between UM 7901 ('Yellowbird') and 7904 ('Orange Whisper') bright colours outnumbered creamy types 3:1. In crosses between UM 7901 ('Yellowbird') and UM 7904 ('Pink Whisper') bright colours again outnumbered creamy types by 3:1. On the basis of the data analysis tentative genotypes for the parents have been developed. These are:

UM 8102 ('Snowbird') $W_1W_1W_2w_2Y_1y_1$— —
UM 7901 ('Yellowbird') $w_1w_1W_2w_2Y_1Y_1Y_2y_2$
UM 7904 ('Orange Whisper') $w_1w_1W_2w_2Y_1Y_1y_2y_2$
UM 7911 ('Pink Whisper') $w_1w_1W_2w_2Y_1Y_1y_2y_2$+ bleacher

Models of cyanic flower colour inheritance were more difficult since seedling populations were very small. From the data collected however, a preliminary hypothesis was prepared that should be useful in future studies. The background petal colour must be taken into account since the anthocyanins may interact with the base pigments. For example, the colour orange appears to be a combination of a reddish anthocyanin and the yellow back-

ground pigment. Secondly, there appear to be at least two anthocyanin controlling genes involved. Colours observed include pink, orange and salmon. Different pigments or pigment combinations are responsible for these colours. The location of the pigment must also be considered. Flowers may be uniformly cyanic, or have a central blotch or feather. Positional genes must therefore be involved. Finally, the anthocyanin pigments observed were temperature-sensitive. There was variability in the sensitivity of these, thus selection for more stability may be possible. Selection for good stable and uniformly coloured flowers should be an obtainable goal.

The second character investigated was extra petals or double flowered plants. Potentillas normally have 5 petals. Selection programs at the University of Manitoba had previously identified plants with petal counts of up to 10 extra petals.

Progeny from the crossing program were analyzed to establish a model of inheritance for this particular character. Comparisons were first made between single and double flowered plants. Any plants with more than the basic compliment of 5 petals were considered double. Double flowered plants were placed into one of two phenotypic classes: those with 6–10 petals and those with 11–15 petals. Ranges within the class sizes were necessary since environmental influences are common (10).

The model developed proposes three genes. The first two act as a trigger or switch. If either gene is fully recessive then up to 5 extra petals are produced. The third gene is a modifier which, if recessive, enables production of up to 5 more petals.

All of the families studied fit with one exception. There were reciprocal differences in the cross between the 10 and 15 petaled plants. Further studies suggest that the genetics of this is quite complicated (Innes 1988). The genotypes of the parents involved are proposed as follows:

UM 8102 ('Snowbird') $D_1d_1d_2d_2d_md_m$?
UM 7901 ('Yellowbird') $d_1d_1D_2d_2D_md_m$
UM 7904 ('Orange Whisper') $D_1D_1D_2d_2D_md_m$
UM 7911 ('Pink Whisper') $D_1D_1D_2d_2D_md_m$

where D_1 and D_2 are the initial switch and D_m is the modifier (double modifier).

Innes (5) has confirmed this model and has suggested that at least one other modifying gene is present. In his population petal counts of up to 25 were recorded. In addition to this he found that the double modifier gene was genetically linked to the self-incompatibility locus. The close proximity of these two genes means that segregation ratios are altered from expectations.

Nearly all shrubby potentillas are self-incompatible. This means that flowers must be cross-pollinated before any seed can be set. The only exception to this was in a tetraploid (2N = 4x = 28).

This plant would set seed when it was selfed; however, resulting seedling vigour was very low. In relation to breeding, self-incompatibility has at least two important implications. Firstly flowers do not have to be emasculated. Pollen from the same plant cannot fertilize another flower on the same plant. This speeds up the field work considerably since less time is required to cross-pollinate. Secondly, it is more difficult to obtain plants that are fully recessive. Many of the floral characters studied are only expressed if fully recessive. Frequency of occurrences are lower which often means more generations of intermating are necessary to obtain the desired combinations.

In conclusion:

1) White and yellow colours are determined by two white (W_1W_2) and two yellow (Y_1Y_2) genes. The role of a bleaching gene to slightly modify these colours is also suspected.
2) Cyanic flower colour inheritance is complex. Future studies should consider genes for cyanic pigments, temperature sensitivity, pigment location and the background colour of the petal.
3) Three or possibly four genes are implicated in the inheritance of extra petals. If one of the first two genes (D_1 or D_2) is fully recessive then up to 5 extra petals develop and if the third (D_m) gene is also recessive an additional 5 petals may be produced. A tentative fourth gene (D_{m2}) also has to be in a recessive condition before any more extra petals are produced.

These genetic models will be very useful in the further development of *Potentilla fruticosa* cultivars. However, the floral characters must be in combination with other characteristics. The plant must be strong, vigourous, and healthy before it can be released to the landscape industry. Too often, we have seen plants promoted for a single characteristic with little attention paid to the plant as a whole. There remains within the *Potentilla* complex a great deal of variability that can and should be exploited. As we gain more and more information about this plant, more and more doors open.

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BREEDING NEW PIERIS CULTIVARS

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Plant breeding was one of the projects to be conducted at the newly established North Willamette Experiment Station of Oregon State University when I was hired in 1959. *Pieris* was chosen as there were several species and a number of named cultivars of *P. japonica*, none of which were known to be the result of hybridization. Among the objectives were development of plants with growth habits different than the narrow, upright habit of *P. japonica*, fade resistant pink flowers, and bright red growth.

Thirty different plants were acquired in 1959 and 1960 from local and eastern nurseries including one or more of the following species: *Pieris floribunda*, *P. formosa* and its variety *forrestii*, *P. japonica*, *P. nana*, *P. phillyreifolia*, and *P. taiwanensis*. Also obtained was a plant of *P.* 'Forest Flame', which is reported to be a natural hybrid between *P. formosa* var. *forrestii* and *P. japonica*. Results of attempts at interspecific hybridization in *Pieris* by Dr. Richard Jaynes and I have been reported (1).

Seven of the *P. japonica* forms were supposed to be pink but all resembled the one honestly named 'Pink Bud'. The pink bud types crossed together did not result in any darker pinks. The real break for breeding dark pink *Pieris* came in March, 1961, when I was called to Lambert Gardens, a display garden and landscape firm in

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Portland, Oregon, about a weed control problem. I noticed a group of almost maroon-flowered *Pieris* for sale and bought one.

A truss was sent to Dr. Donald Wyman at the Arnold Arboretum, who wrote that the plant was very unusual and should be named. This letter was shown to Mr. Lambert and the name 'Flamingo' was suggested to him. The color does not match that of a flamingo but flamingos were among the exotic birds in the garden and the name would have good publicity value.

As far as I have been able to trace the origin of 'Flamingo' was that it was found growing in a Portland garden by David Hutton. Mr. Hutton had come to the U.S. to work for Mr. Lambert after completing training at the Botanic Garden at Edinburgh; he later returned to Great Britain.

'Valley Rose', the first *Pieris* named from the breeding program, resulted from crossing 'Flamingo' with 'Deep Pink', from Mitsch Nursery, Aurora, Oregon in 1961. 'Valley Rose' grows wider than tall but the flowers do become quite light pink at the end of the blooming period.

'Valley Valentine' resulted from a cross of 'Flamingo' with 'Valley Rose' done in 1966. The red flowers of 'Valley Valentine' open by February 14 in the Portland area. The color is impressive close up but doesn't give much contrast with the dark green leaves at a distance. We are still trying to produce a non-fading medium pink but so far if we get this there are other faults such as leaf spotting.

A recent goal in the breeding program is later blooming plants. A high percentage of *Pieris* plants produced on the U.S. West Coast are shipped to the Northeast where flowering starts in April. 'Valley Fire' (*P. formosa* var. *forrestii* × *P. japonica* 'White Caps'), released in 1976, is late blooming but is not hardy enough for the Northeast. Actually 'White Caps', selected in New Jersey, is one of the latest flowering *P. japonica* plants. Promising late blooming seedlings have resulted from a cross of *P. japonica* 'Red Mill' × *P. japonica* (NA 40269D) collected at 5400 ft. elevation on Yakushima Island, Japan by Skip March of the U.S. National Arboretum. They have compact habit, red new growth, and white flowers.

Also late flowering mid- to late-March are a group of compact white-flowered cultivars from Firma C. Esveld in Boskoop, Holland: 'Cavatine', 'Chaconne', 'Nocturne', 'Prelude', and 'Sarabande'. They are also derived from seed collected on Yakushima, Japan.

HYBRIDIZING METHODS

All crossing is done on potted plants brought into a heated greenhouse when the first florets start to open. An exception would be on seedlings blooming for the first time out-of-doors that usually are used as pollen parents.

The corolla and anthers are removed on ten florets on a raceme

for each cross. Florets from the plant to be used as the male have the corolla and pistil removed then the anthers are tapped on a thumb nail. The nail is much easier to guide and clean than a brush. It is also easier to see the tracks in the pollen than to see the pollen on the stigma. By pollinating 10 florets, one or more should be in a receptive condition and sometimes we get 8 capsules; of course, other times it is zero. Very little if any seed results from selfing most *Pieris* plants.

Seed is harvested in late summer when the capsules start to turn brown. Seed is sown on milled sphagnum moss over a sterile potting medium in 6 cm^2 × 9 *cm deep plastic pots after January 1. If* available, enough seed to produce 100 seedlings is sown in each pot. The seed is not covered with the sphagnum moss but is misted almost every day. A sheet of glass is placed over the pots which are 15 cm below a fluorescent light unit operating 16 hours per day. When the lights are on the temperature is about 27°C and drops to 19°C during the night in our office basement.

Any excess seed is held in paper envelopes placed in polyethylene bags which are stored in a refrigerator. Seed remains viable at least one year at 4.4°C (40°F).

Around March 1st seedlings are transplanted, one hundred to a 38 × 50 cm flat. They are grown at 13°C night temperature with a 4-hour light break from 10 pm to 2 am in a double layer polyethylene house. In June, the flats are moved to an unheated polyethylene house where a culture of *Phytophthora cinnamomi*, obtained from Dr. Robert Linderman, U.S.D.A. Horticultural Crops Laboratory, Corvallis, is spread over the flats.

In July and early August, the survivors are transplanted into pots. The initial selection is based on foliage and growth characteristics. Evaluation of flowers takes 3 to 4 years, then propagation trials are started. Evaluation in the ground takes place with cuttings rooted from the selected plants, since plants inoculated with *Phytophthora* remain isolated.

Selected plants are sent to other locations for evaluation before naming and introduction.

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BREEDING RHODODENDRONS FOR THE PACIFIC NORTHWEST AND COMPARABLE CLIMATES

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The breeding, development, and introduction of new plant cultivars can be compared to manufacturers introducing new products and models. To be competitive nurseries should feature these new introductions. Most customers like to try something different. The advertising and promotion of new cultivars increases nursery traffic, elevates profits, and indicates a progressive operation.

In my opinion, it is wrong to produce new cultivars for "new cultivars sake". I have been trying during the past few years to create rhododendrons with new "appearances"; flowers having longer corollas, flamboyant calyxes, also ruffles and frills. Some of these exciting new cultivars have recently been coming into bloom. The best will be selected and propagated for the retail trade. One might wonder about how to obtain them. Distribution by propagating nurseries, such as "Clays", "Briggs", and others, have made some of these cultivars available, world-wide. Others, and the newer introductions, can be obtained as scionwood for propagation. For a list of available cultivars and additional information, you can contact me at the above address.

As most of you may know new cultivars are created from controlled cross-pollination. Corolla and anthers are removed from the selected female flowers 5 to 7 days before the normal blooming time. (This reduces chances of self-pollination.) When the stigma becomes sticky, pollen from the selected male parent is applied. Up to here the procedure has been easy. The really hard part is the selection and development of suitable parents that have the genes to produce excellent offspring. What makes a rhododendron special? There are many cultivars available now, in beautiful colors, and clothed in attractive foliage. Also many sizes from short to tall. But many are not really special because they are so much alike.

1. 'L'Orchid' reminds one of cymbidium orchids. It is being crossed with cultivars having large calyxes to emphasize the orchid emulation.
2. 'Pink Petticoats' is my first rhododendron to bloom of any consequence, going back to 1964. Properly grown, it will bloom for sale in gallon containers. Its special value shows in its hybrids. They bloom early in life, have large flower trusses, and plenty of frills.
3. 'Pirouette' is a hybrid of 'Pink Petticoats' and a species rhododendron, *R. yakusimanum*. It has large "ball" trusses of many flowers on a compact plant with excellent foliage.
4. 'One Thousand Butterflies', a hybrid of 'Pink Petticoats', caused quite a stir when, during its first blooming in 1979, it was shown at an American Rhododendron Society convention in Vancouver, B.C. It has a full truss of 32 exotic

flowers, each having a configuration of a butterfly in its center. It has good foliage and is an excellent plant for growing in containers.

5. 'Excalibur' has outstanding trusses. Deserving its mystical name, 'Excalibur' is in great demand. It is a cross between 'Lem's Cameo' and 'Pink Petticoats'.
6. 'Viennese Waltz' is also a cross between 'Lem's Cameo' and 'Pink Petticoats'. It is probably the most spectacular of the 'Pink Petticoats' crosses. It is reminiscent of the "ball gowns" of the Strauss period in 19th century Austria.
7. 'Yellow Petticoats' has ¼ of 'Pink Petticoats' in its ancestry. It blooms early in life, has big, many-flowered trusses of bright yellow.

This completes the hybrids of 'Pink Petticoats'. Of course, the other parents have influence, too. But 'Pink Petticoats' does seem to greatly influence the early blooming characteristics of the offspring, also the size of truss and number of flowers.

The above descriptions show how one dominant parent can influence the characteristics of the offspring. The next group show a collection of older and newer hybrids of considerable merit. They are shown in chronological order.

8. 'Sierra del Oro' is a hybrid of 'Crest' and *R. lacteum*. Ideal foliage and beautiful flowers makes this one of the finest yellows. Flowering, in early April, lasts up to six weeks.
9. 'Sierra Sunrise' is a natural triploid. Seen at its best, it has one of the world's largest flowers and trusses. I have measured trusses 14 in. high, and flowers 7 in. in diameter. It stays up well in wet weather. The name was suggested by a beautiful sunrise in Granada, Spain.
10. 'Sierra Beauty' is a sibling of 'Sierra Sunrise'. It displays a football-sized truss of slightly deeper color. Both are crosses of 'Mrs. Horace Fogg' and 'Point Defiance'.
11. 'Lemon Float'. A compact, floriferous, yellow hybrid, with deep green, beautiful foliage. Lemon-yellow flowers attract much attention.
12. 'Party Package' is frilled in bud and open flower, and is used to get frills and *ruffles in other hybrids.*
13. 'Supergold', a cross of 'Hotei' and 'Joanita' is, indeed, very yellow. It is set like a jewel on beautiful foliage.
14. 'Sunup-Sundown' is named for its morning and evening sky colors. To me, more important, is its large calyx, which is as large as the flower.
15. 'Sweet Sue' is one of my favorite rhododendrons. I liked it so much I gave it the name, as yet unregistered, of my daughter Sue, who always has a sweet and happy disposition. It is an apricot-colored cross of 'Hotei' and 'Lem's Cameo'.
16. 'Sierra Sunset' is a low growing, salmon rhododendron of great merit. The large calyx comes from 'Sunup-Sundown'. It blooms heavily in April, resembling an evergreen azalea.
17. 'Coral Skies' is one of the new "new", different rhododendrons. Low and compact in growth, the flowers are a light coral inside, and a deeper coral outside. On the back, radials of a deep coral-pink run to the edges of the flowers and the attractive calyx.
18. 'Butter Brickle' is named after that tasty ice cream dessert, the color it so closely resembles. It has attractive, bronze colored, new foliage. The plant is compact and has a nice "habit". Should be a good commercial cultivar. It has a nicely marked flower and large calyx.
19. 'Great Expectations' comes from a cross of 'Sunup-Sundown, and one of

Whitney hybrids. I like this for its own sake but, combined with 'Butter Brickle', it has given me some great hybrids that have just started to bloom in 1987 and 1988. Some would have bloomed earlier, but an early November, 1985, freeze wiped out a crop that was growing in containers.

My eventual goal is to produce unique rhododendrons shaped like lilies and daffodils, but will be beautiful as rhododendrons, and not for the plants they emulate.

BRUCE BRIGGS: John, I have noticed that plants, as Colorado blue spruce, that have a strong root system, will develop a straight leader system very fast. Have you noticed this in your work?

JOHN RUSSELL: One thing I did not mention about the plagiotropic plants is that they do tend to grow out of it. Definitely those that have a strong root system show little plagiotropism and will outgrow it quicker. When Douglas fir is left in containers they show plagiotropism, but when transplanted into the field they grow straight up.

VOICE: John, on your rhododendron selections, do you make any of your selections on ease of rooting, or is it all on other qualities?

JOHN LOFTHOUSE: We really cannot tell about ease of rooting until after they are actually blooming. Most root very easily.

VOICE: This is for John Russell. John, what do you base your selections upon?

JOHN RUSSELL: We are just now approaching our second generation selections with Douglas fir in British Columbia. We have five plant breeders here. We are trying to select for more dense wood as well as trying to keep our superior growth rate. Tree volume is one of our major growth criteria.

LAGERSTROEMIA PROPAGATION

KATHLEEN S. FREELAND[1]

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Lagerstroemia, or crapemyrtle, has been cultivated within the United States for over 100 years and is known as the "Lilac of the South', in much the same manner as the common lilac, *Syringa vulgaris*, is symbolic of colonial homesteads. The name "crape-myrtle" is derived from the crepe-like, crinkled and ruffled petals and the resemblance of the leaves to those of true myrtle. First illustrated and described by a Dutch physician and named by Carolus Linnaeus in 1759 for his close friend, Magnus Lagerstroem, crapemyrtle is a member of the loosestrife family.

More than 50 species of trees and shrubs of this genus are distributed in southeast Asia and Australia, the majority of which are tropical and amenable to cultivation only within warmer areas of the U.S. such as Florida and California. These plants (some of which have proven root hardy if mulched) flower on new wood and will produce vegetative growth that flowers the following summer. However, the flowers cannot equal those of plants grown in climates adapted to them. These plants are very adaptable to being grown in containers or even in perennial borders or as a grouping of shrubs.

At the Chicago Botanic Garden, Assistant Director, Kris Jarantoski has been obtaining cultivars of crapemyrtle from nurseries throughout the United States, planting, and evaluating them for mildew resistance as well as root hardiness. As new plants were needed for possible replacement in the evaluation blocks, propagation was called for.

Several methods were used to obtain the amount of rooted cuttings that were desired. According to the literature crapemyrtle is easy to propagate, so the standard methods were used, i.e.:

Leafy stem cuttings, 1 to 2 in. in length

Commercial root-inducing powder, e.g. Homo-Root C or Hormodin 1

Peat and perlite (50/50) rooting meadium

Bottom heat of 72°F

Intermittent mist, "on" 6 sec. every 6 min.

These methods produced rooting percentages of 70 to 100% in most cultivars. However, there were several clones that were more difficult to root and clearly another method had to be tried. As these plants are tropical, hardwood cuttings seemed to be a doubtful

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[1] Propagator

method, but it was tried just the same. Three weeks at 41°F and then out to the misting bench produced nothing but rotted wood and mildew, but no rooting.

After a perusal of the propagation manual by Dirr and Heuser, it was decided to try another method that was old but new to us at the Garden. Dormant twigs, 6 in. long were cut from parent plants and put horizontally on a pan of peat and perlite, 50:50 and fastened down with florist pins, then put under intermittent mist (6 sec. every 6 min.) and 72°F bottom heat. These conditions caused the twigs to produce small shoots that were carefully excised from the parent and stuck as softwood cuttings, using HormoRoot C. Rooting was very quick, less than 2 weeks, but all these cuttings did not root, nor did all the twigs produce shoots, but enough was successful so that the necessary quantity of rooted cuttings was obtained.

This evaluation project is on-going, but the final results showing the best cultivars for the Chicago area will not be known for sometime. These plants gave a challenge to the propagation department and caused us to try something that was different and new to us.

Lagerstroemia is not the only plant being tested for the "Die Back" shrub project at the Chicago Botanic Garden, but the bulk of propagation information was gathered from this group of shrubs.

Lagerstroemia cultivars used in the "Die Back" shrub project:

L. indica 'Christiana', 'Dwarf Royalty', 'Jet Stream', 'New Snow', 'Pink Ice', 'Pink Ruffles', 'Rose Pink', 'Watermelon'.

Shrubs in the "Die Back" shrub project: *Buddleia, Callicarpa, Ceanothus, Clerodendron, Indigofera, Lagerstroemia, Rhus, Vitex.*

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Egolf, Donald, 1972. *Horticulture Magazine,* August.

Dirr, Michael A. and Charles W. Heuser, Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, Georgia: Varsity Press.

ALLAN ELLIOTT: Nick, you mentioned root piece cuttings with 'Pixie' and 'Malling 9'. Are there other cultivars with which you are using root cuttings?

NICK DUNN: We haven't had much experience with ornamentals. We have used some *Acer* species, but I can't give you the full particulars.

ROBERT MAZALEWSKI: Question for Kathy Freeland. About the *Lagerstroemia,* were the heel cuttings rooted under mist, and how long did they take to root?

KATHY FREELAND: It took about 3 weeks to root under mist, with bottom heat at about 70°F.

RALPH MOORE: You can take a group of soft *Lagerstroemia*

cuttings, put them loosely into an open container under mist, without any hormone, and they will root.

CHARLES TUBESING: Nick Dunn, what rootstock are you using for the medlar?

NICK DUNN: We are using quince. It causes some dwarfing.

CURTIS J. ALLEY AWARD OF MERIT

Presented by Dennis Connor, Western Region President, at the Western Region Annual Banquet, Hyatt Regency Hotel, Vancouver, British Columbia.

Our awardee for 1988 has served as President and Treasurer for the California Association of Nurserymen and has been involved with many other organizations—The Cal-Aggie Foundation at the University of California, Davis, the U.C. Foundation Plant Materials Service for clean seed and nursery stock, California's Governor George Deukmejian's Advisory Staff, the Sacramento Tree Foundation, the U.S. National Arboretum, Board member of Sacramento's Sumitomo Bank, and 54 other business, charitable, political, and educational committees.

He is a charter member of the Western Region and served as its President in 1973–74. He was IPPS International President in 1977.

He was born March 9, 1927, and has three children, Loren, George Samuel, and JoAnn, plus six grandchildren.

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THE BURLAP CLOUD METHOD FOR ROOTING DECIDUOUS SHRUB CUTTINGS

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Canada

The method of propagation which I will present is one that has previously been described (1) by my grandfather, the late Leslie Hancock, in 1953 at the Third Plant Propagators' Society meeting. My intention is to outline the technique as it is being used now, including developments which have enhanced the system over the last 35 years and, moreover, to bring to the surface again a viable system of softwood cutting production.

Leslie Hancock, a recipient of the IPPS Eastern Region Award of Merit in 1968, developed the Burlap Cloud method of propagation as a result of experimentation in adapting a system of propagation he had witnessed in Nanking, China. The system he had observed there consisted of beds of soil which had raised lips of formed soil. These beds were flooded like miniature rice paddies and cuttings of suitable shrubs were plunged into the slurry of water and soil. Immediately following this process the beds were covered with dense reed mats which shaded the cuttings from direct sunlight and helped retain the humidity in the air chamber below the reed mats. In the evening the shades were removed to allow the cuttings to get more light and to air overnight.

The shades were replaced in the morning as the dew evaporated from the cuttings. This cycle was repeated until the cuttings were rooted and the shading was reduced until full exposure was possible.

Intrigued by this somewhat primitive but successful method of propagation, my grandfather experimented over many years adapting this method at his own Woodland Nurseries in Cooksville, Ontario which is near Toronto, Canada. After poor success with making beds with formed edges to retain water, he developed a system using lightweight frames of red cedar lumber (Figure 1). The frames are made 45 in. wide by 12 ft long and is an open bottomed box made from 1 × 10 in. lumber. The frame is fitted with a 1 × 3 in. wood crossbar halfway down the frame to allow rigidity and to make it easy for one person to carry the frame around. Along each top side edge of the frame is added a 1 × 3 in. strip of lumber 12 ft long which is used to later attach a burlap sheet over the top of the frame. We now, as well, add corner braces of inexpensive lightweight shelf brackets, 10 × 10 in. These frames, when partially filled with sifted soil and flooded with water approximated the

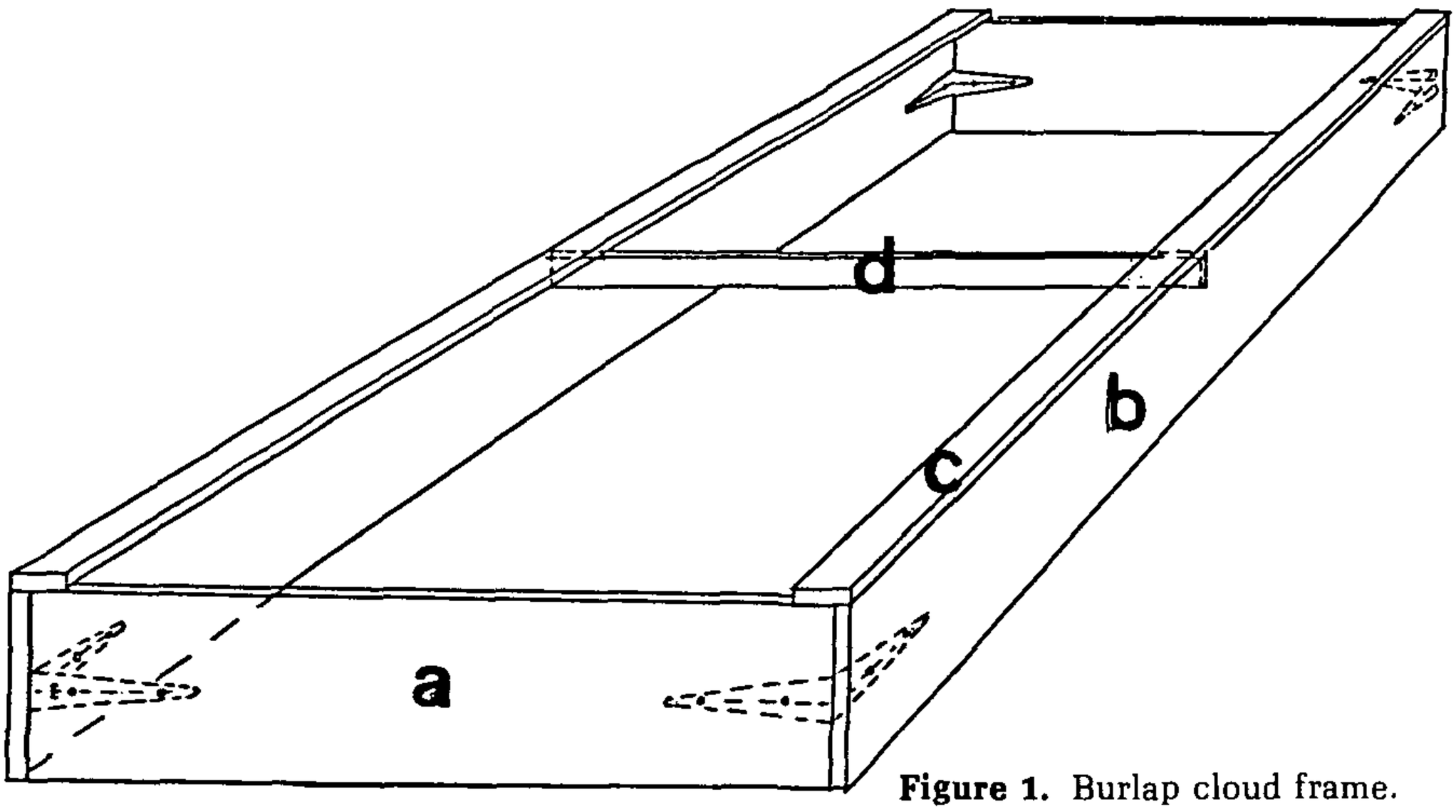


Figure 1. Burlap cloud frame.

MATERIAL KEY

1″ × 10″ Pressure-treated stock	C—12′
A—42½″	D—42½″
B—12′	E—10″ Grey shelf brackets
1″ × 3″* Pressure-treated stock	*—True 3″ wide—ripped from 1″ × 4″ stock

system he had seen work so well in China. Rather than reed mats, we use 10 oz. burlap, 40 in. wide to cover the frames.

Further experiments led to the practice of moistening the burlaps through the day to keep the humidity high in the growth chamber and to keep the cuttings from suffering under the harsh extremes of heat and dry air of the Canadian summers.

CURRENT METHODS

The current method of production has changed in many respects since my grandfather's initial paper, but some techniques have allowed even better results than previously published. As with his paper, I will attempt to detail the production now being used to produce high quality, strong liners of deciduous shrubs and some broadleafed evergreens with the "Burlap Cloud" technique.

Soil preparation. Because this method of propagation uses field soil as a rooting medium, I wish to preface this section by saying that my grandfather realized that particular soil conditions were necessary and crucial to success. A well-drained porous soil is needed so that raised beds can be formed, ensuring that natural and applied water will pass through the bed soil and migrate to the relatively lower pathways. Sitting water will not be tolerated by the rooting cuttings as they will rot before they root. I have witnessed this propagation system being used on several types of nursery soils such as silt loams, sandy loams, and both fine and coarse sandy soils. If allowances are undertaken to offer drainage from the

rooting beds, good results can be achieved with different soil types.

The area to be used for cutting production should be sloped slightly (1 foot fall per 100 feet) so surface water can be taken away via pathways. The soil should be clear of weed clumps and have reasonably clean subsurface of old roots and plant debris. The soil is rototilled with a rear-mounted tiller to break up the clumps of soil and to open up the soil for methyl bromide fumigation. Hoops or peat bales are put in place on the tilled surface to hold up a poly film so as to allow diffusion of the gas vapours to all areas of the beds. Canisters of methyl bromide are set in place on piercing tools just underneath the perimeter of the poly tarp. The edges are then buried in a trench 6 in. deep to trap the gas inside. By pressing down on the canister from outside of the poly, the canister is pierced and the gas is released. Methyl bromide has been found to be the most effective fumigant as it sterilizes the soil to the tilled depth, killing all pathogens, weed seeds, and insects which potentially could cut down on rooting percentages and interfere with subsequent cutting growth. Also with methyl bromide there is a short treatment period—two days under poly, followed by two days of aeration, so that in four days we can begin propagation.

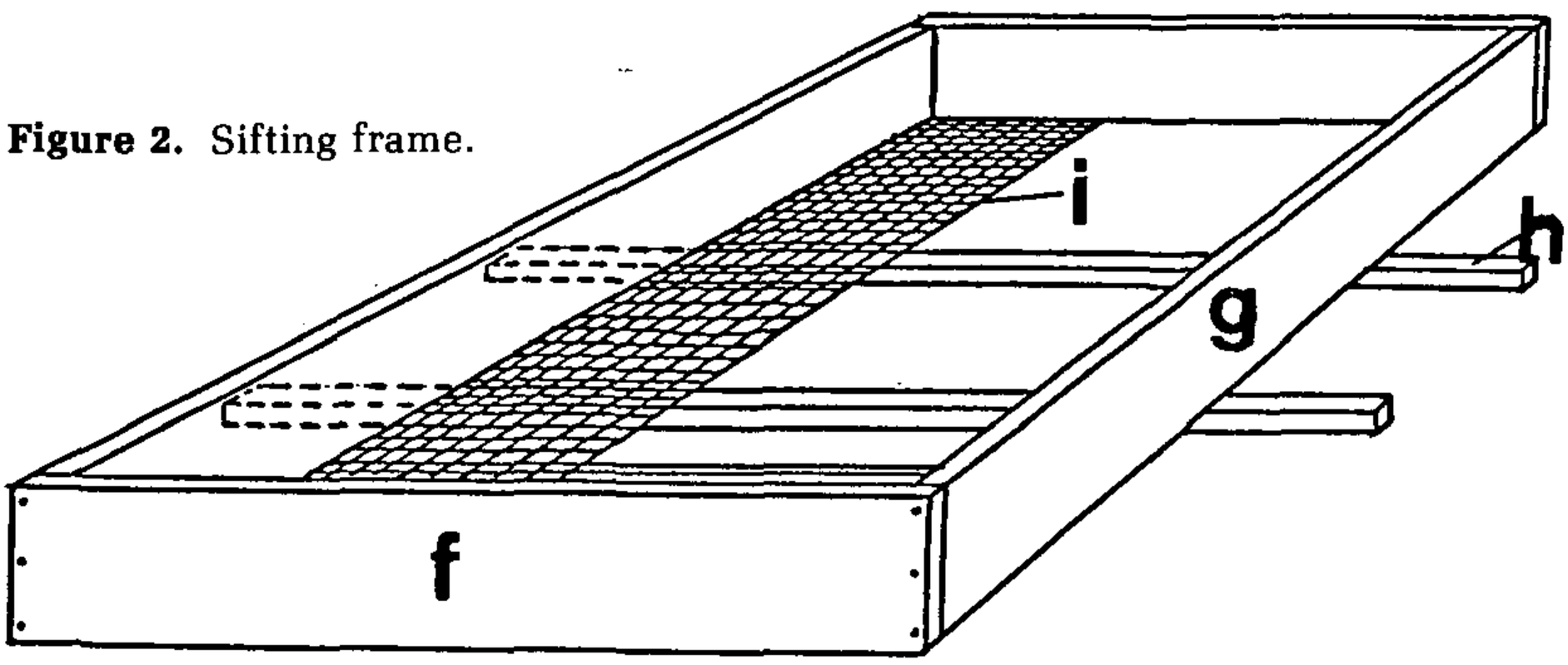
Frame setting. The area we normally use covered with frames is approximately 60 × 125 ft, allowing about 100 frames to be set out with 1½ to 2 ft pathways between them. The frames are set out end to end in rows with a string line to ensure straightness. Normally two sections of five frames are set out in the 125 ft bed, allowing a 5 ft gap between 60 ft runs. This is a convenient arrangement as a centrally located hose 75 ft long with good pressure is able to be pulled up and down the pathways easily.

The frames are sunken down into the tilled soil about 1½ to 2 in. by digging under the inside edges of the frame with a spade and settling them down in the soil. At this time they are levelled side to side with a 4 ft spirit level. End to end, sighting the tops of the frames will allow the frame setter to ensure that there is a uniform slope towards the draining ends of the beds along with the slope of the tilled area. Since the pathway soil will be lowered later this is important because it is easiest if the frames are uniformly graded so the pathways can be dug to a lower depth relative to the frames. Once one or two rows of frames are set out and graded, the soil can be prepared within the frames for cuttings.

Soil preparation. Starting at the beginning of a set of frames, soil is excavated from one half of the first frame to a depth of 1 to 1½ in. below the bottom edge of the frame inside and packed firm by pressing with the feet making the base firm and level. This will be a reference point for later cutting sticking. It is important for this base to be below the bottom edge of the frame so that excess water will be able to move laterally through the soil under the frame to a

depressed pathway. Once the half-frame is excavated, a soil screening frame is placed over the half-frame (Figure 2). This screen is a frame measuring 3 × 6 ft made of 2 × 6 in. lumber and has a hardware cloth bottom nailed on it with 1 in. openings. Soil is removed from the half-frame adjacent to the screen and is passed through the screen to partially fill the first half-frame. As a result, a mound of sifted soil is left which is clean of plant debris and stones and is of uniform consistency. The pathway soil immediately beside the frame being filled is then taken down to a uniform depth with a shovel making sure that its final elevation is below the level of the firmed excavated base inside of the frame. This is critical to allow for drainage from the frames, as previously mentioned. The soil which is taken from the pathway is also passed through the screen into the half-frame. The resulting amount of soil inside of the frame should, when leveled out, fill the frame to a depth of 3 to 4 in. above the firmed base. Several frames are prepared in this manner with the soil left in mounds right up until the cuttings are ready for sticking.

Figure 2. Sifting frame.



2″ × 6″ Pressure-treated stock
F—3′
G—6′
2′ × 2″ Pressure-treated stock
H—4′
1″ × 1″ Square wire mesh
I—3′ × 6′

Cutting preparation. Cuttings are collected from juvenile field-grown shrubs in active growth during June to mid-July. Cuttings of most cultivars can be 5 to 9 in. in length and should be firm but pliable, as normal for softwood cuttings. Pails with a holding capacity of approximately 200 cuttings are filled 2 in. deep with water for use in the field. As cuttings are taken from the shrubs they are stood with the cut ends into the water. When sufficient quantities are collected, they are brought into a cool shed or barn and removed from the water. They are then laid out on clean moist burlap and covered with the same to keep them turgid and cool. Leaves are removed from the basal portion of the cuttings to 3½ in., then they are dipped into a mixture of fungicides (benomyl and fer-

mate). The excess solution is shaken off, then bundles of cuttings are dipped into a hormone powder. For most cultivars 0.2% IBA is sufficient if they are done early enough, but others respond best to 0.4% IBA, or, occasionally 0.8% IBA, if they are woody or difficult to root.

Cultivars which we need in large numbers, we normally do at different dates through the month to avoid misjudgement of the state of maturity of the cuttings. Many times cuttings are taken from plants which were stripped of suitable cuttings perhaps two weeks earlier!

Cutting sticking. Prepared cuttings are taken to the field in plastic flats covered with wet, dense burlap to keep them moist and cool. At this stage the mound of sifted soil is leveled in the half-frame, ensuring that there are no depressions in the centre of the bed. These depressions result in pooling of water causing damage to the cuttings in the form of rotting in mild months or freezing in winter.

The sifted, leveled soil is drenched with water from a large watering can to saturation. This is done to the complete depth right to the firm base soil. A template made of 1 × 10 in. lumber with #10 screws almost fully screwed into it at set densities is pressed onto the moist soil to form indentations as marks for sticking the cuttings. The cuttings are immediately pressed into the slurry to a point where they are pushed down to the firm base (Figure 3).

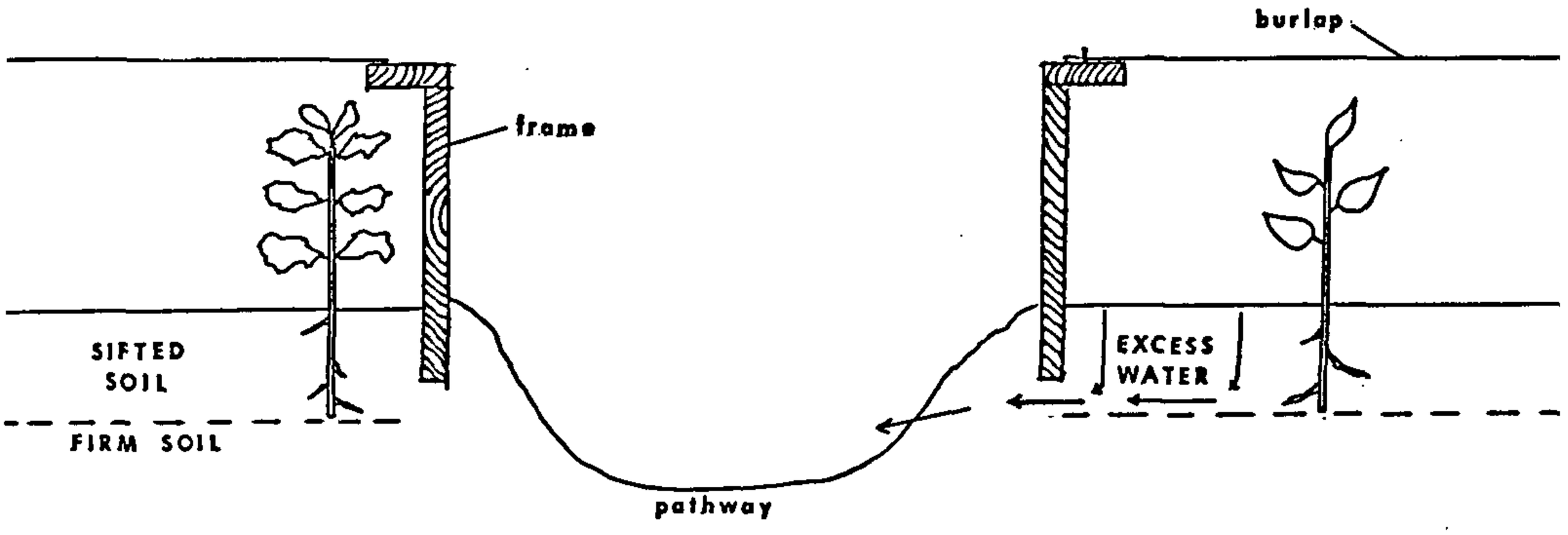


Figure 3. Pathway and frame cross-section.

Frame covering. The wood frames which are being filled with cuttings are covered along one edge of the frame with 40 in. wide, 10 oz. burlap which has been previously cut to lengths of 12 ft, 8 in. to allow for some shrinkage. This one edge is fastened using a construction staple gun at about 5 in. intervals along the 1 × 3 in. fastening strip, along the top edge of the frames. It is then drawn across, pulled taut and is pegged over 1 in. finishing nails which

have been hammered into the opposite fastening 1 × 3 strip on the frame. These nails are driven in halfway, about 1 ft apart.

Burlap maintenance. The burlaps are well watered just to saturation through the day. Drying of the burlaps is allowed but they should never become parched. If the burlaps are kept too wet, too frequently, the burlap cloud chamber does not heat up sufficiently and the cuttings are kept too damp, leading to rotting. The best determiner is to have a responsible member of the sticking crew keep an eye on the burlap's condition. Burlap watering frequency changes day to day, hour to hour, dependent on the wind and sun conditions. Average waterings are normally about 6 to 8 times, from the time the frames get covered in the mornings, until 5:00 pm. The frames are opened up to full exposure in the late evenings about 1 to 1½ hours before sundown unless there is a strong evening breeze which could desiccate the cuttings. Also the frames are left open in the mornings until the dew has almost evaporated from the leaves—usually about 8:30 am. It is for this reason that the burlaps are only pegged down on the one side of the frames. On foggy, rainy or very overcast days when there is little wind, the frames are left open so the cuttings can get extra light. Also, when the cuttings are seen to be rooting, the burlaps can be left open for longer durations to accustom them to more ambient light and moisture conditions.

Burlap removal and cutting care. In the mornings, after 3 to 4 weeks, the cuttings are checked for rooting by tugging on them. Cuttings often start regrowth when they are rooted. When most of the cuttings in the frame are rooted, the burlap is pulled off the frame and the frame is covered with double overlapping shades to initially give very indirect light and increased aeration. After 3 or 4 days, one layer of shades is removed to again increase light and to accustom the cuttings to ambient humidity. We are currently using synthetic snow fencing for our shading, cut from 100 ft rolls, 4 ft wide, which allows about 50% light. Most rooted cutting cultivars can be unshaded totally about 1½ weeks after removal of the burlaps. Because the frames are open bottomed, they are lifted off the beds about 2 to 3 weeks after the burlap removal, then the bed edges are firmed by packing them down by foot.

After the burlaps are removed, cuttings of most cultivars will put on a nice flush of growth throughout August and September. *Cornus, Hydrangea, Weigela, Kerria,* and others often reach heights of 12 to 15 in. with good calibre. *Spiraea, Potentilla,* and *Symphoricarpos* grow strongly and branch well, forming strong transplant material about 10 to 12 in. tall. Fertilization with a Cameron diluter and a garden sprinkler is done in the beds in late July and early August with a soluble 10-52-10 material to promote root development.

Winter storage. Normally, if reliable snow is common through the winter, cuttings can be left in the beds until spring. We usually

root cuttings of tender cultivars in common beds so that we can set up simple ridgepole structures of 2 × 2 in. lumber and erect a poly tunnel of opaque nursery film to moderate the extremes of winter weather. Mulching of the tender cultivars also helps protect them. If one has coolers or sufficient greenhouse storage, the liners can be lifted and overwintered there. We feel that if the cuttings are left undisturbed overwinter and moved before bud break in the spring, that we get the best transplanting success.

Pest control. Very few problems have been witnessed in the use of this propagation system. Fumigation of the soil has drastically reduced cutting losses, which were once due to harmful rooting medium pathogens. Also, the use of the fungicide dip and hormone treatments of the cuttings have been instrumental in dramatic rooting percentage increases. Both the fumigation and cutting preparation techniques have been added to the original "Burlap Cloud" technique since it was originally described to the IPPS members in 1953 (1).

Cuttings are sprayed while they are in the frames during the rooting stage with a fungicide/insecticide solution. This is done about every 1½ weeks unless spot treatments are necessary more frequently to control specific pests such as aphids on *Spiraea*.

Disadvantages. Criticisms of this technique are generally twofold: *Firstly,* the method is fairly labour-intensive in the soil preparation portion. We hope to mechanize the soil sifting in the near future as this is the only real step where we feel the labour is not being utilized effectively through the system.

Secondly, many question the manual application of water to moisten the burlaps through the day. We feel that the only system that could approach the thoroughness that a responsible cutting crew gives us would be a very good mist system governed by an electronic leaf sensor. This would allow the burlaps to get water consistent with the changing water demands of the burlaps through the day. But since there are reliable people around through the production cycle we have found it, to date, to be senselessly expensive and redundant to install a system like that.

Advantages of Burlap Cloud System. I feel that this propagation system is as viable now, if not moreso, as it was when introduced by Leslie Hancock. It can be used by small and large operations alike given soil conditions that are suitable. The beds which have been produced at Sheridan Nurseries in Georgetown, Ontario this year have drawn a lot of interest by visiting nurserymen who are intrigued by the percentage take and strong aftergrowth of the liners. I especially suggest that the system is a great way for new or expanding operations to markedly increase production with very little capital cost. The simplicity of the system is shocking when compared with more typical greenhouse or mist bed propagation structures. Tens of thousands of cuttings can be produced in a small

area of growing land which can be utilized very intensively with field soil as the rooting medium. Cutting storage right in the beds using mulch or simple tent structures of opaque poly also reduces the need for more elaborate cold storage facilities or greenhouse space. Undisturbed cuttings can put on strong growth through early fall, storing carbohydrate reserves to enable them to overwinter well and provides strong transplants the following spring.

Cultivars, such as those in *Prunus* and *Philadelphus,* which do not root well consistently under mist, do incredibly well in the "Burlap Cloud" system with reliable takes and regrowth.

SUMMARY

I encourage growers to look into this simple but effective method of softwood cutting propagation and not to dismiss it due to its basic approach. Elaborate facilities are not always the answer to increases in production. Time has proven this method to be an effective basis of production at Woodland Nurseries and has proven a valuable adjunct to other propagation systems used at Sheridan Nurseries.

LITERATURE CITED

1. Hancock, L. 1953. Shrubs from softwood cuttings. *Proc. Inter. Plant Prop. Soc.* 3:151–164.

CORNUS FLORIDA AND *CORNUS* 'EDDIE'S WHITE WONDER'—SOILS, ROOTSTOCKS, AND PROPAGATION FOR SHADE TREE PRODUCTION

PAUL REIMER

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One of the most beautiful trees that can trace its "roots" to British Columbia is the 'Eddie's White Wonder' dogwood. The tree was bred and introduced by Mr. Henry M. Eddie, a pioneering nurseryman in British Columbia. Mr. Eddie grew mostly fruit trees and roses, subsequently supplying most of the fruit trees for the Okanagan orchards of B.C. in the late 20's and 30's.

During his life in Canada, one of his major interests was the breeding of dogwoods. His goal was to combine the best qualities of two dogwoods: *Cornus nuttalli* (Pacific flowering dogwood) and *Cornus florida* (Eastern flowering dogwood). He hoped to produce a

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plant having the fine flowering size of *C. nuttallii* and the autumn color of *C. florida*. A number of promising crosses were developed, some of which had weeping habits. In 1948, the Fraser and Vedder rivers overflowed wiping out most of his potential hybrids. Fortunately, one cross between *C. florida* and *C. nuttallii* was so promising that it was cloned and lined out at his Richmond farm. Had it not been for this we would not have had *C.* 'Eddie's White Wonder' today.

To describe this plant we could say it is upright with slightly pendulous branching and with dark green foliage with fiery autumn colors. It has a heavy profusion of pure white flowers about 2 weeks after *C. nuttallii*. Dogwood leaf blotch, a fungal disease causing blotching and decay of the leaves and flowers has affected the native species in recent years. However, *C.* 'Eddie's White Wonder' shows a lower susceptibility to the disease.

My father and grandfather started growing this cultivar in the late 50's, early 60's. All the growing was done in the open ground and even today we don't grow any plants in containers. I would like to discuss three things that were learned the hard way as they relate to *C. florida* and *C.* 'Eddie's White Wonder'.

Soil Selection. Any *C. florida* or *C. nuttallii* grown in soil require that soil to be well-drained especially in winter during the heavier rains. The soil may be a clay loam or a sandy loam but the key thing is that it be well-drained. This previous spring (1988), during prolonged rainfall, some of our young budded plants succumbed even though they had only a little surface water for more than 48 hours. I mention this seemingly obvious point because it is essential for the practical propagator.

Rootstocks. In the first decade of growing 'Eddie's White Wonder' we had a good supplier of *C. florida* rootstocks without realizing the importance of fibrous roots to dogwood seedling survival. When this first supplier went out of business, we purchased seedlings from other sources. These seedlings had tap roots with only a small amount of fiber on the side of the tap root. After planting, these seedlings were not vigorous enough to "bud" well. The bark would not slip and bud life was poor. Growth during the following years was also poor. Eventually we found our problem and a number of good suppliers who were able to develop the fibrous roots that were necessary for *C. florida* survival.

Secondly, avoid storage of *Cornus* seedlings in the cooler. When we receive our *Cornus* seedlings in spring we dip the roots into a mud slurry and heel them into a clay field. Perhaps having them heeled into sawdust beds would work just as well. Since we adopted this practice, the plants seem to "jump" into leaf better after planting.

Propagation. Bruce Macdonald writes about grafting *C. florida* under glass in January or February using a side veneer graft.

Our experience has been with budding. We have tried T-budding and chip budding with rubber ties and with plastic ties. The best results have come with regular T-budding and tieing in with plastic ties, leaving an opening for the leaf petiole and bud to "breathe". Chip budding has not been successful for us but perhaps our timing has not been right for chip-budded dogwoods.

Rootstocks that have been planted in May are budded in late August or early September. We like to wait as long as possible in order to give the scionwood a chance to mature. Any scionwood that has too much flex to it or is too pulpy is rejected.

In the morning, scionwood is collected from 2 yr trees. Leaves are removed and the scionwood is wrapped in wet newspaper to maintain freshness. The grafter cuts a 1-in. T-cut near the base of the rootstock and opens the bark by slipping the knife under the bark. The scion is formed by cutting a shallow 1-in. section under the bud, ensuring that a small sliver of wood remains under the bud. This is slipped into the T-cut. Clear plastic chip budding tape is used to tie the bud in, leaving only the bud exposed while covering the rest of the wound. The union should be complete in one month, after which the plastic tie is cut.

The following March the top of the budded plant is cut off just above the bud and the new shoot is tied onto a straight cane to ensure a straight stem. Side branches are pruned off the following winter while allowing the top to continue through, producing a well-branched 2 year tree.

This method has worked fairly well for us during the last few years producing results of 90 to 95% bud "take".

PROPAGATION OF CULTIVARS OF *STEWARTIA*, *ACER PALMATUM*, AND *FAGUS SYLVATICA* FOR OPEN GROUND PRODUCTION

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STEWARTIA SPECIES

A group of small to intermediate sized trees that is not widely known or used, but sought after, is the genus *Stewartia*. Comprised of about six different types, all are somewhat similar, differing mainly in flower size and tree size or shape.

Stewartia pseudocamellia is probably the best known with closely related *S. koreana* being very similar. We have worked with *S. ovata*, *S. sinensis*, and *S. monadelpha*, also with limited success in each species. At Ekstrom Nursery we have had the most success with *S. pseudocamellia*, *S. monadelpha*: *S. pseudocamellia* as rooted cuttings and *S. monadelpha* as seedlings. Because there is little written on this genus most of our knowledge has come from trial and error experiences.

As I said, we use seed propagation and softwood summer cuttings. The seed is held in five-valved pods which we try to collect, generally, just prior to pod opening, usually in October. As they dry they will open but the seed is not easy to remove. Once the seeds are extracted we stratify them, using moist peat at a warm 70°F. Generally the seed takes two seasons to germinate but if the seed has been collected early enough it may begin to germinate. We watch it closely for the first month. By December, if we see no sign of activity, we will sow the seeds in flats and place them in our greenhouses. The flats will remain throughout the following summer and good germination is then obtained the following spring, basically 1½ years after collection. We grow them one more full season before transplanting. Flats are used for sowing rather than field seed beds so as to control the environment where the growth takes place. The plants must not be moved when dormant. This is very important. The young plants are tender and we let them establish themselves in 4 × 6 in. deep pots before taking them to the field to grow on.

We also have had some success propagating softwood cuttings. The cuttings are taken when the wood has become turgid, generally in mid-July. We collect cuttings in the early morning and process them quickly. We like to use 6 to 8 in. cuttings, sticking them about 2 in. deep in 2¼ × 5 in. pots. The medium is made up of about 50% perlite, 25% bark, and 25% peat. The medium must be dry enough to prevent over-wetting but also provide some growing capabilities, because we do not transplant them for at least one full

year. As with the seedlings the young plants are tender. It is possible we are overly cautious, but we have lost a large number due to speeding the process.

We use Dip & Grow or Wood's Rooting Hormone at a 1:5 rate, using a quick-dip. Regarding misting of the cuttings, we have used Pate nozzles and an electronic leaf control system. We tried fog also and it works alright but it is more difficult to control. We use band pots with open bottoms, allowing us to place the pots on expanded metal benches, providing air pruning of the roots as they begin to grow. The process sounds slow but we have had very poor results rushing the process. We have been working with *Stewartia* for six or seven years and I understand why it is not widely grown in the industry. Even with the time and difficulties involved it is a plant that should be grown.

ACER PALMATUM CULTIVARS

We grow rooted cuttings of upright red Japanese maples, *Acer palmatum* 'Bloodgood' and 'Oshio-beni'. They are all done in a very similar manner. We find we can use 100% pumice for the rooting medium. After rooting we can transplant the cuttings the following spring as growth has begun. Here again, the key we have found is not to allow the cuttings to become overly wet. Another grower in our area has used lights to extend the photoperiod with excellent results.

FAGUS SYLVATICA CULTIVARS

Many cultivars of *Fagus sylvatica* exist but probably less than ten are commercially produced in any great numbers. The cultivars that are most popular from our experience are: *F. sylvatica* 'Purpurea Pendula', 'Riversii', and 'Roseomarginata'. The other cultivars that have commercial interest for us are: 'Asplenifolia', 'Pendula', 'Rohanii', 'Spaethiana', and 'Dawyckii'. Another one called *F.* 'Purple Fountain' is a seedling of 'Weeping Purple', introduced in Holland by Grootendorst in 1975. It has narrow upright growth and a central stem or leader. The purple foliage seems to be as dark as 'Purpurea Pendula' and appears to have a little glossier leaf.

Propagation of *Fagus sylvatica* cultivars is normally done in the greenhouse by grafting during January or February or by utilizing the hot callusing pipe method in outside or inside beds during the same months. We grew these cultivars for about 15 years using the winter grafting method, either buying or producing our own grafts. The change in our propagation method occurred about ten years ago. I visited a neighboring nurseryman who was stick budding some 'Roseomarginata'. He was budding the trees up about 2 or 3 ft above ground level. He encouraged me to try a few stick buds at

home and I decided that was a good idea. I double-budded a couple rows of trees and got about 60 to 70% bud take.

Let us now go through the process we use today. The seed we buy is received in December or January and sown immediately or stratified in sand at 34° to 40°F. for approximately 40 days. We plant the seeds when the weather permits or as near their germination date as possible. We watch them closely as the germination date gets closer. The seedlings are grown one summer in beds, undercut, and graded the following winter. We also purchase seedlings from a couple of local growers to add to our own seedling production.

The rootstocks are trimmed, especially the tap root, and heeled in sawdust outside. We tried holding the seedlings in the cooler but we would rather get them planted early and see bud initiation early, normally in April. This way we can get maximum growth the first year.

Spacing of the seedlings in the row is 7 to 8 in., but I would prefer a 10 to 11 in. space if land was available. The width of our rows is 54 in. We try to plant ¼ in. or #1 grade bare-root plants to be able to bud the tree the first year it is lined out. If the plants are not big enough we will bud them the second year.

One other possibility exists that we have not tried, that is planting a potted liner to reduce the shock or setback problems sometimes encountered with bare-root liners. We have the added cost of potting and holding the plant—but more bud uniformity probably could be achieved.

We use about 700 to 800 lbs. per acre of 10-20-20 fertilizer incorporated into the soil as a preplant, along with about two tons of dolomite lime per acre. Each year we side-dress in the same amount of fertilizer. We also put on about 150 lbs. of 34-0-0 in February.

BUDDING PROCESS

The "stick bud" method can be used with *Acer palmatum*, *Fagus sylvatica*, and other plants with good success. *Fagus sylvatica* stick budding generally is done in July and August. Scionwood should be cut so that it will match up with the size of the understock. The flat cut on the scion must match up against the round surface on the understock. Usually two-year-old trees are ready for budding about mid-July and one-year-old trees are ready from late July to mid-August.

Procedure:

1. Scionwood should be mature, a little firm or stiff.
2. Cut the scions and de-leaf by pulling the leaves off.
3. Keep scions in damp burlap in a cool place.
4. Make a slanting cut 1 in. long, close to the bottom of the bud on the scionwood.
5. Make a T-cut in a flat, smooth place of the understock and insert

the stick between the two flaps of bark. The T-cut generally is from 2 to 8 in. above ground level.

6. Tie the stick bud with a budding strip, leaving no gaps between the turns. Sealing compounds can be used on the tip of the scion to help prevent desiccation.
7. We generally use two buds per stick bud, choosing the best one the following spring as our leader.
8. We cut the understock off in April after the buds start to swell, about 1 or 2 in. above the bud.
9. We tie up the new shoots as soon as they are long enough.

Advantages of stick budding *Fagus sylvatica* cultivars during summer

1. The production cost is less as compared to a greenhouse graft.
2. Faster growth both in height and caliper can be achieved.
3. A strong bud union is produced.
4. A well developed root structure and branching structure is facilitated by transplanting a 5/6 ft tree.
5. *Fagus* can be included in the summer budding program easily.
6. No greenhouse space is necessary, thus requiring less handling and initial care than a greenhouse graft.
7. The cost of losses are less based on initial outlay, i.e. budding vs. grafting expense.

Disadvantages of Field Budding

1. There may be inconsistent bud success based on many variable factors, including: climatic conditions, length of season, type of soil, and others.
2. The cost of transplanting a larger tree (4/5/6) and the equipment that is required.

Stick budding of *Fagus* provides another alternative for the commercial producer if climatic conditions exist that make it feasible. The soil and climate in our area is suitable for using the above method but may not be in other locations. In light of these variables, each nursery must determine the feasibility of stick budding Fagus.

ACER PALMATUM—FIELD PROPAGATION

The propagation of *Acer palmatum dissectum* cultivars at Ekstrom Nursery utilizes stick budding similar to the *Fagus* procedure.

Budding usually begins about the middle of July and ends about the middle of August. The rootstock must be actively growing and the bark slipping for a successful union.

We use the early spring growth from our field-grown stock, using primarily tip buds. Tip buds refer to the ends of the new

growth on the stock plant. We use two to four sets of buds on the stick.

The scionwood is mature if it is firm or stiff and has a slight streaking on the bark. The procedure from this point is the same as the *Fagus* stick budding process, except for our spring pruning.

Usually in March we begin to see bud swelling on those stick buds with a successful union. We cut the understock back to one foot above the stick bud and will cut it back to about two in. above the stick bud after the initial growth occurs, usually three to four weeks later.

Stick budding of both *Fagus sylvatica* and *Acer palmatum* cultivars has proven to be a very useful method for open field production.

STRANGE GRAFTS I HAVE KNOWN

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Because grafting involves living organisms, it is not too surprising that there are as many exceptions regarding compatible stock/scion combinations as there are rules. For instance, in most cases a cultivar of a particular species will flourish when grafted onto a seedling of the same species, but there are examples, such as *Acer rubrum* cultivars and *Quercus palustris* 'Sovereign', where grafting onto the species can result in eventual failure of the union resulting from delayed incompatibility. There are many documented cases of graft compatibility between species in the same genus, and a smaller number of successful grafts recorded between members of different genera within the same family. The success of these less closely related combinations offers sufficient encouragement for propagators to continue trying to use more common, readily available species as rootstocks when confronted with unfamiliar species or cultivars to be propagated. In my career, I have encountered several unusual interesting grafts, some of which I will discuss and evaluate in this paper.

The rose family has provided both examples of compatibility between different genera, and incompatibility within a single genus. The medlar, *Mespilus germanica,* is a pome fruit, and when grafted on *Pyrus ussuriensis* will unite and grow, but displays the symptoms of localized delayed incompatibility, (2). Bark is not con-

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tinuous across the union, but is separated by profuse callus tissue. The general appearance of the union suggests that the scion is perched on the stock rather than joined to it.

A similar situation occurred a few years ago, when dormant scions of *Cotoneaster affinis* were received and were chip-budded onto seedlings of *Pyrus pyrifolia* [syn. *P. serotina*] in one gallon containers. Union was successful and growth from the scions was vigorous. Shoots 3 to 4 ft in length were sectioned into cuttings, which were successfully rooted. In this case also there was extensive callus production and discontinuous bark, and when moderate pressure was applied to the scion growth, it broke off cleanly at the union.

A different response was observed when scions of *Sorbus granulosa,* a simple leaved species, were chip-budded onto seedlings of *S. caloneura*. The union appeared normal, but the growth from the scion was spurlike, very short and containing several buds. Similar results occurred when, faced with no pear rootstocks at hand, I grafted unexpected scions of *Pyrus calleryana* 'Capital' onto *Crataegus laevigata* [syn. *C. oxyacantha*]. Some grafts united and, although the scions produced only stubby growths, these provided bud chips for grafting onto *Pyrus calleryana* rootstocks later that season.

The Japanese flowering cherries are frequently top-worked at 5 to 6 ft onto seedling or clonally propagated *Prunus avium* (mazzard). This combination is compatible but, as the plant matures, the stout trunk of the mazzard, and the swelling at the graft union, contributes to an unnatural, almost bizarre, appearance. The resultant tree will look much better if the stock is budded or grafted low, so that the trunk is developed from the scion. A very ornamental alternative for flowering cherry production is practiced at Weston Nurseries in Hopkinton, Massachusetts. There the scions are top grafted onto stems of *Prunus serrula,* which has exquisite, glossy red bark. This practice yields specimens which have great appeal even when out of flower.

Magnolia is a genus which displays little, if any, true graft incompatibility among different species. It is advisable, however, to consider the vigor and ultimate size of the scion cultivar when choosing a suitable rootstock. When the vigorous, large-growing Asian species, *Magnolia campbellii, M. dawsoniana, M. sargentiana, M. sprengeri,* and their hybrids are grafted on *Magnolia kobus* or *M.* × *soulangiana,* they will succeed, but an unsightly overgrowth develops at the union. This "goiter" would be less conspicuous if it were close to the ground, but frequently the grafts are placed 10 to 12 in. up the stock. Because it is the hardiest of the large Asian magnolias, and seed was available locally, I tried seedlings of *Magnolia sprengeri* 'Diva' as rootstocks for this group, and am very satisfied with them. With *Magnolia sprengeri* rootstocks, growth of

the scion is vigorous, and within a few years it becomes difficult to locate the graft union, so similar are the stock and scion in growth rate.

The only indication of incompatibility in magnolias that I have seen occurred when I chip-budded *M. acuminata* var. *cordata* 'Miss Honeybee' onto a seedling of *M. dawsoniana*. The union knit cleanly, but the scion growth was stunted. It grew to only 15 inches over two seasons, and remained much smaller in caliper than the stock. Although the union did not fail, growth was far from satisfactory.

Stunting was also the result when *Betula chinensis* was chip-budded onto *B. pendula*. *Betula chinensis* is a large shrub or small tree. After it was grafted on *B. pendula,* the scion elongated rapidly to about 5 ft in height, and then stopped. Branches which were produced bent down toward the ground. The diameter of the scion growth was one-third that of the stock. The following year, no more extension of the leader occurred. All growth went into the drooping branches.

Robinia pseudoacacia was the rootstock for two interesting grafts I have seen. One year in early June, in Bellingham, Washington, my attention was alerted by a tropical-looking small tree with large, rose-pink clusters of flowers. On closer inspection, I saw that it was a *Robinia* (later identified as *R.* × *ambigua* 'Idahoensis'). It had been grafted on black locust at about two feet, and with the stock being twice the diameter of the scion growth, it had the appearance of a tree growing out of a stump. Here too, grafting as low as possible would do much to improve the appearance of the specimen.

In Seattle, Washington, a few years ago, I noticed some rather unthrifty wisteria standards. Their crowns were thin and contained some dead branches. The wisterias were grafted about 1½ ft up on stems of black locust. The grafts had obviously lived and grown for a few years, and the leaves were still expanding when I saw them, so it is not possible to comment on the appearance of the plants in flower or full leaf.

Girard Nurseries of Geneva, Ohio, for several years have propagated and sold a maple listed as *Acer griseum* 'Girard's Selection' (1). This cultivar appears to be a hybrid between *Acer griseum* and *A. maximowiczianum* [syn. *A. nikoense*]. Its bark differs from that of *A. griseum* in that it exfoliates in small shreds, but it is still very attractive. Peter Girard, Jr. states that in nursery production the hybrid is superior to *A. griseum,* being faster growing and more inclined to form a leader. Girard propagates this cultivar by bench grafting onto *Acer saccharum* rootstock. I inspected several grafted trees as old as ten years, and observed both unions which appeared compatible, with continuous bark and uniform diameter of stem above and below the union, and unions which looked to be headed

for failure, with swelling and a continuous groove around the stem at the point of union. Some of the unions which showed symptoms of delayed incompatibility were tested mechanically and proved quite strong. All of the older trees were grafted 8 in. or more above the ground, but Girard reports that he is now grafting as close to the root collar as possible, which seems to limit swelling at the union.

By this point, it must be obvious that I have a bias toward placement of grafts low on the rootstock. Although oddities such as I have described are of interest, I believe that it should be the goal of every propagator to produce graft unions that are as nearly invisible as possible. It is one manifestation of the art of our profession.

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DEVELOPMENT OF DOUGLAS-FIR CLONES FOR CHRISTMAS TREES

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Coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) var. *menziesii* is the major Christmas tree species in the Pacific Northwest. An estimated 3.7 million trees were harvested in Oregon in 1987, most of which were genetically unimproved planting stock. As a result, there is considerable variation in such important characteristics as vigor, form, needle color, and budbreak, which profoundly affects tree quality, length of rotation, and culture. Genetic improvement of seed parents has been explored by Oregon State University and the Northwest Christmas Tree Association. Because of the long commitment required for seed orchard development, however, this approach has seen only limited application.

Asexual propagation of selected, superior trees is being studied as a more rapid method to realize genetic and economic gains. Development of superior Douglas-fir clones for the Christmas tree industry has been underway in the Department of Horticulture at Oregon State University for about 15 years. We have identified promising clones, developed selection criteria for new clones,

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developed propagation guidelines, and explored commercial propagation and culture. Utilizing net present value analysis, an increase in value per acre is expected for Douglas-fir clones (Table 1).

Table 1. Comparison of net present value per acre for Christmas trees established with improved Douglas-fir clones and unimproved seedling stock (4).

Planting stock	Cost (each)	Rotation time	Grade[1]	Net present value[2] per acre
C-1 clones	$ 0.35	7 yrs	100%	$ 1,655
C-1 clones	0.50	7	100	1,448
2-1 seedling	0.26	7	80	1,444
2-0 seedling	0.15	8	80	1,205

[1]percent of harvested trees that grade number one or better.
[2]net present value calculated using 12 percent interest rate, harvesting 1,094 trees per acre.

SELECTION OF CLONES

In any plantation of seedling Douglas-fir there will be genetic variation (3). Only a small percentage of the trees will have phenotypic traits that are outstanding for Christmas trees. While these traits, such as vigor, form, and color are influenced by the environment, they can also be inherited. When an "elite" tree is selected as a possible clone other traits, not visually expressed, must also be evaluated. Two very important traits that can be inherited are rooting potential and orthotropic (upright) leader growth (2).

Young plantations are well-suited for selecting trees; the more vigorous trees are easy to locate, and cuttings from the juvenile trees are easy to root (1,5). In addition to vigor, form, needle color and quality, branch habit and bud set are also evaluated. Fifteen cuttings are collected from each tree, beginning in January. In May, cuttings are evaluated for rooting percentage and root quality. Acceptable rooting is defined as the presence of three or more large, actively growing roots. Five or more large, actively growing roots are rated good. Only field selections with an acceptable rooting percentage of 80 or better are retained. Rooted cuttings are lined into either transplant beds or containers in May and June. Most of the cuttings are well-rooted and have high survival. The cuttings are grown under conditions common to commercial conifer seedling production. Currently two growing seasons are required to increase plant size and improve the root:shoot ratio.

After growth in the nursery for two years, five trees of each clone are planted at the Oregon State University Horticulture Farm and cultured as Christmas trees. Many of the selections are discarded during this period, usually for failure to grow orthotropically. Clones which show sufficient promise are pruned heavily for cutting production and commercial testing. Plots are

located in Oregon and Washington to observe the effects of different environments on tree performance. Each clone is evaluated annually for height and form and will be graded at harvest age for value. Comparisons with seedling populations are also being made. Characteristics of seven of the most promising clones to date are presented in Table 2.

Table 2. Characteristics of seven Douglas-fir clones for use as Christmas trees.

Clone	Height[1]	Form[2]	Rooting[3]	Comments
Douglass 8	1.48m	5.1	91.3%	Vigorous, somewhat woody.
Douglass 13	1.41	6.9	77.4	Good overall.
Hofert 3	1.41	6.0	88.5	Somewhat plagiotropic.
Douglass 15	1.37	5.6	86.0	Straight, narrow, excellent color.
Douglass 12	1.32	5.4	76.3	Good overall.
Kintigh 21-2	1.28	6.4	57.5	Good overall.
Douglass 10	1.26	4.7	88.4	Weak growth.

[1]average tree height (in meters) of two field plots measured in May, 1988, after three growing seasons.
[2]average tree form of two field plots rated from 1 to 10 (1=poor, 10=excellent) evaluated May, 1988, after three growing seasons.
[3]average acceptable rooting percentage, based on 1983 and 1985 through 1988 rooting performance at OSU, Corvallis.

PROPAGATION GUIDELINES

Guidelines for cutting propagation of Douglas-fir clones have been developed through both research and observations made with commercial propagators. The period of highest rooting potential is from January to mid-March. Cuttings consist of 15 cm of current season's growth with a terminal bud. The needles are stripped from the basal third of the cutting which is then dipped for 5 sec. in a solution of 1000 ppm NAA plus 2000 ppm IBA. The preferred rooting medium consists of five parts perlite to one part peat, but others, including sand may be acceptable. The medium is maintained at 18° to 21°C, while air temperature should be 10° to 18°C.

Douglas-fir cuttings benefit from relatively dry conditions. Overwatered cuttings and saturated media greatly reduce rooting and experiments are being conducted to determine the optimum mist interval. Grey mold (*Botrytis cinerea*) can be a serious problem when excessive moisture is present. Alternate weekly sprays with vinclozolin and chlorothalonil are suggested to help protect the buds and foliage.

COMMERCIAL PRODUCTION

Clones as a group may require slightly different shearing and basal pruning techniques than currently used for seedlings. New

plots are established nearly every year to test more recent selections, modify cultural procedures and acquire a progressively better comparison between clones and seedlings.

Cutting-one (two years-old) plants have been successfully lifted and field-planted in both fall and spring. Site preparation, care, handling, and planting are similar to those methods used for bareroot seedlings. A commercial field plot, using one year-old cuttings, was mechanically planted in March, 1988, and had 98% survival.

In the spring of 1988, data were collected from a plot near Corvallis consisting of 18 clones, 10 trees each. The plot is adjacent to a field of seedlings the same age. Each field had completed three growing seasons at the time. The height of the clones and 18 groups of 10 seedlings was measured, averaged and ranked. Sixteen clones had greater average height than the tallest group of 10 seedlings. The six highest ranked sets of clones and seedlings are compared in Figure 1.

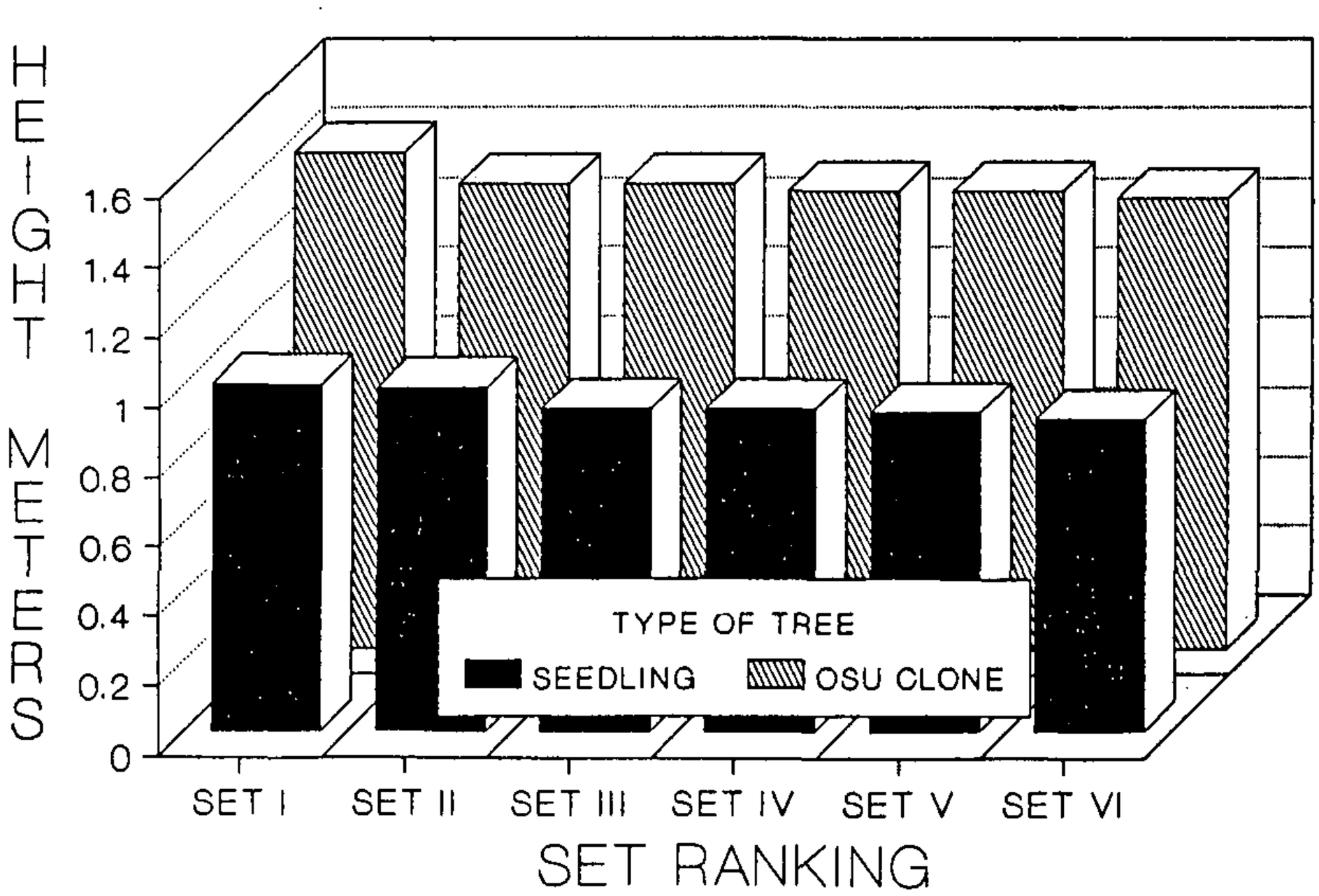

Figure 1. Height comparison of the six top ranked sets of same age OSU clones and unimproved seedlings after three growing seasons.

In summary, Douglas-fir clones have been selected for vigor and ornamental quality in Christmas tree production. Preliminary evaluations in commercial plots suggest that these clones have significantly higher value than seedlings. Additional trials are being conducted to determine the economic and cultural constraints and potential with clones.

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MARTIN MEYER: Stick buds—are they shoved down into a T-cut, or are they put into more of a chip-bud cut?

DON EKSTROM: It is a T-cut in the stock plant with insertion of the stick-bud under the two flaps. You must have good sap flow for success.

VOICE: Fraser, why do you feel the older "burlap cloud" method is so successful?

FRASER HANCOCK: We do fumigate the soil. We caution workers about bringing in contaminated soil on their shoes. We have grass walkways between the rooting beds. We have very few problems. We spray every week or so with an insecticide-fungicide mixture. We have very few losses in the system. But our system is best used as an adjunct to other methods. At Sheridan Nurseries we use the burlap cloud method along with mist beds and standard greenhouse production.

CONIFER PROPAGATION IN DENMARK AND NEW CONIFER INTRODUCTIONS

ANTON B. THOMSEN

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This summer it is 38 years ago since I worked at Bonnell Nursery in Renton, Washington, and at Malmo Nursery in Seattle. At that time I thought that this area must be one of the most beautiful places in the world, and I still think so. It is certainly perfect for most plants.

The first part of my talk is about "Conifer Propagation in Denmark". As we are the largest grower of conifers propagated by cuttings in Scandinavia and, as most of the other nurseries do as we do, it will be our way you will be hearing about. First a few words about the climate and wages because these two factors have great influence on explaining how and why we do things as we do.

Denmark is located approximately as far north as Sitka, Alaska, so we have short days during the winter and long summer days. The winter weather varies a lot from year to year. A few years ago we had temperatures down to −30°C (−22°F), but usually it is between +5° to −20°C, (41° to −4°F), changing between frost and rainy weather several times during the winter. The summers are usually fairly cool with an average temperature of 18°C (64°F) in July. This year the maximum temperature was 30°C (86°F) which we consider very warm.

This year labour goes per hour from 9.5 US dollars (1 US dollar = 7 Danish kroner) for unskilled labour, to 11.5 US dollars for skilled labour + 30% social costs. Of this amount the worker has to pay per year between 40 to 55% taxes on what is over 20,000 Danish kroner. We have a 38 hour work week and 5 weeks vacation. Of course, then we have free medical care, education, etc.

As a potted liner in a 10 cm (4 in.) pot costs approximately 1 to 1.6 US dollars a piece, you can see that it is easier to be a nurseryman in Canada and the USA. By the way, all overtime work is for the first two hours + 50% and, after the first two hours, it is +100%. Almost everybody is a member of a union.

In our nursery we do not grow any plants from seed. We use quite a few *Picea* and *Pinus*. They are all bought from specialized nurseries as 3 or 4 year old liners. Most of our conifer cutting production is done in greenhouses, and most of the shrubs are made outside in June and July, just covered with a layer of white plastic directly on top of the cuttings.

We have four aluminum greenhouses, 20 × 61 m (66 × 200 ft), equipped with bottom heat and normal overhead heat. The two

houses are used for propagation; the one used all year round has automatic shading controlled by a photocell which also turns the shades on at night in order to save energy. It is also equipped with mist propagation controlled by an electronic leaf. Heat, air, shade, *etc. is automatically controlled. Previously we used to have* different media for different species, e.g. for most *Taxus* we used peat and sand mixed, but for *Taxus baccata* 'Fastigiata Aurea' and *Taxus baccata* 'Semperaurea' we had a 2 cm (0.8 in.) layer of sand on top, and that was also used for several junipers. Today we use the same medium for all and that is 75% peat and 25% styrofoam, and the results have been excellent.

All cuttings are stuck in plastic flats, 30 × 60 cm (11.8 × 23.6 in.) or, as we have been doing in recent years, 40 × 60 cm (15.8 × 23.6 in.). Last year we stuck approximately 100,000 cuttings, trying different types of Speedling trays. The results were mostly good, but we found that where we had problems with drying out, it was either because the medium was looser in some places that in others, or that the flats did not have a good enough connection with the sand underneath, so the capillary effect did not work. So this year we have bought a machine to fill the Speedling trays and it does a very fine job giving an even firmness in the trays.

When we have found the right type of Speedling tray and have a new setup for potting, we are sure that we can improve the speed of the potting machine approximately 50% and, as we do not have to prune the roots of the cuttings, we can also improve the growth. Next year I will know for sure.

All the flats are put on a sand bottom which is sterilized between every season and renewed every three years. We use the sand in order to have good connection between the medium in the flats and the sand to achieve maximum capillary action and as much aeration of the medium as possible. Also by having the cuttings at the bottom of the greenhouse and the mistlines 1.9 m (6 ft) above them, we have a very fine mist effect, and in that way use as little water as possible and still keep the cuttings humid at all times.

All conifer cuttings have the lowest 2 to 3 cm (0.8 to 1 in.) branches stripped off, and that way they are also wounded. After being stripped they are laid in flats and dipped in a captan solution. We use a hormone powder by the name of Floramon, containing 0.4% NAA (naphthaleneacetic acid) mixed with 10% captan powder, 1 to 1, for almost all cultivars. We have done a lot of research during the years and there are a few cultivars where we had a slightly better result using IBA (indolebutyric acid), but it is easier just to use only one kind. I am sure that we could get just as good a result using IBA, but we have many years of experience using Floramon, which is a Danish product and therefore easily obtained. Every other week the cuttings are sprayed with Benlate, and every other week we spray with a different fungicide. When the cuttings

are rooted, a fertilizer is also applied. During spring, summer, and fall we try to have 22°C (72°F) in the sticking medium and a maximum temperature of approximately 26°C (79°F) in the air. From October on we lower the temperature and have in December approximately 15°C (59°F) in the sticking medium and a minimum of 10°C (50°F) air temperature, as we have found that a higher temperature seems to cause decay at the base of the cuttings, perhaps because we have very little light during the winter. In February we begin increasing the temperature. This is the way all conifer cuttings in greenhouses are treated, and now to the time of year when we make the cuttings.

Approximately July 1st we begin with juniper cuttings, starting with *Juniperus communis* 'Repanda', which is one of our most used junipers. Then the *Juniperus squamata* cultivars follow, then the *Chamaecyparis lawsoniana* and *C. pisifera* cultivars from approximately August 1st through September. After that we make *Taxus baccata* 'Repandens' and other *T. baccata* cultivars. Starting mid-October we stick the upright *Juniperus communis* cultivars. By this time most of the cuttings stuck in July and August are rooted and they are moved to the third greenhouse. In the empty spaces we now fill up with the *Taxus cuspidata* and *T.* × *media* cultivars. We think it is fine if they can have some frost before being stuck, but it is not necessary; 200,000 of these are not stuck under mist, but covered with plastic tents and we have fine results doing it that way. However, it is more difficult to watch them.

In January and February we pot all the junipers and *Chamaecyparis* in greenhouses three and four. As we empty the propagating houses we put *Thuja occidentalis* cuttings in and want to have them all finished by mid-March when our spring season usually starts. All rooted cuttings have been potted in 10 cm (3.9 in.) pots by that time. Actually we could start potting the *Taxus* in March–April when most of them are rooted, but we do not have the space nor the time. So they are potted during the summer together with *Thuja*.

As you can see, it takes approximately 10 months to produce a fine liner of *Chamaecyparis* and *Juniperus*. If, for instance, a juniper 'Mint Julip' is potted at the optimal time all the way through, then after two years you can have 30 to 40 cm (12 to 16 in.) and 40 to 50 cm (16 to 20 in.) plant in a 3½ liter (231 in^3) container, which is the usual sales size.

I might add that, together with the mentioned plants, we also make cuttings of *Microbiota, Abies balsamea* 'Nana', *Metasequoia,* evergreen shrubs, etc.

All *Picea abies* and *Picea glauca* cultivars are made outside in June. They are stuck in beds which have first had approximately 10 cm (3.9 in.) of peat and 4 kgs (8 lbs.) of NPK (12-3-9) applied and rototilled, sterilized, then covered with plastic for three weeks to

obtain maximum sterilization effect. After this all weeds and fungi have been killed. The beds are 75 cm (30 in.) wide and, after being levelled, we put 2 cm (0.8 in.) of a low pH sand on top.

The largest numbers are made of *Picea glauca* 'Conica', the dwarf Alberta spruce, of which we make approximately 80,000 cuttings. They are not stripped or treated with anything. They are under automatic mist and covered with milk white 50% plastic shade, on top of which we put white Fibertex, a type of cloth during sunny days to keep the temperature down. Nearly all cuttings are rooted by October, but we keep the plastic on during the winter. We have to be very careful that the cuttings are watered during March and April because the sun is strong and we cannot use mist. The unrooted cuttings will root in the spring.

In May the plastic cover is removed and during the summer the rooted cuttings are potted. We use a lot of these for Christmas decoration, from liners to 60 to 70 cm (24 to 27 in.) and larger plants. Sometimes we also root arborvitae and other conifers the same way if we have not made enough during the winter or if we get extra orders for rooted cuttings.

We hardly do any grafting anymore, only our own *Picea pungens* 'Thomsen' (which my father found in Pennsylvania), *Taxus baccata* 'Fastigiata Aurea' and *Juniperus chinensis* 'Blaauw'. The latter two we also make by cuttings without problems, but they grow very slowly, so it still pays to graft them. They are all grafted in January in the greenhouse on established understock, holding 14 to 18°C (approximately 64°F) in the peat medium, then covered with plastic for approximately two months. As the garden centers do not sell nearly as many grafted plants as before due to the high price, we have found it cheaper to buy the relatively few graftings we need. Also it seems to me that in order to have good results, you should either graft so many that you can have a skilled man looking after them all the time, or have a smaller nursery where you can look after the graftings yourself.

I hope this gives you an impression of how we propagate conifers in Denmark. We still experiment in an amateur sort of way every time a new material, idea, or mechanical equipment comes up. I am grateful to my teacher in New Jersey and Dundee, Illinois, Jim Wells, who was always trying new ways and seeing things from a different angle, and that has made life more interesting for me—but at times also more expensive. I was very happy and delighted to find that he is the guest of honour here, and I cannot think of anyone who deserves it more.

NEW CONIFERS IN DENMARK

Juniperus communis 'Green Ace'. A spreading form, up to 30 cm in height, a rather fast growth. Something like *Juniperus c.* 'Repanda' in shape, but higher and grows faster. It has a fine green

colour and it is very healthy. I think the plant will have a great future as a groundcover where the landscape architects want a conifer and where *J.c.* 'Repanda' is too slow growing. I found it on the rugged Danish west coast; it was awarded a gold medal at an exhibition in 1986. This year it is in the trade for the first time.

Juniperus communis 'Green Carpet'. A slow growing, very flat juniper found on the west coast of Norway. Like a dwarf type of *J. c.* 'Repanda'.

Juniperus communis 'Gnom'. Dwarf, columnar shape. Originated in Hungary.

Juniperus communis 'Vemboe'. A rather fast-growing columnar shaped juniper. As this plant usually has only one topshoot, you do not see much damage by snow and, because of that, it is rather popular in Scandinavia. *J. communis* 'Ramlösa' and 'Urshult' have similar characteristics. All three come from Sweden.

We also have an upright blue type of *Juniperus communis* which is not yet in the trade. We think it has great potential. It is the most blue-needled *J. communis* I have seen. It was found in Norway. We also have approximately 12 more types selected from the wild, especially one weeping type, which seems to be a plant for the years to come.

Juniperus communis 'Grethe'. A rather compact spreading type with bluish needles, approximately 40 cm in height. Looks fine but is rather difficult to propagate and might grow too slowly for commercial use.

Juniperus chinensis 'Skalborg'. A seedling we found in our nursery. It is an upright spreading type with yellow needles. It is rather nice but might have a better chance in southern Europe and the U.S. where the climate is warmer.

Juniperus 'Blue Swede'. A very fine and hardy *J. squamata* type. Upright spreading shape and blue needles. It sells very well in Scandinavia.

Juniperus squamata 'Meyeri' × *J. chinensis* 'Pfitzerana Aurea'. Has blue needles with yellow tips. Not named yet. This is from the same lot of hybrids as 'Blue Swede'.

Juniperus scopolorum 'Blue Pyramid'. Selected by me. It is very hardy, not quite as blue as 'Blue Heaven', but the blue colour is fine and the shape is the same but more compact. It seems to me to be the only *J. scopolorum* that does well in our coastal climate.

Juniperus virginiana 'Helle'. A seedling selected by me. Form and colour very much like *J. chinensis* 'Spartan'.

Juniperus virginiana 'Kim'. Also a seedling found by me. I like this very much because of its more elegant and not so compact growth and its beautiful green colour. It carries a lot of blue berries at an early age. It was awarded a gold medal at an international exhibition in Copenhagen.

Taxus baccata 'Thomsen's Dwarf'. A slow growing conical-

shaped yew found as a seedling in our nursery.

Taxus baccata 'Ingeborg Nellemann'. A seedling found in a nursery near Copenhagen. Similar in growth and colour to 'Dovastonii Aurea', but easier to propagate—and hardier.

Taxus cuspidata 'Nana Compacta'. A seedling selected by us. Compact, irregular form. Female plant.

Taxus × *media* 'Farmen'. A seedling found at our nursery. First we had *T. cuspidata* as its species name, but botanists thought it probably was a hybrid and asked us to change it to *T.* × *media*. The shape is upright spreading with long needles and a firm green colour. In test plantings in Sweden it was—together with 'Green Mountain'—found to be the hardiest and best yew, and today it is the most sold in Scandinavia because of its many fine qualities. Used for mass plantings and hedges. Also used as hedge along roads because it is salt and wind resistant, though I do believe most yews are salt tolerant.

Taxus × *media* 'Skalborg'. Also a selected plant from us. Stronger growing and more upright than 'Farmen', but more "open" so it must be sheared more. The needles are shorter and have a greener colour in early spring than most yews.

Thuja occidentalis 'Skogholmen'. Has a columnar shape like 'Pyramidalis', but does not carry seeds, which is an advantage when you sell it.

Thuja occidentalis 'Brabrant'. A fast growing arborvitae. Fairly dense in growth with a fine light green colour. A hardy plant, well-suited for hedges. Comes from Holland.

Thuja occidentalis 'Little Giant'. A round dwarf type with a nice green colour.

Thuja occidentalis 'Yellow Ribbon'. A columnar shaped arbovitae, warm yellow needles. Seems to be one of the best yellow cultivars for containers. We have not had much luck with 'Sunkist' or 'Europe Gold'.

There are plenty of other new conifer cultivars, but these are some of the best for our climate. I have also, during my visits in the USA, seen that *Juniperus horizontalis* 'Blue Chip' is used in large numbers. The real name should be 'Blue Moon', which I named it in 1962 and James Wells baptised it at an exhibition at Aalborg. I found this seedling in a Danish nursery and brought a few cuttings with me to Jack Hill, D. Hill Nursery Co. in 1956. After his tragic death nobody in the nursery knew where the plant came from. By that time it was only named *J. horizontalis*. No. 1, as there were four selected seedlings in all. No. 3 is also in production in Denmark under the name of 'Grey Pearl', but both of them are not very blight resistant in our climate.

Sinarundinaria murielae 'Simba' is a completely new plant which is for sale for the first time in a limited number this fall. This cultivar is smaller than the species, about half the size, and has more shoots and finer leaves. It originates from a batch of

seedlings from Thymes Planteskole and, according to the Botanical Garden in Copenhagen, it is very rare to get fertile seeds from *Sinarundinaria* in our climate.

Though I should only talk about new conifers, I would like to mention that a large number of shrubs have been especially selected by Hornum Research station for landscaping purposes. Among others, two *Ribes alpinum* have been selected; a male cultivar—'Hemus', which has a nice shape, very healthy leaves, and a female—'Dima', which is more "open", but also with healthy leaves. *Lonicera ledebourii* 'Vian', which is a strong grower, very wind resistant, and has very fine leaves.

LOW COST TECHNIQUES FOR SUCCESSFULLY OVERWINTERING ROOTED CUTTINGS AND LINERS

BEV GREENWELL

Happy Hollow Nursery
Abbotsford, British Columbia, Canada

Happy Hollow Nursery is located in the central Fraser Valley, 45 min. inland from Vancouver, B.C. We are on Sumas Mountain, 600 ft. above the flat farmland. Situated in a valley on the mountain we are protected from cold northeast winds which causes desiccation of plants down below, but are subject to being a "frost pocket" caused by air drainage off the mountain, and cold air settling in the valley.

Early fall frosts are to our advantage by putting the plants into dormancy slightly earlier than other places. Late spring frosts can be a problem after plants have started growing.

Our winter protection is based on encouraging acclimation, using the plants own abilities to withstand cold. We do everything we can to encourage cold acclimation in the fall, and everything we can to keep them dormant all winter, until danger of frost is over in spring.

Eighty percent of our business is in the production of lining-out stock, mostly deciduous and broadleaf evergreen shrubs. All cuttings are direct-stuck from plugs, 73 to a flat, 2¼ and 3¼ in. pots in the size of container they are to be sold. Overwintering has been our major limitation on volume production. Winter space is always in restraint. Not everything can go into heated houses, and not everything grows well in heated houses. Many plants require a cold period before they can properly break dormancy and grow in the spring.

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In determining the method of overwintering any particular plant, the first consideration is the plant's inherent hardiness—the ability of a plant to survive a set minimum temperature. The central Fraser Valley is rated as Zone 7B. We grow plants for the north (Zone 1), the prairies (Zone 2 & 3), back east (Zone 3 & 4), and Vancouver/Victoria (Zone 8). Plants rated hardy are only that hardy *when given the conditions to develop that hardiness.*

The roots are the least hardy part of a plant. Plants in containers can be rated two Zones more tender than their counterparts in the ground. Plants, such as liners in small pots, are even more tender.

Any plant less hardy than a Zone 4 (Toronto/Chicago), I protect inside a polyhouse for the winter. Any plant in a pot smaller than a 3¼ in. pot, regardless of hardiness rating, is overwintered in a polyhouse.

Liners kept outside include dogwoods, euonymous, spirea, and potentillas. These are mostly deciduous plants rooted directly in 3¼ in. pots. They are rooted early in summer and placed outdoors as *soon as they are rooted, then sold the following spring. Precautions* with these include doing them early enough to be thoroughly rooted prior to winter. In the fall sawdust is heaped around the edges of flats and in the crack in between. As colder weather approaches more sawdust is added, right over the pots. We hope to have the leaves gone prior to any cold spell.

"Cold spell", means a period of a few days or more of 22°F weather, where the pot surface freezes and does not thaw during the day. Cold weather such as this is our main concern, because as the weather lasts, the frost goes deeper and deeper into the pot, even though the temperature may remain the same. During a period such as this sawdust is shovelled right over the pots, burying the plants *completely. This weather is also very drying. The sawdust is not* only a great insulator, it also holds the moisture in and keeps out the drying winds.

We save our old plastic off the greenhouses for overwintering. Plastic is laid over the beds of liners and held down with pieces of firewood. Water is put over the plastic and left to freeze and hold the plastic down. The plastic is left on until the cold spell is well broken and the pots have thawed. The sawdust is not removed until spring and the danger of a cold spell is past, usually February 15th to March 1st. The sawdust also insulates from warmth in spring and *helps keep the plants dormant longer, helping to avoid damage from* late spring frosts.

Inside the polyhouses we overwinter our broadleaf evergreens and smaller sized liners. We have heated houses, heated with rootzone hot water, fuelled with propane. We let frost in to obtain dormancy and the necessary cold requirements. A plant kept active will be far more sensitive to cold than a plant allowed to enter

dormancy and maintain its own hardiness. House doors are left open in fall. Poly is not replaced before the last week in October. Once plants are dormant deciduous leaves are removed with a commercial vacuum cleaner. Botrytis in a polyhouse can cause far more damage than any cold, deciduous plants being the most difficult. Thermostats in these houses are set at 32°F. In a cold snap, used poly is laid over the plants to keep the heat down at plant level. These houses are also double poly, which will save about 30% of heating costs over single layer.

For overwintering larger sized plants in 1, 2, and 5 gal. containers we again separate according to hardiness ratings. For zones 1, 2 and 3 plants we use no protection. Zones 4 and 5 plants are left outdoors but are packed pot to pot and banked with sawdust around the edges of the beds for insulation.

Plants rated Zones 6, 7 and 8 are moved into unheated, single-layer polyhouses. In a cold spell, used poly is laid over the plants, and left until the weather breaks, hopefully for not more than a week at a time. We again try to use the plants' own abilities by not fertilizing in fall and keeping the plants thoroughly watered. The doors of houses are left open and well-ventilated as long as we can in fall. We want to discourage growth after October 15th and encourage dormancy. In spring we discourage growth until all danger of frost is over; white poly is useful for this. When the houses stay cold in the day, the plants tend to remain dormant several weeks longer.

HIGH HUMIDITY FOGGING PROPAGATION AND TECHNIQUES TO OVERCOME STRESS FOLLOWING MID-SUMMER OPEN GROUND PLANTING

JOHN BYLAND

Byland's Nurseries, Ltd.
1600 Byland Road, Kelowna, B.C. V1Z 1H6 Canada

Byland's Nurseries is a wholesale nursery operation located in the Okanagan Valley of British Columbia. Although we grow fruit trees and have a retail garden centre the main thrust of our business is the production of woody ornamentals for colder climates. The plants we produce are either sold as container-grown plants or bareroot. We grow these plants in a semi-desert, zone 5, climate. Summer temperatures routinely exceed 95°F and winter temperatures occasionally go down to −25°F.

A few years ago when our old temporary wooden propagation structures were beginning to show their age we decided to build more modern propagation structures.

As a part of this modernization we investigated the possibility of using a fog system for the following reasons.

1) To speed up rooting time by using higher greenhouse temperatures so as to turn material in the propagation structure over more frequently.
2) To reduce the occurrence of overwatering the rooting media, causing the cuttings to decay.
3) To reduce the amount of supervision required by conventional mist systems
4) To be able to use the fog system to humidify our refrigerated storage building during the fall, winter, and early spring.

The Mee Fog System was selected and purchased and has performed flawlessly for 3 years, now running 9 months of the year.

The fog system was designed to handle 3 houses 30′ × 96′ in size although we currently use it in just one house. Four lines run down the house with nine nozzles per line for a total of 36 nozzles per house. The lines are set 6 feet above the ground. This may seem like a lot of nozzles but they are needed during the summer with its very low humidity.

For ventilation only a jet fan with a polytube is used. This is set to come on at 90°F. The fog system runs from 7 AM to 8 PM. The on/off interval depends on the temperature and whether or not the skies are sunny or overcast. On very hot sunny days the "on" time is 4 minutes and the "off" time is as little as 1 minute. On cooler days the "on" time is 4 minutes and the "off" time is 4 minutes. On rainy overcast days the "on" time can be as little as 2 minutes and the "off" time 4 minutes.

We try to keep the propagation structure foggy enough so that the fog just starts to clear up after the "off" interval. Trials to reduce the amount of time the fog system runs have proved to be less than satisfactory. Some woody ornamentals require less moisture than our *Sambucus racemosa* 'Plumosa Aurea' but, unfortunately, this species set the minimum fog requirement.

All of our propagation is done on the ground. Our greenhouse has a root-zone heating system in the ground but this is not used for softwood propagation.

For most of our softwood propagation the cuttings are stuck directly into 2½ in. pots or into Styroblocks. Styroblocks are used extensively by the forestry seedling industry but we have adapted one type to fit the needs of our nursery. The Styroblocks we use are cut by the factory to give us exactly the same soil volume as a 2¼ in. pot. The main advantages of Styroblocks are ease of handling and quick extraction of the plants. Styroblocks also have a rib design which we feel produces a superior root system. The main disadvantages of Styroblocks are cost and the fact they are brittle and break easily. Another disadvantage is that one gets fewer plants per square foot due to their design.

In our propagation house we can hold approximately 60,000 2¼ in. pots. We try to turn material in the house 2.5 times during the propagation season. We could probably do this 3 times if we removed the plants more quickly after they have rooted.

Whenever possible, cuttings are cut the same day they are stuck. We try to time the pruning of certain plants to coincide with the optimum time to make cuttings of that particular plant. For example *Prunus virginiana* 'Shubert' cuttings are made the third week of June which coincides with the time they are pruned (feathered) in the field. Cuttings are gathered and placed into large garbage bags and brought back to the cutting shed within 2 hours of cutting. The cuttings are taken only in the early morning. This procedure greatly increases efficiency in the nursery. Before and after the cuttings are made they are stored in a refrigerated room at 40°F.

In the last few years we have experimented extensively with the elimination of wounding the cuttings. We now just strip the lower leaves off of most plants and find that the rooting of most cultivars has been unaffected.

After the cuttings have been dipped in a hormone/Benlate mixture they are stuck into 2¼ in. pots, Styroblocks, or sandbeds according to a set production schedule. The Styroblocks and the 2¼ in. pots have the same rooting medium consisting of the followiing; 50% perlite, 30% peat, 20% sand, plus 1.5 lbs per yard^3 Micromax, and 6 lbs per yard^3 Osmocote (18-6-12).

The flats containing the 2¼ in. pots and the Stryoblocks are filled at the potting department, palletized, and moved with a

forklift to the propagation structures where they are used.

After our plants have rooted they are placed in cold frames with a 25% shade netting stretched on it. We used a green shade netting which we import from Holland. It is far less expensive than shade cloth and is much easier to put on and remove.

The cuttings are misted, using an overhead irrigation system, for the first week after they are removed from the fog house. These plants are irrigated for 5 min. every hour. After a week the plants are incorporated into our normal irrigation schedule. If we run out of room the plants can be moved into the full sun after 2 weeks or so.

During the second week of August the rooted cuttings are transported into the field. Any cover crops which were used have been incorporated into the ground 2 weeks previously. Three of four days before field-planting begins the empty fields are thoroughly irrigated. Just prior to planting, the fields are ploughed using a spading machine and rotovated. A shallow trench is made using a V-plough.

The rooted cuttings are thoroughly watered before going to the field and only the plants that can be planted that day are brought out to the field. The rooted cuttings are quickly and easily extracted from the Styroblocks, as opposed to 2¼ in. pots. They are planted in 4 ft. rows with 6 in. between the plants.

Immediately after an irrigation line has been passed the water is turned on and one-inch of water is applied. This is repeated the second day after planting. Periodic irrigation is continued until the plants have started to form new roots into the soil. The plants are then incorporated into our regular irrigation program. A good quality irrigation system is required to be able to plant during mid-summer in a hot, dry climate like ours. One has to be able to irrigate on demand and provide uniform coverage.

This procedure provides us with young, vigorous 1½ year plants. We found that the regular 2 year program for growing shrubs produced plants which were too large for sales or 2-gallon container production.

BRUCE BRIGGS: Anton, on your work with *Picea,* what time of year do you take the cuttings?

ANTON THOMSEN: We take the cuttings the first part of June and get 80 to 90% rooting at that time. We use a mist line inside a tunnel house.

JIM WELLS: I was interested in your growing *Taxus* in containers. What rooting medium did you use for this?

ANTON THOMSEN: The *Taxus* in containers have been giving us some problems but we cut down on the watering which has helped. The medium is 70% light peat, 20% Grodan, which is a special fiber material to give good aeration—then 10% sand.

VOICE: What is the name of your new lilac that you showed?

ANTON THOMSEN: Jose—like in San Jose.

VOICE: This is for John Byland. In your high humidity propagation, how are you controlling moss and algae?

JOHN BYLAND: The only place we have an algae problem is on the walkways. The flats we use seem to tolerate a certain amount of algae. We really don't have an algae problem.

VOICE: Question for Anton. What is the cultivar of the blue upright growing juniper you showed? What experience have you had in field growing it?

ANTON THOMSEN: I suppose you mean the *Juniperus scopulorum* type. It is 'Blue Pyramid'. We have had no problems with it.

PLANT INTRODUCTIONS FROM MONROVIA NURSERY COMPANY

DENNIS M. CONNOR

Monrovia Nursery Company
P.O. Box Q
Azusa, California 91702

The Monrovia Nursery Company has always taken great pride in helping to introduce new plants or reintroduce old garden favorites into the nursery trade. Many times these plants come from around the world, or from such places as other nurseries, botanical gardens or arboretums, and even from home gardeners' backyards. At Monrovia Nursery, we are constantly scouting the fields of our containerized stock looking for sports of plants that have growing and marketing potential. Often times, these plants warrant a trademark or plant patent. Listed below are a few new and old cultivars of worthy note:

Actinidia arguta 'Ananasnaja'. This is commonly known as the Siberian gooseberry. It is a deciduous vine much like *Actinidia deliciosa*, except that the foliage is narrower and devoid of hairs. This cultivar was selected for the large size of its fruit (¾ in. to 1½ in. in diameter) which has lime-green flesh and a smooth skin; the fruit can be eaten like a grape—skin and all. The fruit ripens in September and October, earlier than *Actinidia deliciosa*. This cultivar is a female plant requiring a male pollinator. This plant is excellent for trellises and arbors, and may be planted as a scrambling shrub. It is hardy to zone 4, growing well at the Arnold Arboretum in Jamiaca Plain, Massachusetts, where it has tolerated −35°F.

Bougainvillea hybrid 'Oo-la-la'™. This plant is a sport of *Bougainvillea* 'Rosenka', and was found in a bed of 'Rosenka' by an employee at Monrovia Nursery Company. This new cultivar has the same dwarf, mounding habit, and free-flowering habit as 'Rosenka', except that the flower bracts are a vibrant reddish-purple. The plant is hardy to zone 10.

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Catalpa bignonioides × *Chilopsis linearis*. Known as chitalpa, this hybrid from the Soviet Union is a new intergeneric hybrid of two American plants, desert willow and catalpa. The plant is a deciduous small tree growing to 30 feet. A rapid grower, it will reach 15 ft in only 3 years. Large clusters of light pink flowers are produced from March through September. This is an excellent water-conserving plant. This hybrid is hardy to zone 6; in colder areas it may dieback completely and resprout.

Clivia miniata 'Moyna Flame'™. This is a new, exclusive introduction of Monrovia Nursery for which a plant patent is being obtained. The large, bright orange-red flowers are produced in large clusters above the dark green, strap-like leaves. This cultivar is a definite improvement over conventional seedlings due to its wide foliage, large flower clusters, and deep flower color. The plants are excellent for shady locations in zones 9 and 10, and as house plants in colder areas.

Dodonaea procumbens. Commonly known as the trailing hop bush, this plant is prostrate, forming a mat 6 in. in height with a spread of 4 ft. The foliage is wedge-shaped and rich green in color. Flowers are not significant. This plant makes a beautiful groundcover but is not a rampant grower. Plants grow best in full sun on sandy or loamy soils, but will tolerate semi-shade or heavy soils. This plant is hardy to zone 8.

Gordonia lasianthus. This evergreen tree, native to the southeastern United States, is commonly known as the loblolly bay or black laurel. In cultivation, the plant will reach a height of 40 ft with a spread of 25 ft. The foliage is glossy, elliptic, and 3 to 5 in. in diameter. The fragrant, 2½ in. flowers are produced for a two-month period during the summer. The tree tends to retain its foliage through the fall, with some foliage turning a crimson color prior to leaf drop. The plant does best in acidic soils and full sun to partial shade. Plants are hardy to zone 7.

Hibiscus rosa-sinensis 'Izumi'. This new cultivar produces long-lasting, double, vibrant-orange flowers. The plants are semi-dwarf with a slightly weeping growth habit and are hardy to zone 10. This cultivar is a hybrid from Earl Izumi, a nursery owner and hibiscus breeder on Maui in Hawaii.

Hibiscus rosa-sinensis 'Jason Okumoto'. This plant produces lovely, semi-double cup and saucer flowers that are bright gold with a scarlet throat. Plants are hardy to zone 10. This cultivar is also from hybridizer Earl Izumi in Hawaii.

Hibiscus rosa-sinensis 'Ruby Brown'. This new cultivar blooms with large (up to 10 in. across), brown-orange flowers with a red eye. The plants are prolific bloomers. Plants reach 6 ft and are hardy to zone 10.

Hibiscus syriacus 'Aphrodite'. An introduction of the U.S. National Arboretum, Washington, D.C., this cultivar features a dense growth habit, growing to only 9 ft tall and 8 ft wide in 20 years. Flowers are rose with a dark red-purple eyespot. Plants are hardy to zone 6.

Hibiscus syriacus 'Helene'. Another U.S. National Arboretum introduction, this cultivar features flowers that are white with a red eye. The compact plants grow to only 6 by 6 ft in 20 years. Plants are hardy to zone 6.

Hibiscus syriacus 'Minerva'. This new cultivar produces 4 to 5 in. flowers that are violet with a dark red-purple eyespot. Plants feature an open-branched growth habit, growing to 8 ft tall by 6 ft wide in 20 years. This cultivar was introduced by the U.S. National Arboretum and is hardy to zone 6.

Leptospermum scoparium 'Nanum Tui'. A new arrival from New Zealand, this plant features a dwarf growth habit, rarely exceeding 2 ft in height. White to very pale pink flowers are produced in mid-February. Plants flower at a young age and are hardy to zone 9.

Liriodendron tulipifera 'Aureo-marginatum'. Known as the 'Majestic Beauty' tulip Tree, this cultivar is slower growing and slightly smaller than seedling liriodendrons. The tree is deciduous, pyramidal in shape, and features bright green

leaves that are edged with yellow. Plants are propagated by grafting. This cultivar is hardy to zone 5.

Magnolia 'Monland Timeless Beauty'™. This is an exclusive patented cultivar of Monrovia Nursery. A small evergreen tree, it reaches a size of 15 ft by 15 ft after 15 years. Large, creamy white, fragrant flowers 9 to 10 in. in diameter are produced from early May until September. After this cultivar blooms, it resumes vegetative growth and will rebloom the same year, unlike other evergreen magnolias that bloom only once per year. This cultivar is believed to be a cross between *Magnolia grandiflora* and *Magnolia virginiana*, and is hardy to zone 6.

CALATHEAS

STEVE LAZARZ
Rancho Soledad Nurseries, Inc.
P.O. Box 1689
Rancho Santa Fe, California 92067

Included in the genus *Calathea*, are some of the most attractive species of interior foliage plants. In their native habitat, they exist as understory plants in the tropical forests of south and central America, and some of the associated Caribbean islands. As a group, they are very desirable due to their very colorful and exotic foliage, and their ability to flourish under interior light levels as low as 50 foot candles. Until recently, most of the cultivars I will describe have been available in the trade only in very limited quantities, and at a premium price. Calatheas are very difficult to grow from seed, and are commonly propagated by the slow and painstaking method of division of the underground rhizomes. Tissue culture micropropagation techniques are presently making many of these cultivars available to the trade in significant numbers at a reasonable price.

Calatheas are a bit more exacting in their cultural requirements than many other types of interior foliage plants. They have a reputation for being salt and flouride sensitive, and sometimes exhibit burning along the margins and leaf tip if grown incorrectly. My personal experience is from growing these plants in San Diego, California, where the level of "Total Dissolved Salts" (TDS) in the irrigation water reaches as high as 700 ppm. Under the correct cultural conditions, even with marginal water quality, these problems can be minimized. Calatheas do best in a light soil medium with a high water-holding capacity. They should be grown at a light level of 1500 foot candles, and fertilized at every irrigation with an N-P_2O_5-K_2O ratio of 3-1-2 at a level of 100 ppm N. They should not to be waterstressed, but should be kept evenly moist. Spider mites can be a major pest, and are controlled with Pentac® or Avid®, as needed.

Calathea orbifolia: A Brazilian species to 24 in. with large 8 to 10 in. elliptical leaves exquisitely striped in two shades of green.

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Calathea roseo-picta: a flat-growing Brazilian species to 12 in. with large 9 in. elliptical, glossy purple leaves with pink markings; undersides purple.

Calathea warscewiczii: a vigorous species to 30 in. from Costa Rica, referred to in the trade as 'Jungle Velvet'; exhibits velvety, deep green leaves with a light green feathering along the midrib; underside a rich burgundy red.

Calathea *elliptica* 'Vittata': a bushy cultivar from Colombia having light green leaves with symmetrical stripes of silver-green to white.

Calathea picturata 'Argentea': an upright-growing cultivar to 24 in. from Venezuela; leaves a shining silver, except for a border of dark green along the margin; underside wine-red.

Calathea majestica 'Roseo-lineata': an upright-growing cultivar to 36 in. from the Amazon having metallic, olive-green leaves on long petioles, marked with closely set pairs of pink to white lateral stripes; underside purple.

Calathea makoyana: a bushy species from Minas Geraes, Brazil, referred to in the trade as the "peacock calathea", eventually reaching a height of 36 in.; oval-shaped leaves exhibit exotic, olive-green markings in a translucent field of yellow-green; undersides purple-red with a similar pattern of markings.

A NEW FOG AEROPONICS SYSTEM FOR PROPAGATING AND GROWING HORTICULTURAL PLANTS[1]

ARIE ALTMAN

Faculty of Agriculture
The Hebrew University of Jerusalem
P.O. Box 12, Rehovot, 76100 Israel

and

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Shira Aeroponics LTD.
P.O. Box 62, Rehovot, 76100 Israel

The advantages of soilless and detached media for propagation and cultivation of many horticultural crops are self-evident. All these systems, including many types of hydroponic units, rely on the use of a solid medium to support the roots. Aeroponics is a unique method of propagating and growing plants with their root systems enclosed within a mist chamber.

Recently, we developed a new, improved, aeroponics system, based on ultrasonic-generated fine fog. The system conists of 4 modules, each made of a lower opaque plastic compartment which contains the roots, and an upper transparent hood for the shoots. The modules are fed from underneath by a central ultrasonic fog generator, which releases a fine, 1 to 5 micron droplet, fog. The fog is equally distributed into the lower and upper compartments of the

[1] Poster presentation

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4 modules, or can be applied to each one of them separately. The system is modular, electronically controlled, and the fog can be applied intermittently, at any pre-set cycle. Water consumption is low (100 to 200 ml/h at continuous operation), as is electrical power requirements (ca. 50 wh). The aeroponics system allows the application of nutrient fog either to the base of cuttings and root systems, or the shoots, or both.

This improved fog-aeroponics system has been used successfully, so far, for:

1. rooting of chrysanthemum, kalanchoe, carnation and mung bean cuttings
2. hardening liner production of chrysanthemum and kalanchoe plants
3. growing mature, flowering, tomato plants
4. germination and initial growth of mung bean and radish sprouts.

The cuttings produced good, well branched, normal root systems. Rooted cuttings were transferred to a standard potting mixture and allowed to develop in the aeroponics system. Top and root fresh weight of these liners was twice as much as liners growing without fog. Large cuttings of mature tomato plants rooted and developed well for at least 3 to 4 weeks, and fruit-set occurred. Seed germination in the aeroponics unit was rapid, producing uniform sprouts.

The new fog-aeroponic system is an advanced, modular, multipurpose propagation and growing unit. This is due to both its constructional-mechanical and physiological-horticultural versatility. Mechanically, it is a simple, non-expensive and fully controlled system. Unlike traditional foggers, the ultrasonic-generated fog system alleviates the need for high water pressure and expensive filtration devices. Water and electrical power consumption is low, and the system is completely safe. Physiologically, it provides for maximal aeration, combined with adequate, continuous, water and nutrient supply to the plant. Taken together, these advantages allow uninterrupted growth of both roots and shoots. The fog-aeroponics system, therefore, seems to be advantageous for various types of propagation programs and horticultural activities, especially for the following:

—efficient rooting of cuttings
—an alternative for standard mist and fog propagation
—hardening and liner production
—production of specific root crops and root-derived products
—high-humidity growing of specific plants (e.g. tropical and epiphytes)
—tissue cultures
—root research programs

COMMERCIAL CONIFER MICROPROPAGATION

CHERNG-HSI LING AND LESLIE K. C. CLAY

Les Clay & Son Limited
3666—224th Street, Box 3040
Langley, British Columbia, Canada

Since 1980 Canadian Forest Products Ltd. has been working with Clay's Nurseries to develop a practical and cost effective tissue culture method for mass propagating conifer trees. The immediate and long range goal of the research project is to be able to utilize the *in vitro* cloning technique to rapidly mass produce species that are slow to propagate by traditional methods, and to clone genetically superior trees obtained through selection, breeding, or genetic engineering in the future.

Micropropagation: Advantages and Disadvantages. The tremendous potential benefits of vegetative clonal propagation in the genetic improvement and mass production of forest trees have been fully recognized and critically discussed in recent years (1,2, 3,5,6,8,9,11,12,13,14,15). The most significant of these is the capture of all the genetic gains obtained through breeding and selection. Micropropagation and rooted cuttings are the two most important vegetative propagation methods that can be employed in the operational production of forest tree propagules for reforestation.

The main advantages that micropropagation has over rooted cuttings, wherever these methods can be applied include the following:

1. Only a small amount of source plant material is required. Once a genotype is established *in vitro*, it can be rapidly bulked up and maintained over a long period of time in a small amount of space.
2. Micropropagation is a much more rapid mass production method once a suitable protocol is developed for a species, by virtue of the high *in vitro* multiplication rate of the plant material.
3. Some conifer species whose cuttings cannot be rooted with ease may lend themselves more readily to *in vitro* clonal propagation.

The major drawbacks of micropropagation, in comparison to rooted cuttings, when both are used in operational production are:

1. It is still, at the present time, a more labourious method requiring a stringently controlled environment.
2. In addition to the *in vitro* plantlet production stage, an acclimatization procedure is usually required, where the micropropagules are given special treatments in order to

adjust them to the normal plant growth environment.

3. It may take years of research and much capital investment in order to develop a cost effective micropropagation production system.

Having taken into consideration all the pros and cons of micropropagation both in theory and through practical experience, we have persisted in our research. We are now close to the point of making it a fully viable alternative to both seedling and rooted cutting production methods in the case of Alaska yellow cedar (*Chamaecyparis nootkatensis* [D. Don] Spach). This is a species that exhibits an indeterminate growth habit. This makes the small amount of explant materials required for tissue culture inoculation available all year around under a controlled environment.

Since the last report (7) on our micropropagation research work, we have brought yellow cedar into its first operational production phase. The following is a report on the materials and methods used.

MATERIALS AND METHODS

Source Plant Materials. Shoot tips 3 to 5 cm. long with radially symmetrical morphology were obtained from 20 hedged plants 4 to 7 years old. These were raised from seeds of four different seed lots originally collected from the following areas in British Columbia: Morseby Island, Harrison Lake, Campbell Lake, and the Fraser Valley.

Surface Sterilization. The source plants were treated with various fungicide sprays (Benlate, Rovral, and Captan) for four weeks prior to explant collection. The explants were then surface sterilized according to procedures previously described (7). Damage due to oxidation by polyphenolic compounds was reduced with the use of blue light in the first week after inoculation.

***In vitro* Treatment.** Modified MS media (7,10), with a reduced ammonium nitrate level, were used for shoot induction and elongation. Cultured shoots were allowed to multiply and grow for 12 weeks and then subcultured on new media. Roots were subsequently induced to form plantlets. (See Figure 1)

Acclimatization Procedure. Plantlets growing in 313A Capilano containers were put through the acclimatizatiion process under a mist tent in the greenhouse for six weeks. (See Figure 2) During this period light intensity was gradually stepped up from 2000 to 20,000 lux by use of layers of shade cloth. High humidity conditions were maintained by a mist system operating initially on a 16 min. cycle with 6 sec. mist burst to protect the young plantlets from desiccation. Temperature was kept at 20° to 23°C. Pathogen problems such as damping off, botrytis, and fungus gnats were controlled with Benlate, Captan, and Diazinon treatments. The medium

Figure 1. *In vitro* rooted yellow cedar plantlet.

Figure 2. Yellow cedar plantlets in 313A Capilano containers under a mist tent.

used was a 3:1 peat/vermiculite mixture, as has been used by the B.C. Ministry of Forest Nurseries. The plantlets were fully acclimatized after six weeks.

Nursery Phase. The acclimatized plantlets were allowed to grow on to one year old until they were ready for field planting. After the acclimatization step, the plantlets were grown under growth regimes corresponding to those used for containerized propagules by the B.C. Ministry of Forest Nurseries.

RESULTS AND DISCUSSIONS

Results from the early phase—the period between 1980 and 1985 of our research on micropropagation of coniferous species have been reported (7). In the last three years, we have greatly increased our *in vitro* shoot multiplication rate in yellow cedar. We are now able to induce the formation of an axillary bud from almost every single axil of the needles on the explant shoot (see Figure 3). Microshoots have been rooted at 80% efficiency level. Micropropagated yellow cedar have grown to a height of 85 cm and a root collar diameter of 5 mm (see Figure 4) in 15 months when grown in 1 gal. containers. Some of these yellow cedar plants are now growing in a demonstration plot at a permanent site at Clay's Nursery.

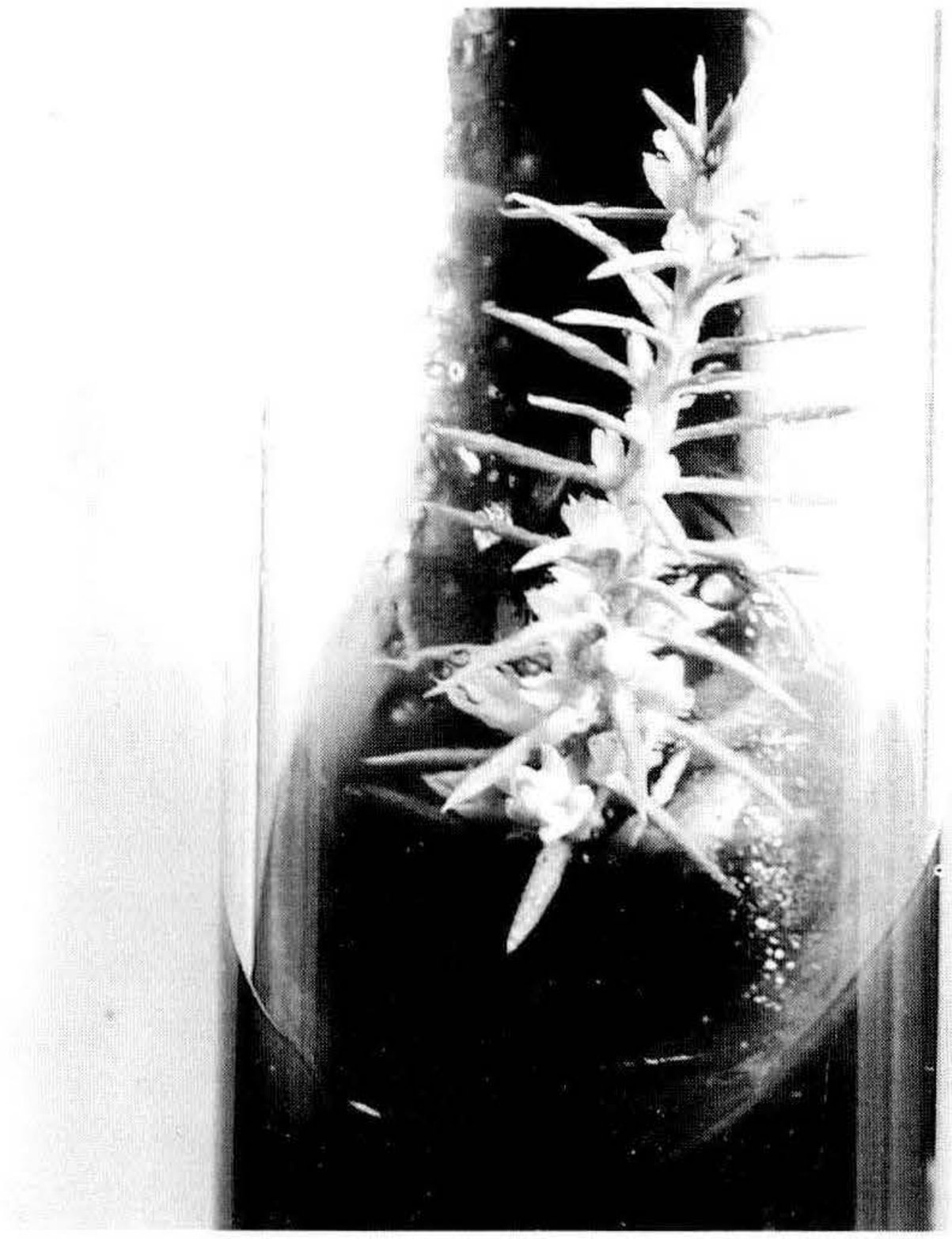

Figure 3. Axillary bud formation in axils of yellow cedar.

Figure 4. Fifteen month old micropropagated yellow cedar grown to a height of 85 cm with a root collar diameter of 5 mm.

So far no apparent difference in growth rate has been observed among yellow cedar micropropagules, rooted cuttings, or seedlings. Currently we are carrying out experiments to evaluate greenhouse performance of yellow cedar micropropagules by comparing several important shoot and root morphological traits of these propagules with those of rooted cuttings and seedlings from the same seed source. Results from these are forthcoming and will be presented in our next report. Assessment of long term field performance of our yellow cedar micropropagules will begin next spring.

Other conifer species that we have been working on in the hope of developing a similar micropropagation production system in the future include Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco), white spruce (*Picea glauca* [Moench] Voss), and Sitka spruce (*Picea sitchensis* [Bong.] Carr). These species have a determinate growth

habit and are apparently much more recalcitrant to *in vitro* treatments than yellow cedar. However, we have achieved some very encouraging results. In the case of Douglas fir, we have produced many plantlets from 12 year old source plants but have difficulties in getting them acclimatized to greenhouse growth conditions. In white spruce we have succeeded in inducing an enormous amount of bud differentiation from 7 and 8 year old materials, but these buds have so far failed to elongate. Sitka spruce, a recent addition to our tissue culture research project has shown some bud differentiation in culture. An *in vitro* clonal production system for Sitka spruce will have great economic implications to the B.C.'s forest industry since the long term soluton to our serious weevil problem in Sitka spruce is believed to be in the planting of weevil resistant trees (4).

Acknowledgements. The conifer micropropagation research project at Clay's Nursery has been funded by Canadian Forest Products Ltd., the Science Council of British Columbia, and by the Government of Canada through the Forest Resource Development Agreement (FRDA).

Special thanks are extended to each of these funding bodies.

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A PRELIMINARY REPORT ON VEGETATIVE PROPAGATION OF CALIFORNIA LIVE OAKS FOR DISEASE RESISTANCE[1]

EVA I. HECHT-POINAR, F. W. COBB, JR., R. D. RAABE, AND J. B. FRANKLIN

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Since about 1981, a branch dieback of oaks caused by *Diplodia quercina* has become rather widespread in California. This disease is most severe during dry years. More recently, twigblights caused by at least two fungi: *Cryptocline cinerescens* and *Discula quercina*, have also become a serious problem in California. These fungi cause most damage during wet years. The diseases occur in landscaped as well as non-landscaped areas of California and can be serious on *Quercus agrifolia*, *Q. lobata*, *Q. kellogii*, *Q. chrysolepis* and *Q. wislizenii*. They have also been recorded on *Q. douglasii*, *Q. robur* and *Q. suber*.

Sixteen native oak species are recognized in California. These belong to three subgenera: the intermediate oaks, the black oaks, and the white oaks. However, extensive hybridization within each subgenus has been well documented, resulting in highly variable intermediate types. Noticeable differences in disease susceptibility and levels of insect attacks of individual trees have been observed. For instance, it is quite common to see two *Q. agrifolia* trees side by side, one with severe infection of twigblight, the other with a negligible amount. It is customary in California to produce oaks

[1] Poster Presentation

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from acorns, since they germinate readily and with a high percentage of success. Other means of propagation are difficult but some techniques have been found to be quite successful in producing oaks of a known genotype.

With that in mind and our desire to provide the nursery trade with oaks that may be resistant to those disfiguring branch and twig diseases, we set out to test rooting and grafting techniques for *Q. agrifolia*. Once the techniques are refined to yield a satisfactory level of success, source material could be selected on the basis of a number of additional desirable horticultural characteristics such as shape, moisture or drought tolerance, and resistance to insect attack.

We have adapted a technique used in the Netherlands (1) to graft *Q. robur* 'Fastigiata' and *Q. frainetto* commercially and have to date 45 successful grafts with 150 currently in the process of developing callus. We are trying to determine in which month we get the highest percentage of successful callus formations by making 30 grafts each month of the year. The Dutch workers found that they got a higher percent take when the grafts were made in the fall than in the winter months.

We have used 2-year old rootstock and selected scion material from apparently healthy and from susceptible mature trees. We will test a number of our grafted plants by planting them outdoors in an environment where the pathogens are known to occur. We will also test-graft oaks by making inoculations with the twigblight organism in the spring of 1989 in our greenhouse to see whether we can detect a difference in the susceptibility of the grafted plants to the diseases in question.

We also have 46 rooted oak cuttings, 12 of which are excellent, the tallest and strongest having grown to a height of 80 cm in just 16 months. However, the technique of etiolation of shoots to achieve rooting (2) is difficult to adapt for shoots from mature trees and, therefore, this method may not be as practical as producing grafted plants.

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UPDATE ON TISSUE CULTURE OF WOODY PLANTS

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Our first experience with tissue culture was in the late 1960's with Dr. Wilbur Anderson of the Western Washington Research Station in Mt. Vernon. Dr. Anderson (2,3), an early student of Dr. Murashige (23) of the University of California at Riverside, was anxious to do tissue culture research with woody plants. We were very excited to have him in our area and spent many hours moonlighting with him and two other nurserymen to get a breakthrough on growing woody plants using tissue culture.

My eldest son, who at that time was in junior high school, also joined us as he was very interested in research, and we put him to work making media. Along with fellow nurserymen, Les Clay and Bob Hart, we worked first on trying to get plants established in aseptic 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 compared to research that was being done with herbaceous plants. It was really a matter of adjusting techniques and refining the medium (24).

Later Dr. Anderson received research grants, and through many tests was able to refine the medium to determine the level of nutrients in which rhododendrons grew best.

In those days it was certainly an aid to everyone to understand how the plant that one is working with 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, we could be way off on the medium and the plant would still grow. After one gets the plant started it is possible to refine the medium so that the plant grows much better (21). This is true of many plants that are easily grown in tissue culture.

In the early days when Lydiane Kyte (16) was with us, our work involved developing the correct medium on which to grow rhododendrons. At that time, we found ourselves varying our growth regulators trying to get the maximum number of shoots. At times the plants looked almost like moss on the medium. From this experience and others, we learned to always use the lowest cytokinin concentration that will give the shoot production you wish. What we are really concerned about is not how many shoots we get, or

how many micro cuttings we can get from a jar, but how many plants from a jar that grow into strong healthy plants outside it.

As we progressed, rhododendrons did come out of the lab successfully. In addition to ourselves, three other nurserymen worked on how to make them grow 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 micro cuttings into a 4 in. pot using a well-drained soil. Almost all our plants are stuck, and then these are graded when they are transplanted. Grading should be done, since plants of one cultivar coming out of the lab do not all grow at the same speed, nor are they all 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, and then we also had to continue growing that cutting, after it was rooted, within the same medium. We prefer to root everything, if possible, outside the lab. In most cases, it's simply cheaper.

Within this area we would like to become more mechanized. Although we feel we now have a very good system, perhaps a plug system, more commonly used in the bedding plants industry, might be more space and labor efficient. The problem that we have had with plugs is that they 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, you end up with them drying out. We are still trying to devise methods of using a plug system. Whether it is in the lab or outside, we want to prevent stress in order to have the best production from tissue culture. The key to producing a good final product is to start with high quality, and keep the plant continuously growing.

Many things have changed with time (10,18). In our lab we have more and better chemicals, we have learned what types of growing media to use (27,28), and we have learned how to refine our media. For example, rhododendrons or other woody plants coming out of the lab sometimes look vitreous or waterlogged, or even variable in shoot quality and numbers. When these conditions exist, we do not have the type of plant we really want. One needs a plant culture that has reached the stage that produces quality shoots of uniform growth, so that when the plant comes outside it will continue to grow in a stabilized manner.

Shoot tip propagation from tissue culture is just another propagation method, and in areas where it works it certainly has its place. I feel many times the system is excellent, but problems may occur caused by the people using the system.

When I compare the plants that we produced in the early 1970's with what we are now producing, I am amazed at how we have improved the uniformity and growth of our cuttings. We try to keep contamination at the lowest possible level but we have not found a

way to be absolutely clean. Many times the bacteria that may be in the tube is not that harmful, except that it becomes very evident when you put it in cold storage, or when you fail to subculture often enough. Perhaps in the future there will be an antibiotic (20) that will control these things within the jar.

One of the greatest tools we have in our laboratory is our cool room. We maintain a cold storage temperature of 5°C and 60 percent relative humidity in a room some 10 by 8 by 24 ft. Our cool room acts as a stock block, in that 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. It is true that certain plants will not store very well. We are learning more all the time about how to maintain plants through cold storage. For example, a few years ago when I was in Belgium, Dr. Boxus (5) had strawberries which seemed to be very easy to store, but I saw other plants that he had stored four or five years which, although they survived, did not store as well.

We have used many types of growing containers and we still use some test tubes when studying new plants. Our main growing containers are still baby food jars. We try to streamline all our production so that we can save man-hours in handling our product and this area is a good example. 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, (6) but this still remains an art as well as a science. You have to be able to look at a plant and determine where you are in the range of media, you have to make adjustments and continue to make them because a plant may change with time on the same medium. You will find with some plants that a small adjustment of the growing medium, perhaps lowering the nutrient concentration, or eliminating some other element, or maybe just lowering the amount of light, seems to help the initiation of roots.

Researchers in Europe, particularly France and Belgium, have done a lot of work with varying daylength to initiate roots. This has helped rooting, especially with apples (14) and some kinds of trees. We have not seen this positive response to light. I am not sure that what we are doing is so different, but we don't seem to get the same response. Recently, Dr. Anderson at Mt. Vernon has published a very interesting paper on his work with vegetable crops that refused to root. By reducing the amount of light to less than 12 hrs they responded very well to rooting in the greenhouse.

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. We find ourselves in the summer using a fog system. Most of the time we like to use a mist system, in conjunction with either fog or a closed tent, to make sure that the small cutting coming out is not put under stress from lack of water. Whatever system you choose, the important thing in rooting tissue-cultured plants is to always 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 has been something we learned very early: do not stress a small plant from tissue culture by planting it in an open field where it may be hot or dry. The plant may not die, but it will not grow fast. 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. They were also slow in changing from the juvenile to the adult stage, in which the plant produces large mature leaves and achieves a normal flushing growth pattern. Some growers in the Portland, Oregon, area working with tissue-cultured trees have found it helpful to grow the plants with drip irrigation. The drip tube is placed beneath the trees when they are planted in the field. It provides adequate water to the plant at all times and allows the grower to control what they are doing. Here the results were similar to those of a small bedding plant sitting on a capillary mat in a greenhouse.

This is the area in which nurserymen probably have the most trouble—the transition from controlled conditions within a greenhouse to the open field—specifically, when the plant is too small and not ready to go there.

Another important point is to grade all plants for uniformity, because growing conditions and water requirements will then be the same for all plants in a row. We encourage the bedding of plants at a small stage, or growing them in a greenhouse to develop a large enough rootball so the plant can better sustain itself. As a result, we now do not see a lack of growth or uniformity.

Many plants from tissue culture will grow faster than from a cutting, but like all things there are exceptions. Some of the outstanding plants that seem to respond for us from tissue culture are Exbury and other deciduous azaleas. They can be produced the year around, you do not have the loss you may experience when growing them from conventional cuttings, they branch better, and they grow faster. It does change your production schedule because you then have to do more shearing. We shear many young plants—including rhododendron, azaleas, lilacs and several others—very low to make them compact. This is one of the major things that growers that are

accustomed to producing cutting-grown plants need to learn. You do need to learn to handle a plant in accordance with its pattern of growth.

It is interesting why plants like lilacs from tissue culture 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 others. We need to realize that not all things coming from tissue culture respond the same. A tissue culture plant may grow faster or slower as a juvenile plant than a normal cutting-grown plant. We have to focus on those plants that respond well to tissue culture and work on what is wrong with those that do not do as well. A good example is *Kalmia*, which can be very difficult to grow. After years of growing this plant, we found that it needs to be pruned very heavily when it is small, fertilized often but not heavily, and that it grows best 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. Some of the easiest conifers to grow *in vitro*, like *Thuja*, loblolly pine, and *Sequoia*, respond very well, and production seems to be progressing on these plants. Conifer tissue culture research worldwide includes Weyerhaeuser in Washington (7), Dr. Boulay (4) in France, Les Clay (15), Dr. Thorpe in Canada, and Dr. Aitken-Christie (1) in New Zealand.

Dr. Don Durzan from University of California at Davis (11), with fellow researcher Dr. Gupta (12), has and is now continuing research on embryogenesis of conifers (13). In the future this may prove to be an economical way to propagate conifers. At present, research continues in developing techniques to tissue culture these hard-to-grow conifers, but I am sure we will advance in this area as we did with non-conifer plants.

Tissue culture is an avenue to improve a plant, or possibly stabilize it, as Dr. Mapes (22) did with plants in the pineapple or Bromeliad family. She was able to improve stability using tissue-cultured plants compared with plants from divisions of pineapple growing in the field.

In the 1950's, Dr. Mapes studied under Dr. Steward (26), one of the pioneers in single cell research on carrots. At a meeting, I remember expressing my concern to him about how they would be able to take a single cell and stabilize it to the point where one would 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.

Remember: 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 (19). Many times quality lines can be improved by adjusting culture practices in the lab, such as light, heat, media, humidity, contamination, and the upgrading of shoot tips to maintain the very best standards for growing outside.

Quality begins in the lab and ends with the grower of the product.

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NOTCUTTS' EXPERIENCES WITH MICROPROPAGATION

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INTRODUCTION

Notcutts' interest in micropropagation began in the late 1970's when the company realised the potential for the technique on a modern nursery. What was less clear was what specific role would develop for micropropagation in the nursery stock industry and what production levels for the technique would be appropriate.

Initially micropropagated plants were brought in from commercial laboratories and closer links were formed with one of the UK laboratories. However, it soon became apparent that an on-site laboratory was necessary and in 1980 a laboratory was constructed within the propagation unit at Woodbridge.

The laboratory now produces approximately 120 subjects and represents perhaps 10 to 15 percent of Notcutts' production.

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NOTCUTTS' EXPERIENCES WITH MICROPROPAGATION

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INTRODUCTION

Notcutts' interest in micropropagation began in the late 1970's when the company realised the potential for the technique on a modern nursery. What was less clear was what specific role would develop for micropropagation in the nursery stock industry and what production levels for the technique would be appropriate.

Initially micropropagated plants were brought in from commercial laboratories and closer links were formed with one of the UK laboratories. However, it soon became apparent that an on-site laboratory was necessary and in 1980 a laboratory was constructed within the propagation unit at Woodbridge.

The laboratory now produces approximately 120 subjects and represents perhaps 10 to 15 percent of Notcutts' production.

PRODUCTION TIMING

The key to the existence of a nursery-based laboratory is very clearly the growing-on of propagules to saleable size. It was clear at an early stage that the classic approach of the laboratory producing all propagules for a spring lining-out was impractical.

Propagules were always difficult to wean in February and March, although sodium vapor lights have subsequently aided winter weaning, meaning that laboratory production peaks during April and May clashed with traditional cutting production. If weaning was later, perhaps in June and July, subsequent lining out of propagules in August and September often proved just too late in the season for successful establishment. So, although spring lining out of propagules is clearly advantageous, other avenues had to be opened.

Lining out of dormant propagules under cold glass has proven to be a very useful strategy, particularly for herbaceous perennials, such as hosta and *Dicentra spectabilis*. This is also so with roses, particularly the climbing, hybrid tea and floribunda. Laboratory production of roses is now geared to produce plantlets leaving the laboratory in September and October, weaning under sodium vapor lights giving approximately a 2,500 Lux intensity. After weaning, the plants are allowed to become dormant.

Dormant propagules can then be lined out at leisure in November, December or January. No top growth will occur but, interestingly, root development will occur if the liners are watered very sparingly.

A bark/peat based compost with 8 to 9 month Osmocote at 2kg/M^3 is used and at low winter temperatures feed is released very slowly.

Watering and perhaps supplementary feed can begin, under glass, in mid-January and February and by March top growth appears in profusion as dormancy breaks, supported by the good root system developed over the winter. This is an important advance because our experience with roses is that while micropropagated climbing roses produce very good saleable plants by September, if they do not quite make it they are extremely difficult and therefore, uneconomic to overwinter. We have found that the liner must be in the saleable container by the last week in May. Clearly spring lining-out would put great pressure on the plant to make up in time, and those of our early rose batches which were even just a few days too late, were never sold.

Winter lining-out of herbaceous perennials is often advantageous, producing much larger plants later in the year. However, in this case ensure the crown is very near to the compost surface, no deeper than 1 cm. If this is not done, the first leaves or shoots become drawn through the compost and because they are very soft and produced early in the spring will damp-off quickly.

Other plants are better weaned in January and February—again under lights. The propagules then produced in March and April are obviously ideal for early lining-out under protection and then have the whole growing season to develop. This is ideal for rhododendron where a propagule lined-out into a 7 cm plastic pot and severely pinched back in March will produce a very good liner which, in September, can be put into an intermediate one litre pot and overwintered. It can then be put into a saleable 3 litre pot in July to be sold that autumn or the following spring.

However, while very good rhododendrons can, with a little care, be produced from micropropagation, in Notcutts' particular circumstances, with our excellent Waterers' rhododendron cuttings, traditional propagation would appear to be more economically effective.

Attempts to line out propagules much later than mid-August while they remain active, have met with poor results. However, propagules weaned later in the year over-winter reliably in the cellular modules we now use. The small size of these plants densely packed in modular trays is an economic use of space, since they are then ready for lining out very early the following spring.

One hazard to over-wintering is *Rhizoctonia*, which destroys the root system of propagules in modules very quickly, particularly in a cold damp January and February. A drench of fungicide, e.g. Rovral or Basilex in either late December or early January, appears to prevent this problem.

Some plants are successfully lined-out at any time during the year, irrespective of seasonal and weather conditions. Clematis is a good example. Lined-out at any time between March and October, a year's top growth will die back over winter leaving a crown of 4 to 8 buds just below the compost, which break in the spring to give a bushy, vigorous plant.

LINING OUT

Our liner unit is approximately 3 miles from our propagation unit and the movement of plants to it is a change in environment analogous to commercial laboratory-produced plants being bought in by the nurseryman.

Micropropagated plants are generally allowed 2 to 3 weeks acclimatisation in their new environment before lining-out.

A modular established plantlet does not appear to require extra shading after it is potted-on as damage to root systems is usually minimal and this has released areas of shading to other crops. However occasionally the top growth of the propagule evident in the modular tray will drop off or die-back after potting on. Although initially alarming, this does not appear too detrimental to the plant as the crown quickly regenerates leaf growth and new shoots.

Hard pinching back is often a very good idea and this is straightforward since the plant's crown is often at compost level. Hard pinching is particularly useful for producing very bushy rhododendron liners.

We spray with fungicides all newly lined-out micropropagated material since laboratory-produced plants are smaller and softer than a traditional cutting would be. *Phytophthora* is a common nuisance and a light foliar spray of Aliette is good at control and protection. For established liners a heavier drench with Aliette is a better technique.

Weaned propagules are very tough and resilient to mechanical damage. A cold shock however, is a very efficient killer and special care is needed to avoid it, especially when plants are growing in the small compost volume associated with modules.

We have found that the correct liner container is important. Plants with a fibrous root system, particularly rhododendron, will perform much better in a plastic 7 cm pot, rather than an equivalent peat container, as will ophiopogon, which is particularly slow to establish in a peat container. Generally we favour the plastic pot despite its higher cost.

The roots and particularly the growing point, need high levels of oxygen for good establishment. Oxygen starvation is easily caused by overwatering and this is a real killer, especially in a plastic container. Yuccas are a good example where better establishment is achieved by careful, light watering only.

We prefer composts with high air-filled porosity and, as a standard, we would use 50 per cent 100-grade bark: 50 per cent Finnish peat with Osmocote 16:10:10 added at 2 kg/M^3.

Over-wintering established liners under protection is reasonably straightforward but we have noticed one or two common problems. Roses, in particular, are prone to botrytis and to downy mildew as temperatures rise in the spring. A proprietary chemical, Rovral perhaps, will control this but may produce a wet and cold liner, difficult to dry out in mid-winter.

One cost-effective technique is not to spray, but to push up the glasshouse heating for a few hours and then raise the vents. This gives a short period of a hot dry atmosphere which helps to control botrytis. This may consume 50 gallons of oil, but this should be cheaper than two or three hours labour and chemical costs.

Micropropagated liners are often embarrassingly vigorous and we have noted very high levels of bud-break at the plant crown. This is ideal for some plants such as rhododendron and ground cover roses but can produce over-bushy plants, especially if the liners are not moved on to their intermediate or final pots quickly. This means that liners often need cutting back, leading to a thick crop of new shoots. HT roses are often far too bushy with 10 to 20 weak shoots being produced rather than 4 or 5 much stronger stems.

LINER TO SALEABLE SIZE

The old adage of "produce a good liner and you will produce a good saleable plant" is very true of micropropagated plants. We have had few problems producing a high quality product once the liner is established and growing and once we have gained experience at the container fields with individual crops.

Timing can once again be critical however and the sooner an established liner is potted on the better, especially for plants where hard pruning of an oversized liner would produce too bushy a final product.

We have mentioned the need to have climbing, HT, and floribunda roses in their final container by late May. This is crucial as the plants just do not make up in time to be sold that September and will not over-winter well in containers.

We noted Roger Bentley's (1) work at Luddington EHS and increased our feed levels in container-grown micropropagated roses from a standard 4 kg/M^3 12 to 14 month 17:10:10 Osmocote to 6 kg/M^3. This produces a better quality plant by the autumn.

Liners derived from micropropagated plants remain a little softer than liners from traditional cuttings, especially since our liners are protected under glass throughout the year.

We have had some problems with *Phytophthora* on final potted *Sambucus racemosa* 'Plumosa Aurea' when protected under polythene tunnels. We have incorporated the fungicide Fongarid into our composts but have found that a better strategy is to grow this crop without protection. The plants remain clear of problems and grow well without the shading we would normally give.

We have had problems with downy mildew, particularly on the very free branching ground cover roses. We have found that by beginning a routine spraying regime very early and keeping this up the problem is eased.

CONCLUSIONS

We have found micropropagation to be a very useful tool, providing an economical method of producing some cultivars of plants and for cost-effective bulking up of new cultivars.

With a little care and acceptance some micropropagated plants do need slight modifications to established production techniques, but very high quality saleable plants can be produced in volume at realistic prices.

Micropropagation has a role to play in the nursery stock industry and although we do not anticipate it becoming the dominant method of propagation at Notcutts' we will continue to develop it as another very useful string to the propagator's bow.

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THE VITAL LINK: THE NEED FOR GOOD LABORATORY/NURSERY COMMUNICATIONS

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The Vital Link between laboratory and nursery is a matter of life and death for the plant. A dramatic situation—so where are the heroes and where are the villains? It is always easier to identify villains than to recognize heroes so let's start with them.

One villain is the white coat worn by the laboratory worker. People in white coats seem threatening but the white coat has its place. A lot of bleach is used for sterilisation and white is the only practical colour to wear. It also shows up any grubbiness and this helps to maintain high standards. So the white coat is just a useful tool.

The second villain is the "Keep Out" sign on the laboratory door. This is even more destructive. The funny person in the white coat kept behind closed doors must be up to something sinister. Again there are good reasons for "Keep Out" signs. A laboratory where muddy boots are frequently tramping through will be impossible to maintain to the required standard of hygiene and too many curious visitors can use up a lot of time with disastrous effects on profitability.

There are good reasons why there should be a sharp division between the laboratory and the nursery, but there are better reasons why they should be integrated.

There are basically two interfaces between the laboratory and the nursery. One before micropropagation and one after. In the first case the laboratory needs to know what plants the nursery requires, in what quantity, and when. The nursery, on the other hand, needs to know what is possible from the laboratory. "How long will it take?" is a frequent question and one to which there is usually no straight answer.

Taking this as an example, suppose a market was perceived for 10,000 units of a plant. This might take as little as 4 to 6 weeks to establish in culture, or it might take as many years. Here the nurseryman can help by supplying high quality stock plants that should be as young as is feasible, true to type, and of a superior clone. They should be as healthy as possible and plants given regular fungicidal sprays in the greenhouse are much easier to clean up in the laboratory than open ground plants.

When a plant is new to micropropagation it can also help to know what conventional techniques are most successful. Sometimes information on the best type of cutting or time of year can be useful.

Stage two is the multiplication phase. How long will that take? Suppose the target is 10,000 plants and the subject is multiplying at a rate of ×5 every two months. If there are 100 pieces to start with then after eight weeks there will be 500 pieces; 400 of these can be sent for rooting and 100 retained for multiplication. Then at 16 weeks the process can be repeated and this can continue until the desired number have been produced. At this rate, of 2400 per annum, it will take over 4 years to reach target!

Micropropagation involves a lot of capital expenditure and is labour intensive, so it is important to make maximum use of both facilities and manpower. The system just described is very good for the laboratory as there is a constant use of space and the labour requirement is distributed through the year. But does the nurseryman like this? Does he want six different batches of plants of different ages? Does he want to wean 400 microcuttings at a time? What is his market requirement?

An alternative system involves continually multiplying until the required number is reached, then planting them out all at once. Using this system, the target can be reached in 6 months—so of course that is the way to do it. But what are the implications in space and labour requirements and how can these be accommodated? Ideally, the laboratory would produce 12 different crops each requiring 10,000 per annum but to be weaned at monthly intervals.

In order to approach this situation, the requirement for plants should be decided 12 to 18 months before they are planned to come off the production line. The system must ensure that space will be available in the weaning house at all times, since delay in moving material from the laboratory leads to its deterioration and also overcrowding in the growth room. This can only be achieved if everyone concerned understands what is going on and is committed to its success.

Here we see the other interface with the nursery where plant material is leaving the shelter of *in vitro* culture to return to the "normal" world. Maximum cooperation is essential between laboratory and weaning house so that problems can be identified at the earliest possible stage and steps taken to minimize damage.

People who have years of experience working on a nursery know how to grow plants but these microcuttings are not like normal cuttings. They are very small, fragile, and susceptible to water loss, heat stress, and disease. They are also easily damaged by chemicals—so what is good about them? The potential is terrific if only they can be nursed through those first few weeks when they do need constant attention.

There is a temptation, because of the system of micropropagation, to think of it as a production line for nuts and bolts. But these are living plants and need care to survive this period of adapting from a highly controlled environment where neither roots nor

photosynthesis are necessary, to a rooted plant capable of absorbing water and nutrients from the compost—avoiding excessive water loss by growing leaves with normal cuticle and functional stomata, and able to provide their own energy supply instead of relying on sugar supplied in the gel medium.

These are problems which must be faced on the nursery but which can be influenced by treatment of the material in the laboratory. If there is a sharp line of division then it is easy for each side to blame the other when plants do not survive or perform poorly.

If plants die during weaning, is it because the nutrients in the gel in the growth room were wrong, or the growth regulator balance was inappropriate for rooting; or was it because the plantlets received the wrong temperature and humidity control; or because the compost dried out or became saturated; or because sciarid flies chewed the emerging roots; or botrytis took its toll? With goodwill and determination to succeed the answers can be found.

CONCLUSIONS

Micropropagation will only work to the advantage of the industry if it is considered as part of a continuing process in which each phase is dependent on that before and influences that which follows. Many of the problems encountered are similar to those met in conventional propagation but they must be recognized and solved by cooperative action by all those concerned. The result of this can be the production of excellent plants at a competitive price.

MYTH & MONEY IN MICROPROPAGATION

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Cost disadvantage is the main reason for the relatively slow expansion of the micropropagation industry in relation to the industry which it serves—commercial ornamental horticulture.

The starter plant producer suffers from disadvantages shared by all component industries. They are at the base of a long production chain (Table 1). Very little of the cash which funds the chain gets back to base. In the example chosen the retail margin is four times the starter plant selling price.

This is less significant than the vulnerability of the producer to competition from more conventional propagules which have a price advantage over most of the market and buyers are familiar with the technique of handling them. Most of all the supplier has no real control over the market nor any means to influence it.

Until recently the micropropagation techniques were found to be so intriguing that the industry seemed to be driven by technology with the market a secondary force. At that time it seemed that everything produced could be easily sold and customers were relatively tolerant of mistakes, failures and disappointments that were common. Looking back one can question the survival of micropropagation. It had a good 'press' as one of the few sectors of plant biotechnology to show any tangible results. Its advantages seemed to be manifest. There were some successful operators running laboratories with good systems, but the commercial laboratories built up a bad reputation.

Table 1. Added Value Chain for Pot Plants.

Retail selling price	£2.50
Value added tax	.33
Net retail price	2.17
Retail margin (40%)	1.00
Distributor selling price	1.17
Wholesaler including transport + 30% markup	.26
Importer selling price	.90
Importer margin including transport	.45
On-grower selling price	.45
On-grower margin	..20
Microplants/seedling price	.25
Producers margin	.13
Microplants/seedling production costs	.12

[1] Technical Director

The 20 years from the 1960's to the 1980's were unusual for ornamental horticulture in being years of phenomenal expansion in cut flowers, pot plants, and hardy nursery stock. All sectors have benefitted from an exponential increase in demand. For instance, the indoor foliage plant market in the United States was worth $16 million in 1969 and is now worth well over $300 million. Figure 1 gives the per capita per country value of Dutch exports to several European countries from 1970 to 1985. Since Holland provides around 50 per cent of these the graph is a reasonable index of the state of the trade. This expansion has created a demand for starter plants, increasing for 8 to 10 years at around 20 per cent per year. In this situation it is said that a new entrant to a market can take up to 15 per cent of the new business without upsetting the price structure or alarming the existing suppliers.

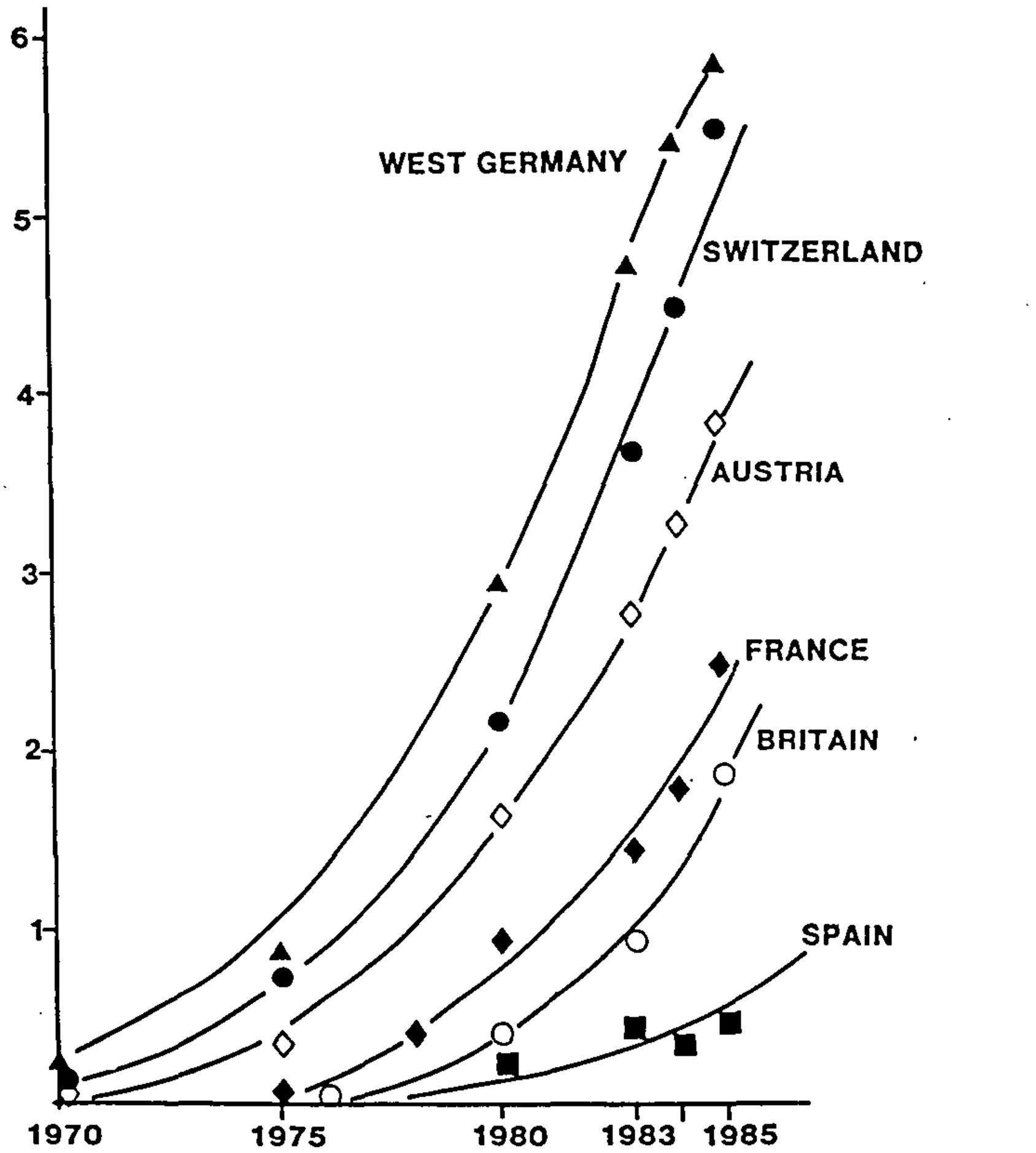

Figure 1. The per capita per country value of Dutch horticultural exports to several European countries from 1970 to 1985.

The development of the market provided the opportunity for a new product to enter without too severe competition from established wares. The same conditions may have given some micropropagation companies a false sense of success and shielded them from the disciplines that could have helped in facing the slower rates of increase and more stable conditions now prevailing.

In the last 10 years a huge list of plants has been cultured. Micropropagation systems are published frequently. Lists provided by the companies can be impressively long. Sadly, the majority of subjects are produced in small numbers.

Table 2, which is derived from Professor Pierik's data for Holland, shows that the industry is founded on a very narrow range of products. Cut flowers take 30 per cent of the output of microplants and pot plants 80 per cent, in the Netherlands. Closer examination finds the cut flower group to be almost wholly gerbera while 94 per cent of the pot plant group is made up by ferns (57 per cent), Saintpaulia (19 per cent), cordyline, syngonium, spathiphyllum and anthurium. Amongst the bulbs, lily shows the fastest recent growth. No other plants rise above the half million level. The same is true for other producing countries.

In the United States all of the stand-alone laboratories—those

Table 2. Microplant production in the Netherlands (after Peirik).

Total orchids (1984)	2.13 million
Total cut flowers (1986)	12.6 million
of which gerbera is	12
Total bulb (1985)	2.027 million
of which lilies are	2
(1986 est. = 7 million)	
Total pot plants (1986)	19.8 million
*Nephrolepis	11.19
*Davallia	0.34
*Saintpaulia	3.7
*Cordyline	0.78
*Anthurium	1.75
*Ficus	0.15
*Bromeliads	0.25
Syngonium	0.603
Spathiphyllum	0.512
Balance of 27 plants = 0.525 million	
*Always listed from 1980–86. The others appear in occasional years.	
Total vegetable (1984)	60,040 plants
Potato & sugar beet (1984)	180,000 plants

without associated nurseries—are heavily dependent upon foliage pot plants. A combination of oversupply and competition from third world imports has depressed prices and led to the closing or sale of several laboratories in Florida.

There are estimates—but no good figures—for the total output of the industry. These vary from 100 million plants per year to 300 million, or a value of between £20 million and £60 million world-wide. Total US production is unlikely to be more than 60 million microplants. Although there are thought to be 100 laboratories, it is difficult to distinguish state-funded research, special purpose (i.e. owned by seed or chemical companies) and propagation adjuncts of existing nurseries from commercial producers.

There are 14 well known American microplant factories and six of these are capable of producing around 5 million plants per year. Various figures are quoted for new laboratories opening each year but in this dynamic industry many close unnoticed. This familiar pattern of many setting out on the race and few surviving is illustrated in Table 3. The pattern is one of 80 per cent of the production arising from 20 per cent of the factories. This may well be an underestimate. Small laboratories are inclined to overestimate their production, often inflating the figures well beyond the numbers which their facilities and staff could possibly sustain. In general a sterile cabinet, when fully worked results in 130,000 plantlets for sale, or 170,000 if a twilight shift is worked. Growth room holding capacity must be 10 per cent of total output allowing for only a 2 per cent contamination rate. I doubt that there are more than 25 commercial laboratories in the world with the capacity to produce more than 1 million plantlets per year.

Table 3. Number of laboratories in Britain and Holland and estimates of their productivity [from Harper (GB) and Professor Peirik (NL)].

Annual production of microplants	No. of labs.	Total production
Great Britain		
>4 million	1	4.3 million
2 to 3	1	3
1 to 2	1	1
<1	8	est. 1.5
		9.8 million
Netherlands		
<5 million	3	15 million
1–5	7	21
0.5–1	2	1.5
100–500 thousand	6	1.8
10–100	18	0.81
<10	14	0.07
		42 million

For the future, large nursery businesses can be expected to integrate micropropagation with their normal propagation departments. The mix of conventional and tissue culture will supply the range they need. Independents are in a more fragile state. Price levels do not give them the opportunity to make enough to support the research and development that could take them up into the next level of technology and production. Too many small laboratories, especially the back room operators of East Europe and the low labour cost operations of Asia, are price cutting to obtain a share of the market. For a time seed companies and agro-chemical businesses would buy up micropropagation units as a useful adjunct or a gentle introduction to bio-technology. These have proved to be unreliable parents. At best, they shed the less profitable activities and integrate the residue with a plant breeding or chemical screening unit, at worst they offer a quick termination.

As this phase is passing, and with it the opportunity to build a business over 3 to 5 years before selling on, it is difficult to attract venture capital.

The future for truly independent companies in Europe and America is not likely to be easy, but it is very hopeful for those who can stay the course. For investment they will look to sources with a longer term in mind. They will seek out niche markets which allow them to concentrate on long runs of fewer clones. Increasingly the units will be run by professional managers and sales staff rather than by horticulturists and academics.

After the shake out when prices rise to sensible levels and some surplus cash is generated, expansion and mechanisation can be tackled.

In the near and middle term it is unlikely that somatic embryogenesis (artificial seed) or robotics will be of any significance in ornamental horticulture. The factories will be equipped, as nurseries are, with labour saving devices to move materials and products around. Better control of sterility and of the environment will help to provide the uniformity at present lacking.

Investment needed for this advance will be in the region of £3 to £4 million per factory. The present ceiling on production which is set by management and contamination problems is around five million plants per year. The improvements we look for would demand that production be in the region of seven to 13 million plants per year.

Robotics and vision analysis would take development costs and capital investment far beyond these estimates. Commercial ornamental horticulture will not sustain the astronomical output needed to justify this. Forestry and plantation crops in the third world might demand the numbers but are not likely to pay the price.

DEVELOPING THE MARKET FOR MICROPROPAGATED PLANTS

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Tissue culture, as a propagation technology, will only develop if it can deliver plants which provide clear economic benefits over those propagated by conventional means. In developing the market we are seeking those species and cultivars where the technology can deliver the benefits.

Twyford Plant Laboratories is principally active in the ornamental plant sector and it is here that tissue culture is growing fastest as a propagation technique. Over the last 10 years, the market for tissue-cultured plants in Europe in the ornamental sector has grown from under 10 million to approximately 100 million in 1987/88.

There are seven major factors which account for this outstanding growth.

This paper will take each of these attributes in turn and examine how one company, Twyford Plant Laboratories has used each of them to develop a market.

1. High health plants. In this area we have looked for plants which have significant disease problems arising from repeated conventional vegetative propagation. These are generally viruses and their impact will vary depending on the activity of the vector or the particular season. Most propagators need to start with the highest health status material possible and so, for this reason, we have been delivering thousands of high health chrysanthemum plants from tissue culture each year since 1983, which are then used as motherstock for future conventional propagation. Clearly, once out of the laboratory, the health status of the crop deteriorates and so there is a recurring need for this quality of plant material.

In addition to chrysanthemum, we have delivered high health plant material of potato this year for the first time. This was one particular cultivar for use on the Channel Islands where the quality of stock currently in use was so poor that replacement was essential. It is likely that these tissue culture plants will be used for propagation through one or two seasons before being replaced themselves.

2. Rapid introduction of new cultivars. The cut gerbera crop in Europe is currently about 24 million plants per year and around 90 per cent of these are now produced through tissue culture. Before 1980, propagation was almost entirely through cuttings, which had two distinct disadvantages:

i) It took a very long time to introduce a new cultivar, and

ii) plant producers had to keep very large stocks of mother plants in heated glass over winter from which to take cuttings in the following spring. This was expensive, it limited output, and it restricted the range of cultivars the growers had access to. In addition, it could also give rise to disease problems.

The impact of micropropagation on this market was very significant. Breeders could introduce a new cultivar in perhaps 3 years compared with up to 8 years using conventional methods. It has also had an impact on the overall market for gerbera because removing the mother stock bottleneck gave the crop additional scope for expansion. We estimate that consumption of gerbera plants in Europe has risen approximately 3-fold in the last 10 years, although the last 2 to 3 years has shown a levelling off in total demand.

The same argument holds for the lily crop, where propagation of new cultivars is again a lengthy process. Even with relatively high multiplications at scaling, it still takes 2 to 3 years for the bulb scale to reach a size where it can be scaled again. A breeder needs a minimum of 10,000 bulbs of a cultivar to introduce it into the market. These could be achieved from a single bulb in tissue culture in one year, and then with a further two years growing on would give a total time to introduction of three years. The time for conventional propagation is at least double that and if your competitors are using micropropagation, by the time the cultivar reaches the market the opportunity for the cultivar may have disappeared.

3. Improved uniformity and rapid propagation of elite clones. Clearly, the improved uniformity that one can gain from tissue culture should mean the plants are uniformly good, not uniformly poor. These are examples from three very different crop sectors:

i) pot gerbera from the ornamental sector;

ii) asparagus from the vegetable sector, and

iii) oil palm from the plantation sector.

Pot gerbera is normally propagated by seed and the resulting crop is somewhat variable both in colour, date of flowering, and quality of plant. Propagation through tissue culture enables the grower to select his very best plant and produce a whole glasshouse crop which is identical to that plant. It is only worth doing if it saves costs or if the additional revenue he gets justifies the additional cost of the tissue-cultured plant over seed. This is certainly the case for pot gerbera. The idea of a uniform, programmable, predictable pot crop which the grower can rely on all the year round that does not have the variability of colour, flower form, and flowering date that is prevalent with seed-produced crops, is just what the market requires.

The same argument holds true for both asparagus and oil palm, which exhibit a high degree of variability from seed-propagated crops. Tissue-cultured asparagus plants that have been selected for high quality, high yield, and improved vigour, can increase yields by up to 100 per cent over conventional production and this economic benefit can be transferred across the whole of the grower's production by clonal planting.

Asparagus is in the ground for up to 10 years, which is a long time to enjoy these yield benefits and enables the grower to justify paying something extra for his starter plants. For oil palm the same argument applies, but it can take some time to select the elite tree. The effort is well worth it, as once the selection has been made and clonal propagation undertaken the yield benefits accrue over almost 30 years.

5. Propagation of plants which are difficult conventionally. This is perhaps where many plant propagators held out a great deal of hope for micropropagation techniques but the unfortunate reality is that many plants that are difficult to propagate conventionally are also fairly recalcitrant in aseptic culture. One example of where micropropagation has widened the market for micropropagated plants under this category is *Phoenix dactylifera*, date palm.

Conventionally, date palms are propagated by offshoots which grow from the base of the palm, but this only happens during the vegetative period of the palm's life and some of the most desirable cultivars produce very few offshoots and those offshoots sell for several hundred dollars each. Using the tissue culture technique of somatic embryogenesis several tens of thousands of date palms have been produced and exported to the Middle East for crop production. The first tissue-cultured palm fruited in autumn, 1987, which was about three years after its planting date.

6. Overcoming seasonality. This applies to a wide range of plants, particularly in areas such as foliage or flowering pot plant production. For crops such as ficus or syngonium, the demand for starter plant material is virtually all year round because growers producing these crops have to keep their benches full. It is difficult using conventional propagation to produce uniform supplies of quality plantlets on a year round basis. However, using *in vitro* conditions, this is clearly possible.

7. Decreasing unit costs. As tissue culture techniques improve and the volumes of plants propagated increase, so the unit costs of individual plants should come down. This will require a number of technological breakthroughs in certain areas and we are not yet in a position where it is possible to produce plants from tissue culture with totally uniformly predictable multiplication rates of all cultivars that we would wish. Clearly the technology is developing all the time and with every step forward the market itself becomes wider. Labour is the largest variable cost of tissue culture plant

production and much of the development work focuses on ways of reducing the labour input by either improving the multiplication rate that it is possible to achieve *in vitro*, or exploring areas such as mechanisation or automation.

PITFALLS IN MICROPROPAGATION AND HOW TO AVOID THEM

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Micropropagation has established a market niche largely in the higher value sector and value-added areas of introduction of new cultivars and virus-free stock. High production costs have limited its market share but the latter is likely to increase with the introduction of automation (18).

The aim of this article is to attempt a state-of-the-art appraisal of micropropagation strategies so that the purchaser of microplants can be reasonably assured that they are likely to be fit for the purpose intended.

Micropropagation pathway analysis. The micropropagation procedure involves critical decision and monitoring steps as outlined in Figure 1. The nursery operator should appreciate the significance of these decisions and make sure that the micropropagator has adopted the appropriate strategy for any given cultivar. These steps are discussed below.

Genetic selection. Genetic selection, allied to the cloning pathway chosen is of critical importance to the production of true-to-type progeny. Many cultivars are inherently unstable in micropropagation because of their genetic construction. Cultivars to avoid, or to accept for micropropagation only after consideration, are chimeras—usually, but not always recognisable visually, e.g. *Pelargonium* × *hortorum* 'Mme. Salleron', 'Mr. Wren', 'Skelly's Pride'; beneficially-infected cultivars, e.g. *Abutilon sellovianum* 'Marmoratum' and those with unstable loci, e.g. *P.* × *domesticum* 'Grand Slam' (1). Only the breeder or grower may be adequately familiar with a cultivar or its antecedents to recognise its instability, but mutation-bred cultivars and those which tend to sport would be included. If these are to be micropropagated, significant levels of variation should be anticipated and the level of acceptability decided.

Guidelines for genetic selection, aside from the exclusions listed above, have been published by Johansen *et al.* (12) for potato,

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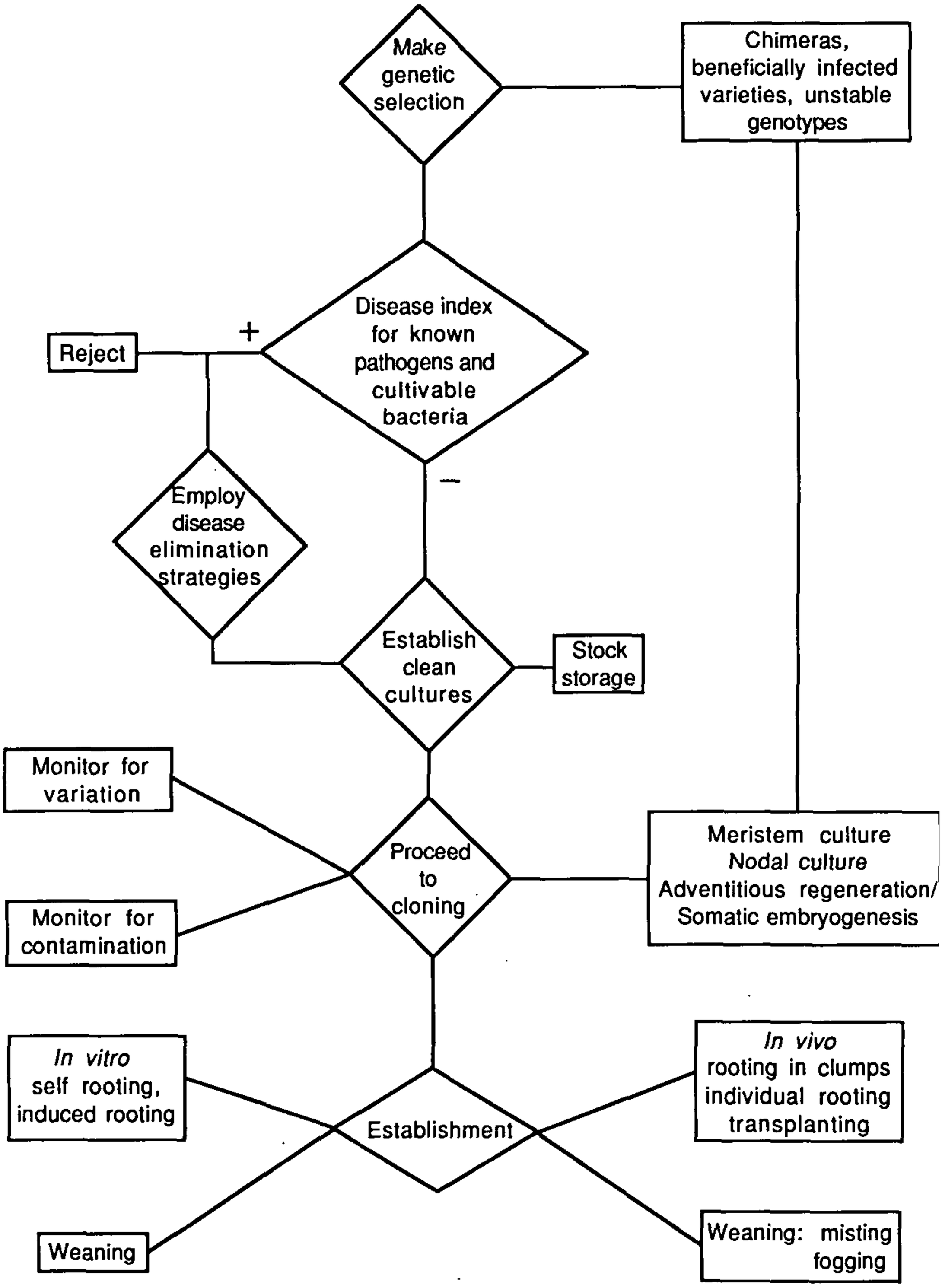

Figure 1. Factors influencing the production of good quality microplants.

viz, that not less than 10 vigorous uniform individuals be used to initiate clonal propagation. In addition, it is recommended here that the client/breeder and micropropagator should discuss the question of inherent stability for each cultivar entered for micropropagation. If a suspect cultivar is entered, special consideration should be given to the cloning strategy to be used (see below).

Disease indexing and contamination monitoring. To avoid clonal disease transmission and losses *in vitro* and on establishment, it is essential to clone clean ('axenic') cultures. To achieve this, rigorous screening procedures should be employed. Pragmatically, one should look for known pathogens of the crop—viruses, bacteria, and vascular fungi (12). One should also screen for cultivable bacteria, which include common endophytes, e.g. *Erwinia, Pseudomonas, Corynebacterium,* and *Xanthomonas,* and be aware that occasional exotic bacteria may also be found (4).

Screening techniques should be sensitive and non-strain specific for the known pathogens of the crop, e.g. ELISA and DNA probes. Culture indexing may be employed for the cultivable bacteria. Screening is an aspect fraught with potential problems and can only be covered by a "best endeavours" approach.

Management of clean cultures. Once clean, or preferably axenic, cultures have been obtained they are at risk of contamination in the laboratory. Sources of contamination are transferred from contaminated cultures or directly from the micropropagator. *Bacillus* and other heat-resistant, spore-forming bacteria are commonly encountered.

Two management approaches should be used. Firstly, sample cultures should be regularly culture-indexed during subculture for cultivable bacterial contaminants. Secondly, stock handling should be minimised by storage under slow growth conditions (16). Deep cold storage should be avoided for cultivars that are unstable in adventitious regeneration.

The cloning pathway. Plants may, at least in principle, be cloned by a number of pathways (Figure 1) that are grouped into two fundamentally different types—bud culture and adventitious regeneration. In the former, which includes bud tip, meristem and nodal culture, the structural organisation of the somatic layers is theoretically maintained. In the latter, buds arise *de novo* from single cells or groups of cells in one or more somatic layers (6).

Nodal culture, and meristem culture, if *via* precocious axillary bud proliferation and not *via* intervening callus, can be used to propagate "normal" and chimeral cultivars, giving true-to-type progeny with the *caveat* that in chimeras one genotype may be selected for preferentially, under *in vitro* pressures, resulting in increased instability. Meristem culture but not nodal culture may result in the elimination of beneficial infections (1).

The use of adventitious regeneration in complex explants or

callus cultures will result in chimeral breakdown and may result in high levels of genetic instability—somaclonal variation (14). The variation found may depend on the specific genotype being cloned, particularly in ornamental plants where, as in pelargoniums, polyploid and aneuploid genotypes may exist side by side in different cultivars (8).

Cultivars containing unstable loci may mutate at very high frequency *in vitro* and these should be handled with special consideration (5).

Production monitoring. Production should be regularly monitored for bacterial contaminants as discussed above. It is important in this regard to recognise that media constituents, e.g. salts, may inhibit bacterial growth and consequently visual examination may not be adequate. Consequently, losses of cultures to contamination may occur on transfer to reduced strength rooting media.

Monitoring production for variation must always be carried out for each new genotype entered into micropropagation to avoid risks. Two types of variation may be encountered in micropropagated plants—random and non-random (or directed) changes. Random variation may be anticipated in adventitious regenerants at relatively low frequency at around 1 to 10%, while directed change may occur at high frequency, occasionally up to 100 per cent, e.g. change in leaf shape in *Saintpaulia ionantha* 'Rose' (6).

The above are examples of changes in the genome which may or may not be heritable. Epigenetic (non-heritable) changes may also be expressed in the phenotype, the latter induced by the microenvironment and/or media factors and by the presence of contaminants in the cultures. The gaseous environment: O_2, CO_2, C_2H_4, and H_2O, interacting with the hormone concentration in the medium, may induce vitrification and/or apical necrosis (13). Both conditions affect multiplication rates and quality of growth. Apical necrosis may result in break of lower buds and uneven cultures and progeny.

Problems resulting from the microclimate may be controlled by provision of appropriate light intensity and quality and by control of the gaseous environment by the use, for example, of differentially permeable membranes as covers (3). The latter may also facilitate weaning (see below).

Finally, it should be recognised that there may be residual effects of the hormones on the performance of the established progeny (15).

Rooting and establishment. A number of strategies are used for rooting and to achieve the establishment of microplants (see Figure 1). Where induced rooting is employed, care should be taken to avoid influencing the root/shoot ratio in such a way as to alter the plant habit. In the case of plants to be used as stock for cuttings,

manipulation of the root/shoot ratio to achieve reduced apical dominance may result in more productive stock (11). This is an area which merits further research.

Self-rooting, or rooting in clumps, is also frequently used to reduce costs. The latter may result in irregular progeny requiring grading by the grower.

The issue of rooting aside, the establishment of microplants may be difficult because of poorly adapted photosynthetic apparatus and softness (subliminal vitrification) (9,10). The latter problem can be addressed by the provision of misting or fogging facilities (17), or by hardening the material *in vitro* by manipulation of the micro-environment, for example by the use of differentially permeable double-membraned containers (3) (Figure 2).

CONCLUSIONS

Mass clonal propagation via micropropagation depends on careful genotype (cultivar) selection. Inherently unstable genotypes may, on grounds of rarity etc., merit consideration but for these it is imperative that the appropriate cloning pathway be adopted and that the prospect of variation in the progeny be accepted. The breeder or grower has an important role in advising the micropropagator of potential risks due to instability. The micropropagator for his or her part should avoid unstable genotypes or issue a disclaimer.

The micropropagator has responsibility, unless exempted, to ensure the clean (axenic) status of mother cultures and to monitor production for contamination. Further, the micropropagator, should monitor production for clonal stability and should provide the appropriate microclimate and media to ensure quality growth on establishment.

Finally, if micropropagation is to increase its market share, production costs must be reduced. It is likely that this may be achieved eventually, for example by exploiting adventitious pathways of regeneration to produce artificial seed *via* somatic embryogenesis. It has been stressed here that this pathway carries the greatest inherent risks of variation in the progeny. Nursery operators should be alert during the "learning phase" of the risks associated with adventitious regeneration.

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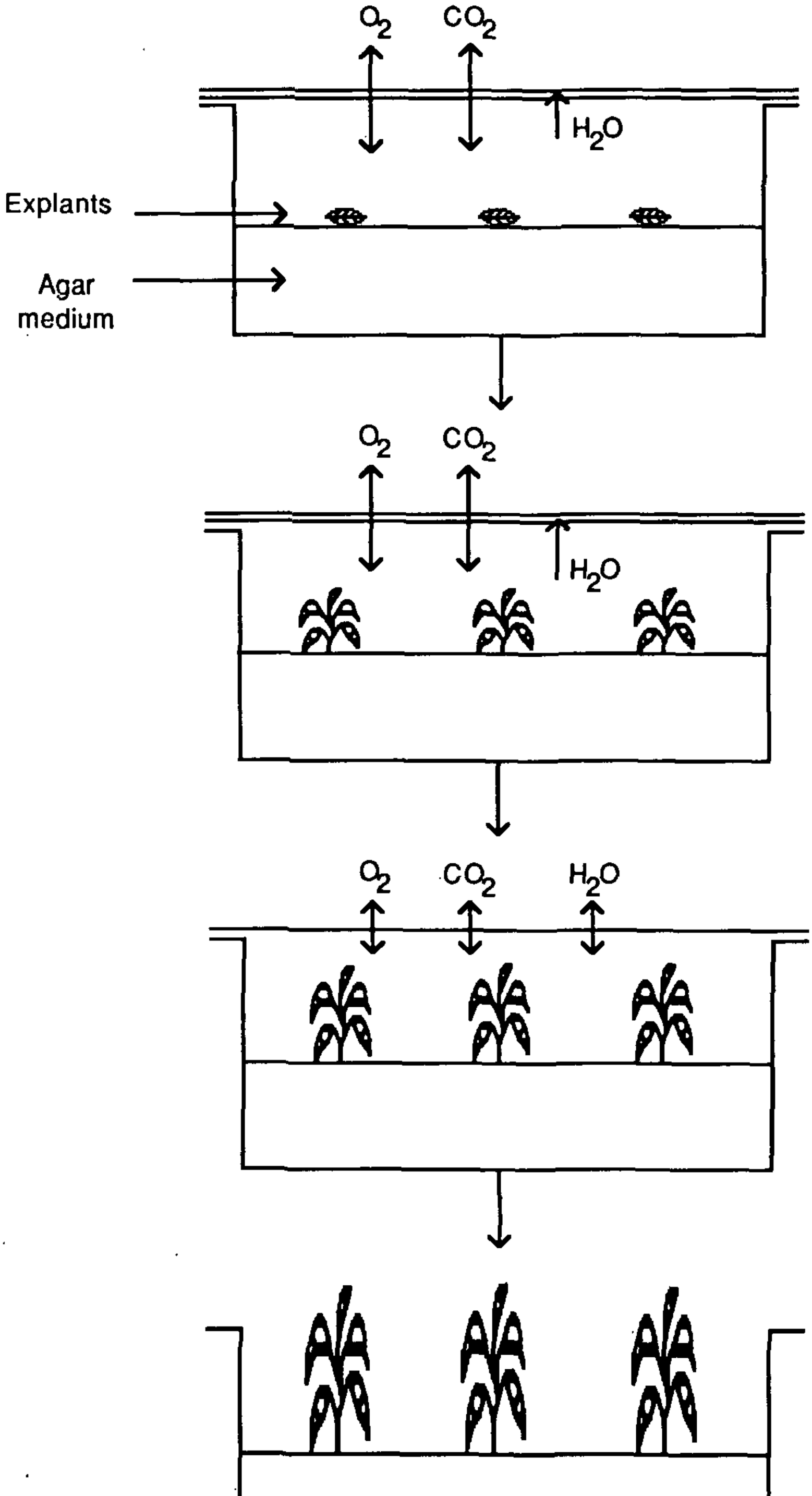

1. Implantation: free diffusion of O_2, CO_2, H_2O loss controlled.

2. Growth: diffusion as above.

3. Weaning: removal o outer membrane, increased H_2O diffusion.

4. Growing on

Figure 2. A double membrane patented system that allows control of the gaseous culture environment during microplant development and weaning (3).

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INTERACTIONS BETWEEN MICROPROPAGATION AND CONVENTIONAL PROPAGATION

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INTRODUCTION

When shoot culture *in vitro* was first recognized as a method for vegetative propagation there was a tendency to view it as a "stand alone" technique, not as one to integrate into general propagation.

There are various reasons for this. Tissue culture is a novel and highly technical process, requiring special and costly facilities more akin to a hospital than a nursery. It provided a wide range of research opportunities extending beyond plant propagation to plant improvement and was taken-up by specialist groups, often based in universities, some without contact with commercial horticulture. Initially, micropropagation was seen to have special opportunities, enabling the creation, maintenance, and exchange of healthy plant material for example.

The tendency to develop as a technology separate from the rest of propagation is only being eroded slowly. Of the 20 or so commercial tissue culture laboratories in England in 1986 concerned with vegetative propagation (as opposed to seed or other special purpose) only three were part of a commercial nursery enterprise (3).

As commercial laboratories increasingly focused on plant production they encountered problems of product acceptability. Plantlets supplied bare-root as removed from the culture flask were unfamiliar to nurserymen and many small plants died, often through over-watering. The majority of laboratories responded by establishing their micropropagules in modules or plugs, so providing liners to the nurseries and building another bridge between the two technologies.

Knowledge and technical skills in conventional cutting propagation are improving rapidly, and in many respects micropropagules behave as very small cuttings which can benefit from this progress. On the other hand, micropropagules *in vitro* comprise highly meristematic and "plastic" tissues which can be exposed to complex chemical conditions and finely controlled physical environments in a way that is not possible during auxin treatment and rooting of conventional cuttings.

To investigate and exploit the opportunities for interplay between micro- and macro-propagation will ensure faster progress in the science and practice of propagation than if the techniques are allowed to develop separately.

Nature of the opportunities. Micropropagation has broad

relevance across horticulture from the production of plants for cut flowers, herbaceous perennials, foliage plants, bulbs, ornamentals and fruit trees and shrubs, and even some vegetables.

Trees and shrubs embody most of the problems and opportunities. Many of the 8000 woody subjects grown in the UK are propagated commercially, presenting the problem of diversity. Trees exhibit strongly the problem of phase change, whereby commercial horticultural characteristics cannot be identified until the adult phase of flowering and fruiting is reached, by which time the juvenile period, with its associated ease of propagation, is passed.

Opportunities for an integrated approach include taking into culture difficult-to-propagate adult material, creating "rejuvenated" material in culture, identifying methods to culture successfully a wide range of genera, and developing less costly processes. This last objective is particularly relevant to the rooting stage where individual shoots rooted *in vitro* attract all costs, whereas these are spread over increasing numbers of shoots during the earlier multiplication stage.

Culture initiation. The importance of maximizing efficiency at the start of culture is obvious. The material may be scarce because it is of a new cultivar or healthy clone. Early losses set back production schedules seriously. For example, increasing the number of successful initial explants from 1 to 100 reduces the time required to exceed 50,000 cultures from 8 to 5 months given a 5-fold monthly multiplication rate.

Techniques that raise the rooting potential of shoots for use as conventional cuttings can assist culture initiation *in vitro*. An investigation of why an apple rootstock failed to root from cuttings, but rooted when stooled, showed that severe stockplant pruning and localized exclusion of light were important components of the stooling process (4). General dark treatments, in which stockplants are covered with ventilated tents of black polythene, raise the rooting potential in shoots of different species (Table 1).

Explants taken into culture from field stockplants grown in darkness or heavy shade survived in greater numbers than those taken from light-grown plants. The improvement was associated with a decrease in the production of oxidized phenolics. In *Quercus robur* 'Fastigiata', the frequency of detrimental phenolic oxidation was reduced from 33 to 13 per cent, and in *Garrya elliptica* 'James Roof' from 100 to 0 per cent (6).

Table 1. Effects of dark-preconditioning stockplants on subsequent rooting percentage of leafy cuttings.

	M.9 apple	*Syringa vulgaris* 'Mme. Lemoine'	*Quercus robur** 'Fastigiata'	*Tilia* sp.
Dark	90%	92%	30%	67%
Light	10	43	4	45

*1 per cent available light

'Rejuvenation' and rooting potential. It is now well-established that the rooting potential of shoots grown *in vitro* increases over a period of successive subcultures. The number of subcultures and the precise culture conditions required to obtain a high rooting potential varies with the cultivar. More than 90 per cent of the explants of the apple scion cultivar, Jonathan, rooted by the ninth subculture, while 31 subcultures were required for the cultivar, Red Delicious, to reach 79 per cent rooting (8). Deciduous azaleas show a similar but faster response (2).

The *in vitro* process can be used therefore, to achieve propagation in hitherto difficult subjects, but there may be reasons why this approach is not sensible as the sole propagation method. The cost to nurserymen of buying-in micropropagated liners may be relatively high compared to production on the nursery, and the small liners may not fit easily into production schedules.

It is of considerable importance, therefore, that plants whose rooting potential has been increased during production *in vitro* produce cuttings which retain an enhanced rooting potential in conventional cuttings taken subsequently from container-grown and field-grown stockplants. This effect occurs in genera as different as plum and rhododendron (Table 2), but the "memory" of the initial micropropagation event is not consistent. The effect on rooting potential of plum was still present in hedge-grown material derived from micropropagules nine years previously and it has lasted for at least a year in *Rhododendron* 'Hoppy', whereas it disappeared within a year or so for *Rhododendron* 'America'. Associated characteristics such as increased shoot vigour, spinyness, and slight delay in flowering support the view that 'rejuvenation' occurred.

Table 2. Rooting percentage of conventional cuttings from *in vitro*-derived stockplants compared to rooting *in vitro*, and from normal stockplants. (*In vitro*-derived and normal plum material was grown as field-hedges and *Rhododendron* material was grown in containers).

	In vitro	*In vitro*-derived	Normal
Prunus insititia 'Pixy' hardwood cuttings	100%	67%	39%
Rhododendron 'Hoppy' softwood cuttings	100	60	20

Maximizing shoot multiplication. When first taken into culture many subjects are difficult to grow, with the all-important axillary shoot production lacking. Approaches used to overcome this problem include relating *in vitro* conditions to those in which the plant does best in its horticultural environment. A low pH in the culture medium is required by *Magnolia* × *soulangiana*, the most calcifuge of that genus, and also for the acid-loving *Disanthus cer-*

cidifolius. *Magnolia* shoot production increased from 3.7 to 5.7 by reducing the medium pH from 4.5 to 3.5, and *Disanthus* increased from 2.3 to 7.2 shoots over the pH range 6.5 to 4.5, respectively.

Acid soils are often nutritionally poor, and both rhododendron (1) and *Kalmia* (5) require lower nitrogen and potassium levels than those provided in Murashige and Skoog medium. Such specific requirements explain why results may be poor when a wide range of species are processed in laboratories using relatively few standard culture media. Because economies of large-scale production are not available when specific media must be prepared for runs of a few thousand cultures, commercial micropropagation laboratories may find difficulty in producing a wide range of plants cost-effectively and may need to specialize. In laboratories attached to commercial nurseries, where overheads can be carried by the parent organization, micropropagation should be cost-effective when it is used as a special tool for a relatively few subjects.

Rooting, weaning, and establishment. As with conventional cuttings the availability of auxin is central to success in rooting micropropagules, either by increasing the auxin:cytokinin ratio *in vitro*, or applying exogenous treatments and rooting the micropropagules as mini-cuttings *ex vitro*.

After removal from closed culture vessels, micropropagules, with reduced cuticular wax on their leaves and stems, require particularly supportive environments to avoid desiccation or excessive hydration. Fog systems are particularly effective (7). In experiments at East Malling, cuttings performed better in fog produced by a centrifugal system (Agritech), then under mist, with actual leaf wetting prevented in both cases. For *Embothrium coccineum* rooting was improved from 38 to 88 per cent in fog and, although all cuttings of *Schizophragma hydrangeoides* rooted in both environments, those from the fog subsequently grew faster.

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HOW FAR DO WE GO? FUTURE DEVELOPMENTS AND OPPORTUNITIES IN MICROPROPAGATION

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INTRODUCTION

There is no doubt that amazing advances have been made since plant tissues were first cultured *in vitro* in the 1930's. Orchid propagation by both seed and meristem culture (mericloning) was an early use of these techniques. Florist crops and pot plants probably still account for the largest number of plants propagated in culture. Increasing use of micropropagation techniques is being made in hardy ornamental nursery stock and plantation crops with considerable effect being expended in investigations in micropropagation of forest species.

Currently at least 205 laboratories are in operation worldwide (3), but it is difficult to distinguish between production and research laboratories, making any realistic output estimate impossible. There are a number of units in operation or planned with a production capacity of 5 to 20 million plantlets. The theoretical capacity of a facility and what is actually produced are often widely different and the logistics of the very large units present enormous problems.

The rapid development of micropropagation and interest in its possibilities, resulted in a crisis of confidence in the 1970s. Micropropagation had begun to be perceived as a panacea for all problems but a credibility gap grew between the theory and what was actually delivered. Nurserymen became disillusioned as contracts were not always met and insufficient account was taken of limitations of the technique. These problems have been, in many cases, overcome, but there are five outstanding problems to be faced before the technique can be fully used.

The first is synchronous development *in vitro*. We need to be able to understand and control the physiology of the plant more exactly.

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INTRODUCTION

There is no doubt that amazing advances have been made since plant tissues were first cultured *in vitro* in the 1930's. Orchid propagation by both seed and meristem culture (mericloning) was an early use of these techniques. Florist crops and pot plants probably still account for the largest number of plants propagated in culture. Increasing use of micropropagation techniques is being made in hardy ornamental nursery stock and plantation crops with considerable effect being expended in investigations in micropropagation of forest species.

Currently at least 205 laboratories are in operation worldwide (3), but it is difficult to distinguish between production and research laboratories, making any realistic output estimate impossible. There are a number of units in operation or planned with a production capacity of 5 to 20 million plantlets. The theoretical capacity of a facility and what is actually produced are often widely different and the logistics of the very large units present enormous problems.

The rapid development of micropropagation and interest in its possibilities, resulted in a crisis of confidence in the 1970s. Micropropagation had begun to be perceived as a panacea for all problems but a credibility gap grew between the theory and what was actually delivered. Nurserymen became disillusioned as contracts were not always met and insufficient account was taken of limitations of the technique. These problems have been, in many cases, overcome, but there are five outstanding problems to be faced before the technique can be fully used.

The first is synchronous development *in vitro*. We need to be able to understand and control the physiology of the plant more exactly.

Secondly, the least spoken of, yet most immediate problem, in commercial production is chronic contamination *in vitro*. Both bacterial and fungal problems occur with, in some cases, insects such as mites acting as vectors.

Thirdly, it is essential to aim for consistent high yield of quality plantlets. In the past insufficient attention has been paid to grading. Work within the Ministry of Agriculture's Agricultural Development and Advisory Service has demonstrated the importance of grading and we are understanding more of the effects *in vitro* conditions can have upon grading and growing on.

With some 50 per cent of production costs attributable to labour, efficient labour utilisation and management is essential. Savings in this area can be highly significant but should not be at the expense of quality.

Finally, it is essential for realistic business strategies to be adopted; over-capitalisation and too rapid a growth rate can create problems. Similarly a realistic marketing plan is required.

FUTURE DEVELOPMENTS

1. Automation. Aspects of automation will become increasingly important with simple aids and ergonomics such as media dispensing and container handling systems from the food industry; other aids and work study can be exceptionally cost effective. Developments in containers, especially the use of various types of plastic, may result in significant improvements in systems without high capital costs.

A number of possibilities present themselves using computer technology and robotic arms. A key component of this approach is an accurate vision system to guide the robot arm. It is possible to site the system in a sterile cabinet to ensure aseptic manipulations (5) and a number of groups are investigating these possibilities around the world.

Solutions will be technically possible but with high costs, especially of programming, the economics may be questionable in many cases.

2. Liquid Culture Systems. These offer a number of possibilities as they are potentially very flexible. Thin stationary liquid cultures have been used for some foliage plants and laboratory shakers have been crudely scaled up to demonstrate the potentially large increases in shoot production, such as 7-fold in fuchsia and amelanchier (7). Aeration of liquid systems can increase growth and yield in orchids (Pennell, unpublished data) with a 3-fold increase in protocorms. The natural progression of these studies would be to utilize bioreactors (fermenters) as is the case in work on alfalfa embryos (11).

Another approach would be a system using liquid media

together with an inert support such as agar, fibres, or granules. Maene and Debergh (8) adopted this approach, of a secondary liquid phase, with a range of species including cordyline, philodendron, magnolia, and spathiphyllum, initially to improve elongation and rooting. The concept has been used by others (2) where shoots of *Pinus radiata* have been maintained in the same culture vessel on agar, with liquid replenishments, for 18 months. An automated plant culture system based on replenishment of liquid media has been developed and can be monitored and controlled by computer (14). Such a system is almost *in vitro* hydroponics, in which manual handling of cultures is reduced to the absolute minimum and is only needed for the initiation of cultures and singulation (if required) of shoots prior to weaning.

The use and investigation of these potential options require a detailed knowledge of the various physiological systems which are used in micropropagation systems and especially their limitations.

3. Somatic embryogenesis. Literally, *in-vitro* embryo formation without pollination and with embryos often arising from a single cell. The main studies in this area have concentrated on carrot and celery although progress has been made with some plantation crops, notably the palms, using this approach. Palm embryoids develop into plantlets *in vitro* prior to transfer to compost (12). The key problems are that not all species will respond in this way. The development and synchronization of embryo production is difficult to control and developing delivery systems with high germination rates can be difficult.

Theoretically the long term aim would be to create an embryo which can be fluid-drilled (6) into compost or alternatively be encapsulated (9). Encapsulation consists of forming an artificial seed coat around an embryo consisting of a gel matrix and could enable seeding machines to be used.

4. Adventitious shoot systems. Many ornamental herbaceous plants have the ability to develop secondary meristems and adventitious shoots from plant organs, *Saintpaulia* leaves for example. Where species respond in this way, it may be possible to develop systems where mechanical cutting and transfer of tissues may be possible. Extreme examples of this approach are in the propagation of *Davallia* and *Platycerium* ferns (4).

Stock cultures are added to a sterile blender and homogenised for a few seconds. Fragments of tissues are then dispensed into culture containers. The potential yields from this system are enormous but are limited by:

(i) very few species survive this type of treatment;

(ii) cellular debris produced may have toxic effects;

(iii) limited number of plants can produce adventitious shoots;

(iv) uniformity of plants produced can be variable *in vitro* and

in the field with dangers of phenotypic and genetic variation;

(v) a long regeneration period may be required;

(vi) at some stage plantlets will probably still require singulation;

(vii) sterility is essential but may be difficult to maintain.

Nevertheless, this could be a valid approach in some circumstances.

5. Axillary shoot systems. Stimulating axillary branching or culturing nodal sections is the most stable and widely used system in micropropagation. There is scope for manipulating plant development by changing culture conditions. Most significant advances in systems using this type of plant development will centre on reducing labour at transfer by the use of a secondary liquid phase or by the development of robotics.

6. Specialization. Micropropagation companies will specialize in young plants and move away from pure contract work. There will be a trend to buy—in research and development to make best use of resources. A number of relatively small nursery units are likely to be set up for the micropropagation of a limited range of plants and be treated much like a mist unit, frame yard, or any other propagation facility.

7. Spin-off from micropropagation. There will be better utilisation of microplants on nurseries to make best use of growth rates and changes in plant form. Also, exploiting the observed juvenility and enhanced rootability of cuttings from microplants could have significant effect upon propagation generally.

The application of micropropagation techniques to conventional systems such as inducing juvenility in stock plants or the use of hydroponic culture in propagation are worth investigation.

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APPLICATION REQUIREMENTS AND COSTS OF A TISSUE CULTURE FACILITY FOR THE NURSERYMAN

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INTRODUCTION

Plant cell and tissue culture technology has in recent years advanced so dramatically that today, not only does it serve as a research tool for plant scientists, but also has found a powerful niche in ornamental plant propagation. This technology had its origin in 1902 when Haberlandt postulated that if plant cells and tissues were excised and cultured on a nutrient medium under controlled environmental conditions, the phenomenon of cell totipotency should occur.

A number of major discoveries trace the development of plant tissue culture since then. It received a major stimulus when Morel (13) commercialized tissue culture of orchids. This encouraged scientists to explore its applicability for the propagation of diverse ornamental crops.

As a measure of its importance and significance in the nursery stock industry, the rate at which it is being adopted is indeed, remarkable. Reviewing the literature, one finds evidence of more than 50 plant genera presently being commercially propagated using the technique and at least another 20 awaiting commercialization. Additionally, some of these genera represent numerous species and cultivars, so that thousands of individual kinds of plants are available throughout the world. This compares with just four genera which showed a potential for tissue culture in 1979 (14).

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ADVANTAGES OF TISSUE CULTURE

The advantages accruing to the nurseryman may be categorized as horticultural or business. The horticultural advantages include:

(i) its unmatched potential for the rapid asexual multiplication of uniform high quality plants;

(ii) the ability to produce crops independently of weather and seasonal influences;

(iii) the elimination of stock plant holding areas;

(iv) the ability to store genetic material.

The business advantages include:

(i) the potential to produce vast quantities of plants with short generation cycles in a limited space;

(ii) the enhanced image accredited to the nurseryman using sophisticated technology for plant propagation;

(iii) the strategic marketing advantage accruing through earlier distribution of new and elite genotypes;

(iv) access to international markets afforded by the legitimate movement across national frontiers.

APPLICATIONS OF TISSUE CULTURE

Rapid clonal propagation has emerged as the greatest application of plant tissue culture to the nursery industry. Genera hitherto deemed difficult to propagate are now readily available to nurserymen in virtually limitless quantities (10). In forestry clonal propagation of *Eucalyptus* is predicted to produce large economic gains (9). Other applications include the propagation of conventionally difficult to propagate plants (e.g. *Rhododendron* c.v. Brittannia), the production of elite plants with a high commercial value, and the reduction in time required to release new plant cultivars, a phenomenon particularly relevant to the hardy fruit nursery industry.

REQUIREMENTS FOR A TISSUE CULTURE FACILITY

The fundamental principles underlying successful tissue culture procedures involve the isolation of a plant organ or part (explant) from the mother plant, its culture under aseptic conditions in an appropriate environment, and the re-establishment of a high percentage of the microplants. Special laboratory and environmental facilities are required for this:

(a) A greenhouse structure for growing or forcing mother plants. For the nurseryman this is usually not an additional requirement.

(b) Suitably equipped laboratory areas for medium and plant

preparation, explant manipulation, and transfer and culture room/growth chamber facilities.

(c) A weaning facility complete with environmental control.

The following appliances are necessary:

(a) Laminar air-flow cabinet for aseptic manipulations.

(b) Autoclavê for culture vessel, media, dissecting instruments, and water sterilization.

(c) Balances: (i) electronic analytical to five decimal places, with 300 gram weighing capacity.

(ii) Top-loading electronic, analytical to two decimal places with 1500 gram weighing capacity; suitable for less accurate measurements.

(d) Stereoscopic binocular dissecting microscope for dissecting apical and axillary meristems, shoot tips and stem pieces, and for culture observation.

(e) Water purification system to provide quality water.

(f) Magnetic stirrer with hot plate facility to aid in dissolving and agitating chemicals.

(g) Refrigerator/freezer for storage of chemicals and stock solution.

(h) pH meter to measure the alkalinity or acidity of the unautoclaved nutrient medium.

(i) Spirit lamp/bunsen burner for flaming instruments.

(j) Trolley for transporting cultures.

(k) Miscellaneous instruments (scalpels, forceps, automatic pipette.).

(l) Supply of laboratory glassware, plasticware, culture vessels, and high quality analytical grade chemicals.

Laboratory. Three distinct laboratory areas must be created:

(i) preparation

(ii) transfer

(iii) culture.

The preparation laboratory is the general work area where chemicals are stored, culture media prepared and sterilized, and plant material made ready for disinfestation. Hence, it should be equipped with balances, water purifier, magnetic stirrer, pH meter, autoclave, and have adequate bench space and shelving for operation and storage. Other equipment should include a refrigerator/freezer. Any preparation laboratory must have an adequate supply of tap water and sufficient washing facilities. At least one large sink and draining board is necessary. Sufficient space should

be available to set up baths for acid and detergent treatment of glassware and for drying racks.

The transfer area is the nerve centre of the facility and ideally a totally sterile atmosphere is the optimum environment for this process. Unfortunately, this concept is uneconomic and for practical purposes laminar air-flow cabinets are used. Such cabinets should be sited within a self-contained room to minimize the risk of chance contamination. In a laminar air-flow cabinet, air is initially drawn through a pre-filter, followed by forcing through a highly efficient one and the air is subsequently directed either horizontally or vertically at a uniform rate over the work area. This maintains a sterile area, within which operatives may manipulate explants and microplants.

The growth chamber constitutes the third component of the plant tissue culture laboratory and they can range form simple environmentally-controlled commercial incubators to sophisticated computer-controlled phytotrons. The deployment of an inexpensive growth chamber of the structure described by Morgan and Clarke (12) is adequate, provided it is equipped with temperature, lighting, and daylength control. Although a temperature of 24°C ± 1°C is the most frequently adopted one for incubating tissue cultures, Gardiner *et al.* (5) used 20°C for *Pinus contorta*. Hence, the necessity to have a system with the facility for setting and maintaining any pre-determined value from 12°C to 30°C ± 1°C.

The usual method of providing lighting facilities is the incorporation of banks of fluorescent tubes suspended by flexible mountings from tiered benches. Such an arrangement will provide various illuminance values by raising or lowering the light banks or altering tube numbers. To capitalize on energy efficiency, the tube type selected should emit a high proportion of energy in the spectral range 550 to 600 nm.

Photoperiodic control is also necessary and is achieved using time-clocks. It should range from continuous darkness through multiple darkness/lighting combinations to continuous lighting.

Sterilization. The need to continually maintain sterility is fundamental to the success of the tissue culture process. It requires that the media, instruments, re-usable culture containers, (glass and plastic) transfer area, and the plant material be made and kept sterile. Excepting the latter two, sterilization is effected by autoclaving for 15 minutes at 121°C and a pressure of 103.4×10^3 Pa. However, Biondi and Thorpe (2) recommend a minimum of 15 minutes for 50 ml volumes rising to 40 minutes for 2,000 ml volumes.

It is important for the propagator to note that not all plasticware is autoclavable. Polycarbonate, polymethylpentene, and teflon are; polyvinylchloride, polystyrene, and acrylics are not. It is recommended that this factor be considered when obtaining cul-

ture containers.

Filtration. Filtration using bacteria-proof membranes is an alternative method for media sterilization. However, it is expensive and so is usually only used to sterilize substances destroyed by heat.

Disinfestation. Plants are invariably contaminated with microorganisms and therefore must be disinfested before inoculation onto the growth medium. The donor material is initially prepared by removing superfluous tissue followed by washing under running tap water, frequently for many hours. Surface disinfestation may be achieved using a variety of sterilants, most of which are used in low concentrations. Commercial household bleaches containing hypochlorite are often used at rates ranging between 0.5 and 5.0 per cent. The inclusion of a wetting agent is beneficial to ensure thorough wetting of the plant surface. Sterilants must be completely removed by washing in several changes of sterile distilled water.

Water. Tap water contains many contaminants (gaseous and particlate) and as such is unsuitable for tissue culture purposes. It is necessary for the nurseryman to obtain a supply of high quality water. Several methods for obtaining such water are available (2) including glass distillation and reverse osmosis. The former is cheaper to install and is the preferred source in the author's laboratory. However, it has high running costs and may produce sub-quality water if not carefully maintained.

Weaning. The re-establishment of autotropism ("self-sufficiency") of a high proportion of the tissue culture-derived microplants is central to the economics of the system. Seabrook (15) argued that the microplant ought to have a well developed root system prior to transfer to the *in vivo* state, while more recently the trend is toward the establishment of unrooted ones (19). Tissue-cultured plants are both physiologically and anatomically different from seedlings or softwood cuttings (16,17), differences which cause difficulties during the acclimation process and often lead to reduced survival and establishment rates. Several factors have been identified:

(i) poor vascular connections between shoots and roots thus reducing water conduction (7)

(ii) delayed functioning of the stomates and lack of structural epicuticular wax resulting in excessive water loss (6, 16)

(iii) poor development of the photosynthetic system (8)

(iv) culture medium composition and transfer from heterotrophic to photoautotrophic nutrition (3)

(v) disease susceptibility at this developmental stage (11).

The humidity levels in the *in vitro* environment frequently approach 100 per cent. Accordingly, Conner and Thomas (3) suggested that humidity should be gradually reduced in the weaning

chamber to minimize initial transpiration shock, and the risk of wilting and desiccation. High humidities may be maintained with the use of fog, intermittent mist, or an enclosed polyethylene case. Fogging has emerged as an ideal method for weaning microplants. Intermittent misting systems are less favoured since leaching of the leaves and root asphyxiation of the microplants tends to occur (1, 11). The use of polyethylene tents are also useful but are less favoured than fog.

As with humidity, temperature and light control are also important. Wong (18) suggested that an air and compost temperature related to that used *in vitro* should be maintained while low lighting levels during the initial photoautotrophic stage, followed by higher levels with plantlet development, has been suggested (4).

COSTS OF ESTABLISHING A TISSUE CULTURE FACILITY

The costs of establishing a tissue culture facility is highly variable and is influenced by many factors:

(i) Whether a building exists on the nursery that could easily be converted into a laboratory, or whether construction of a purpose-built one would be required. In the former instance, the conversion and refurbishment costs; in the latter, the construction costs.

(ii) Proximity to essential services such as electricity and water supplies.

(iii) The manufacturer, model, and specification of the equipment purchased—(portable versus fixed autoclave; small versus large laminar air-flow cabinet).

(iv) Presence or absence of a weaning facility. On nurseries, where propagation facilities exist, additional facilities are unlikely to be installed. However a weaning facility specifically for tissue-cultured plants is strongly recommended

The costs of establishing a minimum recommended tissue culture facility for the nurseryman are given in Table 1. Prices are given in pounds sterling and exclude VAT, but represent present (1988) prices in Ireland.

Table 1. Requirements and cost for establishing a tissue culture facility.

Laboratory*	£10,250.00
Culture room*	£ 2,550.00
Laminar air-flow cabinet (1.5 sq m)	£ 1,660.00
Balance (i) analytical (5 decimal places)	£ 1,440.00
Balance (ii) top loading (2 decimal places)	£ 940.00
Stereoscopic binocular microscope	£ 1,025.00
Autoclave (portable)	£ 350.00
Water still	£ 290.00
Glassware drier/oven	£ 340.00
Magnetic stirrer with hot plate	£ 215.00
Trolley	£ 215.00
Refrigerator/freezer	£ 200.00
pH meter	£ 100.00
Instruments (forceps/scalpels)	£ 85.00
Glassware (flasks/beakers/cylinders)	£ 430.00
Weaning facility (72 square meters)	£ 2,990.00
Initial supply of chemicals/plasticware and containers	£ 600.00
Total capital cost	£23,680.00
Annual charge @ 13% (× 0.1715)	£ 4,061.12

*Combined floor area 75 sq m

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SUCCESSES AND FAILURES WITH MICROPROPAGATED PLANTS: THE BLOOMS' EXPERIENCE

ADRIAN BLOOM

Blooms of Bressingham, Diss, Norfolk

Micropropagation is hardly new but is only now being accepted by the majority of the trade as a useful and standard method of propagation. Twenty years ago, it was barely talked about in the hardy nursery stock industry nor considered a viable alternative or replacement to more traditional methods. We looked upon it with a mixture of excitement and dread. On the one hand it had a potential benefit for producing hitherto difficult to propagate plants, apart from new or unusual forms—but on the other it seemed to open the way to very real dangers of overproduction.

Questions were asked like: Would it revolutionize propagation methods? Would it put the skilled propagator out of business? Would it make the rare plant common, bring down prices and flood the market?

At that time there was no way those questions could be answered. As a company we had to ask the question, "What was in it for Blooms?" Whether or not you like to face change and new technology, if you don't you will soon find progress passing you by. We had to avail ourselves of this science to help us produce items that were consistently in short supply and for rapidly building up stock of new plants. Plants in test tubes did seem rather far-fetched but it was exciting to consider getting new, rare, or unusual plants into

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Micropropagation is hardly new but is only now being accepted by the majority of the trade as a useful and standard method of propagation. Twenty years ago, it was barely talked about in the hardy nursery stock industry nor considered a viable alternative or replacement to more traditional methods. We looked upon it with a mixture of excitement and dread. On the one hand it had a potential benefit for producing hitherto difficult to propagate plants, apart from new or unusual forms—but on the other it seemed to open the way to very real dangers of overproduction.

Questions were asked like: Would it revolutionize propagation methods? Would it put the skilled propagator out of business? Would it make the rare plant common, bring down prices and flood the market?

At that time there was no way those questions could be answered. As a company we had to ask the question, "What was in it for Blooms?" Whether or not you like to face change and new technology, if you don't you will soon find progress passing you by. We had to avail ourselves of this science to help us produce items that were consistently in short supply and for rapidly building up stock of new plants. Plants in test tubes did seem rather far-fetched but it was exciting to consider getting new, rare, or unusual plants into

micropropagation and hopefully on the market before others. The next question was . . . do we consider setting up our own unit, or go to outside independent laboratories?

Travelling quite widely gave me the opportunity to assess what might be best for Blooms. Nurseries in the USA I visited were dubious about getting returns for some years on their investment. This, coupled with finding and keeping qualified research technicians and many teething problems, decided us to, at least initially, look for specialist tissue culture labs to provide the resources for early experimentation and production. The one large scale lab in the UK at the time didn't seem interested in any new work unless guarantees for large quantities could be given. We found that both Neo Plants of Stoke on Trent and ourselves had a common purpose. They were a small lab looking for diversification, we had a considerable range of plants and a requirement for quite reasonable quantities once propagation was achieved.

It was very much a give and take situation for the first few years. There were few quick results, and in many cases no result. Success and disappointment. It soon became evident how susceptible these plants were to contamination. First results from pricking out cultures from flasks on our nursery were mixed. It seems elementary now, but it was obvious the laboratory would have to do the weaning, producing a plug or liner for the nursery.

We also learned not to rely on forecasts for plants until they were in the weaning stage and, if possible of course, to take delivery at the beginning of the natural growing season, since we did not have sufficient protected cropping or heated glass to handle large quantities. This, of course, was and is no different to most traditional young plant trade.

Both Neo Plants and ourselves had to learn the hard way, they with the techniques for a wide range of mainly perennial plants, the growth and weaning, Blooms with the growing-on to saleable plants. We have, and one must, be prepared to enter a sort of partnership in which there is trust and understanding. In the end all one is doing is forming a business relationship with expert propagators working on a long term contract. If a plant is agreed as exclusive then the lab must resist the temptation to overproduce and offer the surplus to what may be a very large open market. Such an action would immediately bring a stop to any future relationships.

We, of course, do not now only deal with one lab, since with the broad range of subjects we deal with, one could not supply all our requirements, but the same principles apply for all unless you are buying purely from a list.

Frankly, once the lab, whether it be your own or not, has weaned the plants—if good nursery practices are followed—one should not fail to succeed. But perhaps we should look a little further than the nuts and bolts of this new technology and what

questions arise for now and the future.

The first question is: do you first find a plant and look for a market—or a market and then find a plant? In the old days it did not matter so much, the markets were more traditional and competition less fierce. There seemed to be good possibilities for *Hosta* and *Hemerocallis* for which, surely, there were good markets in the U.K. and elsewhere. So off I went to Japan and the United States in search of these and other plants. The selection of new hostas and daylilies in the US was amazing; some of the best hostas also originated in Japan. Over two or three years we built up a trial of over 100 hostas and 150 hemerocallis at Bressingham to test for best selections for northern European conditions. We selected some of the best and they were ideal for micropropagation—or were they?

Any self respecting nursery has a duty to be sure that what it sells is true to name—so hemerocallis must be grown for at least two years, possibly three to ensure they flower true-to-type. Tissue-cultured hostas have received some strong criticism from hosta buffs who suggest they do not come true from tissue culture and are liable to revert. Single foliage colours seem to be no problem, but variegated forms have shown instability, as the labs and growers are now aware. They might produce anywhere between 5 and 50 per cent true—but like any other nursery, the labs who are clever enough to come up with the highest percentage win the prizes, if not the business.

But for the grower with these and many other tissue-cultured crops it means a long delay from the date of receiving the material to the point where he can recoup. With large quantities of such plants it needs patience and an understanding bank manager.

With certain herbaceous material, once you have large two or three-year stock beds it will be much cheaper to produce vegetatively, so unless there continues to be strong demand, this particular line maybe lost to the lab. So two, three, or four years after you begin to micropropagate you get the plants on the market—hopefully before the competition. There are two risks to be taken—*first* that the perceived market demand will be there when you finally get the plants ready for sale, and *secondly*—that other labs and growers have not been doing identical work, coming onto the market with the same products at a similar time!

Once it is known that one lab is having success with say, rhododendrons, kalmias, hostas, or hemerocallis, such plants may be seen to be "fashionable", or in demand at least by the growers, then everyone jumps onto the bandwagon. Thus demand can be often grower-led, rather than market-led with inevitable consequences of overproduction. Most micropropagation laboratories are now realizing the benefits of specialization and contract growing.

Such unique plants as *Choisya ternata* 'Sundance' or *Betula* 'Golden Cloud' are perfect examples of the successful use of

micropropagation. These and other plants, discovered by individuals, growers, or breeders, which otherwise would take years to build up stock, can be mass produced and the production cycle shortened by several years.

I have strong views on Plant Breeders Rights and Plant Patents. Whether we like it or not they are here to stay and with home and international competition speeding up, investment in breeding and promotion of new plants increasing, it will be seen as not only desirable but necessary for more new plants to be protected.

The world is becoming more interdependent than ever, with such markets as the Australasian, North American, and Eastern European—including the new Russian—plus the Chinese and, of course, the Japanese becoming potentially available to us. This may not be as significant as the fact that the more developed economies are becoming available to Third World or underdeveloped countries, with their much cheaper production costs. One European company discovered it cost the same to set up a lab in China, employing 150 people, as it did to have a small 5 person lab in Holland. The implications are obvious. Perhaps the Japanese and even the Dutch have been a little slow off the mark with micropropagation but they are quickly making up for lost time.

A new £10 million lab in Holland is only one of the latest large scale world-wide investments in micropropagation and biotechnology facilities, though the first priority of these labs is seldom ornamental horticulture. But horticulturists from Japan, Holland, and elsewhere are looking for new plants, and new products that might be suitable for pot plant or cut flower markets.

What easier way than to despatch plants or cultures in the tube from one lab to another across international borders, plant health requirements not withstanding. Whether in Tasmania or Alaska a lab works in totally controlled conditions and, with modern communications, making possible deliveries from one part of the world to another within 24 hours. The answer to the question of how to control and protect becomes somewhat difficult under such potentially secretive and fast moving modern technology.

Biotechnology, including such techniques as mutagenesis, organogenesis, cell fusion and symbiotics—which may mean as little to most of you as to me—can, we are told, revolutionize plant breeding and selection. Micropropagation is the production method to produce these new wonder or monster plants—according to one's views.

If this sounds frightening then an article in a recent edition of American Nurseryman sounds even more so. This reports on Native Plants, Inc. (N.P.I.), that has its own Phytotec labs in Utah, Belgium, and Australia, as well as nursery production facilities. This company suggested in a recent magazine article that by the year 2000 *most* horticultural crops will be produced by tissue cul-

ture. Another statement by the same company contends that "over-production benefits the nurseryman and the consumer", concluding that "through mass production prices will drop and nurseries will be able to compete better with the mass merchandizers". If that principle is taken up by other larger labs who do not have their feet on good horticultural ground we could be in for a very interesting decade. Perhaps the questions asked at the beginning of my talk have yet to be answered. Though we should be aware of what is happening and what could happen, perhaps we should not be too alarmed.

Of course micropropagation is here to stay, and is becoming more relevant to the nursery stock business as a propagation technique with which we are quickly coming to terms. That it will become possible to propagate a wider and wider range of plants is without doubt.

But let us not allow this modern technology to divert us from paying attention to the importance of the traditional and skilled propagator in our business, and be prepared to respect and pay them accordingly. If we don't we may not only lose our skills to the laboratory, but we may find ourselves hijacked by other cultures.

OBSERVATIONS ON THE ROLE OF CYTOKININS IN MICROPROPAGATION AND JUVENILITY

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Micropropagation is a tool with many uses. As propagators we are most interested in its use for rapid multiplication of subjects that are difficult to root by other methods. Plants coming from micropropagation yield cuttings which, in many cases, root more easily than the original source of micropropagated material. This result may be compared with traditional methods of inducing juvenility in stock plants, such as hedging. It may be that cytokinins could be used on traditional stockbeds to induce juvenility.

In 1977, the staff at Rochfords Nurseries' Technical Department were examining methods of increasing the numbers of shoots on *Dracaena marginata* for propagation purposes. Various methods of introducing cytokinins into the plants were investigated but none resulted in substantial increases in shoot numbers. One method

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tried was injection of cytokinin solutions into the stem at various points. The same treatment on Schefflera arboricola [syn. *Heptaplurum arboricola*] resulted in a proliferation of shoots.

In 1978, *Ficus lyrata* was micropropagated at Rochfords. The resultant plants were multi-stemmed. From a sales point of view this was undesirable. It was felt that the plants were suffering a "cytokinin hangover" from the multiplication stage in micropropagation.

To cure this cultures were taken from sterile conditions and established in seed trays. After establishment, cuttings were taken from these mini stock beds and rooted in the conventional way. The cuttings were 2 cm long and rooted easily in peat pots. This method was successful and provided a useful alternative to micropropagation.

In 1980, I moved to Bord na Mona's Lullymore Nursery, which has a specialty of ericaceous plants.

Dr. G. Douglas at the Kinsealy Research Station was investigating rhododendron micropropagation at that time. One cultivar under examination was *Rhododendron* 'Britannia', which is very difficult to root conventionally. He found, however, that cuttings taken from micropropagated liners rooted with 100 per cent success. Similar results were found at Kinsealy and elsewhere. As good propagators do, we asked ourselves why this should be so. At this point the possible connection between micropropagation and juvenility came into mind. We had induced stem proliferation at Rochfords by injecting cytokinins into plants. The process seemed similar to conventional hedging. We had established mini stock beds of *Ficus lyrata* from micropropagated material and now had apparently rejuvenated *Rhododendron* 'Britannia'.

Cytokinins act in many ways on plant tissues. One mechanism they influence is cell division. Rapid cell division is associated with juvenility. Juvenility is associated with ease of rooting. Rhododendrons produced from micropropagation may therefore be rejuvenated by the process and cytokinins may be the switching agent.

Taking the experience with schefflera as a model, it may be possible to achieve rejuvenation by introducing cytokinins into plants *in vivo*. Injection by hypodermic syringe may be a method of overcoming the difficulty of introducing cytokinins into the plant.

There are many plants that we would produce if rapid multiplication were possible. Production through micropropagation is often not feasible because of the high start-up costs per cultivar. As an alternative it is suggested that the introduction of cytokinins to plants *in vivo* should be examined.

Acknowledgements. I would like to thank Prof. J. V. Morgan and Dr. G. Douglas for their assistance in preparing this paper.

OUTLINE OF A SYSTEM FOR *IN VITRO* PROPAGATION OF *SEQUOIA SEMPERVIRENS*

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Abstract. An outline system for the propagation of *Sequoia sempervirens* is described. Propagules were excised from juvenile tissue forced from epicormic buds, disinfected using a calcium hypochlorite and tincture of iodine solution and cultured on half-strength Shenk and Hildebrandt medium. Explant growth and development was stimulated by the inclusion of benzyl amino purine and kinetin in the medium. Shoot elongation occurred in their absence. *In vitro* rooting was inferior to that obtained *in vivo*.

INTRODUCTION

During the past decade, demand for timber and forest products has rapidly increased and, according to Thorpe and Biondi (16), consumption is now outpacing the rates with which forests are maturing. This pressure has led to demands: (a) to develop new methods for the mass production of trees with improved production indices (16), and (b) to grow more trees of all kinds (6). This is further substantiated by the number of symposia held or books published on this topic in recent years (2,3,8,10,14,17).

Most forest trees are sexually propagated and consequently exhibit tremendous variation, variation which cannot be assessed commercially for many years following seed sowing, because of their long life cycles. This variation could be reduced if it were possible to propagate selected clones vegetatively at a sufficient rate to satisfy re-afforestation programmes (11). Although tissue culture has the potential to propagate desirable genotypes rapidly on a large scale and has been applied to several coniferous species (9), in most instances only embryonic or seedling tissue has been satisfactorily propagated (1). However, there are reports where explants from mature trees have been successfully used (4,7,13).

This paper describes an outline procedure using epicormic shoot explants for micropropagating *Sequoia sempervirens*.

MATERIALS AND METHODS

A log measuring 250 × 150 × 100mm (l×b×h) and containing epicormic buds was obtained from a mature field-grown tree in March, 1987. It was placed in a dish containing water to a depth of 25mm and transferred to the laboratory where it was forced for four weeks at 20°C to develop juvenile tissue. Shoot tips measuring 10 mm in length were selected and cultured from the developing shoots, washed under running tap water for 20 min. and then disinfested. This was achieved by placing the shoots for 10 min. in a solu-

tion containing 7.5 percent w/v calcium hypochlorite plus a trace of Tween 20, followed by rinsing in sterile distilled water and re-disinfestation in tincture of iodine for a further 10 min. Finally, the shoot tips were rinsed in sterile, distilled water. All damaged tissue was aseptically removed and the shoot tip explants vertically implanted in a sterile nutrient medium adjusted to a pH of 5.6 ± 0.1 with 0.1 N potassium hydroxide or hydrochloric acid and solidified with 0.8 percent Difco Bacto Agar.

The nutrient medium was autoclaved for 15 minutes at 121°C and 103 kPa, allowed to cool, and approximately 30ml aliquots were poured into disposable 100ml sterilin containers. The cultures were incubated under low light conditions (13.3 $\mu E\ m^{-2}\ sec^{-1}$) with a 16-hr photoperiod provided by cool white fluorescent tubes. The temperature was maintained at 22°C ± 2°C.

Shoot initiation, multiplication, shoot elongation and rooting were stimulated on half strength Schenk and Hildebrandt (SH) 1972 nutrient medium (Table 1).

No hormones were added to the elongation medium. The auxins, *indoleacetic acid* (IAA), *phenylacetic acid* (PAA) and indolebutyric acid (IBA) were individually used at 1.0mg per litre to stimulate rooting.

Ten explants were initally cultured; thereafter 25 propagules were used. Subculturing occurred at four-week intervals when the numbers of shoots and buds produced were counted and the propagules re-inoculated onto the multiplication, elongation, or rooting media. A minimum of three subcultures were carried out prior to transfer to the latter two.

In vivo rooting and weaning of the microshoots was achieved in a 100 percent peat compost or maintained in a high humidity greenhouse enviroment provided by fog. The temperature of the rooting medium was maintained at 18°C, while that of the greenhouse fluctuated between 15°C and 25°C.

Table 1. *Constituents of the ½ dilution Shenk and Hildebrandt caulogenic medium.*

A. Mineral Salts			
Macro elements	Mg l^{-1}	Micro elements	mg l^{-1}
KNO_3	1250	$MnSO_4 \cdot H_2O$	5.0
$CaCl_2 \cdot 2H_2O$	100	$ZnSO_4 \cdot 7H_2O$	0.5
$Mg\ SO_4 \cdot 7H_2O$	200	H_3BO_3	2.5
Na_2 EDTA	7.5	KI	0.5
$Fe\ SO_4 \cdot 7H_2O$	10	$Na_2\ Mo\ O_4 \cdot 2H_2O$	0.25
$NH_4\ H_2\ PO_4$	150	$Cu\ SO_4 \cdot 5H_2O$	0.1
		$Co\ Cl_2 \cdot 6H_2O$	0.05
B. Organic constituents			
Sucrose	30,000	Niacin	2.5
Agar	8,000	Pyridoxine HCl	0.25
Myo-Inositol	500	BAP	1.1
Thiamine HCl	2.5	Kinetin	1.1

RESULTS AND DISCUSSION

Surface sterilization. The sterilization of explants from mature conifers grown under field conditions is regarded by many investigators as being difficult to achieve. For instance, Boulay (5) obtained less than 50 percent asepsis on *Sequoia sempervirens,* while Gupta and Durzan (7) obtained 90 percent for *Pseudotsuga menziesii* and *Pinus lambertiana* using a multistep sterilization procedure, one which was ineffective for mature field grown and immature greenhouse forced *Pinus contorta* shoots (O'Donnell 1987 unpubl.). In this work, 100 percent asepsis was achieved with explants derived from epicormic shoots, a factor being attributed to the double sterilization technique involving tincture of iodine, and forcing of the juvenile tissue.

Shoot initiation and development. Establishment and development of shoot tip explants occurred on the 50 percent dilution Schenk and Hildebrandt medium (Table 2).

After four weeks in culture each explant had developed two axillary buds, with a mean height of 2.4mm. When these were subcultured, growth and development occurred rapidly and after a further four weeks produced 5.2 shoots and 10.9 buds, respectively. The average length of these shoots was 19.8mm while bud size was similar to that of the developing explants.

These results are superior to those reported by Boulay (5) and reflect at least a 25 percent increase in growth rate compared with that obtained from the 50 percent dilution Murashige and Skoog (MS) (12) medium. When the propagules were subcultured onto the elongation medium (minus hormones) both extension growth and further shoot multiplication occurred. However, bud initiation was suppressed (Table 2). Shoot length ranged from a minimum of 10.0mm in length for the newly initiated shoots, to 67.0mm for those that were subcultured. The mean was 38.5mm.

Table 2. Influence of medium on explant establishment, multiplication, and elongation.

Medium	Mean No. of buds per explant/ propagule	Mean height of buds (mm)	Mean No. shoots per explant/ propagule	Mean shoot height (mm)
Inoculation	2.0	2.4	—	—
Multiplication	10.9	2.5	5.2	19.8
Elongation	0.0	—	3.0	38.5

The occurrence of rapid elongation in the absence of activated charcoal is in direct contrast to the work of Boulay (4,5) but is in agreement with that of Que (13) and demonstrates clearly that activated charcoal alone is not a prerequisite for inducing shoot elongation; 50 percent dilution SH medium is superior to the 50 percent dilution MS for micropropagating this species.

Rooting *in vitro* was unsatisfactory. In fact, indolebutyric acid (IBA) was the only one of the three auxins used individually in the rooting medium that stimulated root formation (Table 3).

Rooting was erratic and only 25 percent of the cultures rooted, even after eight weeks in culture. This is similar to the results obtained by Boulay (5) with IAA.

Contrary to expectation, PAA failed to induce root formation, even when used at higher levels than that recorded in Table 3. It is thus probable that its slow rate of degradation in the culture medium was insufficient to counteract its low activity levels.

Satisfactory rooting (at least 95 percent) was obtained when the *in vitro* produced shoots were inserted in a medium grade peat compost and maintained under fog. Root initiation was observed after seven days and the micro-cuttings were sufficiently rooted for potting-on after 28 days. Satisfactory *in vivo* rooting has also been achieved with Sequoia by other investigators (4,5,13).

Table 3. Effect of three hormones on rooting *Sequoia sempervirens* propagules after 8 weeks in culture.

Treatment	Percent rooting	No. roots/propagule	Mean root length (mm)
IAA	0	0	0
PAA	0	0	0
IBA	25	3.5	44.5

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MICROPROPAGATION: WHY WYEVALE NURSERIES TOOK THE PLUNGE

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In early 1988 Wyevale Nurseries entered the field of plant micropropagation by setting up a small self-contained laboratory next to its existing propagation facilities. This unit consists of a Portacabin with internal fittings supplied to our own specifications. It is divided into three areas:

1) The main work area comprised of a laminar air flow unit, media preparation area, and sink,

2) Growth room

3) Changing room that doubles as an airlock avoiding direct introduction of air, dust, and people from the outside.

We decided to go for a purpose-built unit because we believe this will reduce the chances of cross contamination and help us run a small lab efficiently. This will leave us more time to consider plant growth problems and thus reduce the lag time between start up and full production which many labs have encountered.

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At present Wyevale Nurseries produce 20 acres of field-grown stock and 1.7 million container plants. The lab was set up not so much to dramatically increase these figures, but primarily to enable us to fill gaps in our present propagation schedule. These gaps are mainly existing crops we are unable to produce in large enough quantities, being either slow growing or requiring large numbers of stock plants to get sufficient propagation material.

Micropropagation thus offers an excellent method for mass production, programmed sequential cropping, and the bulking up of new plant introductions. The author remains to be convinced, however, that crops that are difficult to produce by traditional methods will be any easier by micropropagation—quicker, perhaps, but not necessarily easier. It is for this reason that a reasonable period has been allocated for experimental work before production.

Plants coming out of culture will be weaned and grown on at Wyevale within the present production program, by using available skills and thus closely linking micropropagation to established horticultural practices. For example, we have been using a large fogging unit in the propagation department for 2½ years and have gained experience in handling it and the plants going in and out.

Although we have not yet reached the rooting stage, we are planning that plants coming out of culture, with or without roots, will go into a fogging unit separate from traditional cutting material. From there they will be hardened off and grown on in a separate area before going for potting into 9 cm plastic pots and entering the liner stage along with conventionally produced crops.

At present, weaned micropropagated crops bought in from other producers enter the system at the potting stage and experience gained with these will be applied to our own crops.

In summary, Wyevale Nurseries has found a niche for micropropagation within its present production structure. This may develop into other areas in future, but for the time being we are content with getting to grips with this technique and endeavouring to integrate it with our existing nursery practices.

CLEMATIS OF RECENT INTRODUCTION FROM THE WILD AND FROM CULTIVATION

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Clematis viticella was the first clematis species to be introduced to the UK in the mid-1500's. Since then, many fine, small-flowered cultivars have been raised from *C. viticella*, giving a good range of colours. One of the latest is a fine, deep purple blue form, which has yet to be named. It seems very free flowering and has an unusual, deep red centre.

C. cirrhosa, a species from southern Europe, was another early introduction to England. This quite variable species has given us several deep couloured forms, including a new one to be called *C. cirrhosa* 'Freckles'.

In my collection there are not only new clematis of recent introduction, both small and large-flowered, but also old, large-flowered cultivars and species almost lost to commercial cultivation in Europe, as a result of changing fashions and trends.

Following is described a small selection from my collection, which numbers over 300 species and cultivars.

Clematis 'Empress of India' is a large-flowered cultivar brought back from the U.S.A. Its pucey violet-red flowers have a light brown centre.

C. 'Royalty' is a new, double or semi-double clematis raised in England. Its deep violet-purple flowers have contrasting deep yellow anthers. Single flowers are produced during late summer on current season's stems.

C. patens is a Chinese species now naturalised in many parts of Japan. It gave the early European hybridists the opportunity of producing the large-flowered cultivars that we grow today, such as 'Nelly Moser'. In the wild in Japan, collectors have found over 25 forms of *C. patens*, even double forms.

C. 'Asao' is a new Japanese cultivar very typical of the early forms of *C. patens*. This rounded flowered form has tepals that are pink, which become almost red at the margins.

C. montana var. *Wilsonii* is an important re-introduction. This white-flowered *C. montana* flowers four weeks later than most montanas and is a plant lost to production until recently, when it was found in a garden in Herefordshire, England.

The New Zealand clematis species, I believe, will become useful plants for the sheltered patio garden or for the growing number of conservatories that are being built. *C. paniculata*, a species with bright white flowers and pink anthers has good evergreen foliage and grows to three metres. *C. forsteri* also has delight-

ful evergreen foliage that is a light apple-green colour. Its greenish-cream flowers are strongly scented.

Of the more hardy clematis, *C. alpina* is a most useful garden plant for exposed areas. Two cultivars, 'Helsingborg' (very deep violet-blue), and 'Tage Lundell', (reddish violet-blue), are fairly new introductions from Sweden—both raised by the well-known *Swedish plantsman, Tage Lundell.*

I found *C. alpina* var. *ochotensis* on Mount Fuji in Japan in 1984 but a different form, collected in Kamtchatka in 1922, has given Magnus Johnson in Sweden the opportunity of producing cultivars such as 'Betina', a beetroot coloured seedling.

C. koreana, collected in Korea during the late 1970's, is again a variable species. There is a dark purple-red form, with a pale yellow margin to the tepals, which need a light background to show the flowers off well. However, *C. koreana* 'Lutea', a pale greenish-yellow form, stands out well in any situation. Both forms are very hardy.

C. texensis, a species from the USA, is still rare in cultivation. Some fine forms, with upturned, deep red, pitcher-shaped flowers are now being grown in Japan. However, I am still searching for a form with foliage that does not succumb to mildew.

C. orientalis—the true species—has again been re-introduced from Turkey by Mr. and Mrs. Dick Banks, from Hergest Croft in Herefordshire. It has greyish-green foliage, with small, nodding flowers that are yellow but with contrasting red filaments. This species, again because of its wide natural distribution, is variable. The second form, recently re-introduced, has yellow tepals that have a central flash of red.

C. recta, a European species, also varies. We all long to find again the lovely double-white form that seems to be lost to cultivation. However, I recently found an extra-large flowered form in a Worcestershire garden, with flowers double the usual size of *C. recta.*

In 1981, on an expedition to China, I found a great number of clematis species, including a white form of *C. lasiandra,* a pink, pitcher-shaped flower species and a good, large-flowered form of *C. connata.* Near to our base camp at 12,500 ft. in an old part of Tibet, I found an extremely good form of *C. buchananiana,* as well as a delightful form of what was probably *C. glauca* var. *akebiodes.* Among other delights found there was also a good form of *C. gracilifolia.*

During 1984, I visited China again, this time near Beijing (Peking). At one part of the Great Wall area I found *C. hexapetala**, a semi-herbaceous clematis with galucous foliage and 4cm wide

*Bot. ed. note: The specific epithet is incorrect. By 1886 *C. hexapetala* was already a synonym for 2 other species; *C. hexapetala* L.F. = *C. hexasepala* DC.—New Zealand, and *C. hexapetala* Pall = *C. flammula* L.—Mediterranean region.

white flowers. *C. aethusifolia* was also growing very well in that harsh climate. This delightful, pale yellow species had been re-introduced to cultivation by Roy Lancaster in 1980.

C. heracleifolia in its many forms also grew in this area. *C. heracleifolia* var. *davidiana* is a great attraction to butterflies. However, Mr. Lancaster collected seed in this area in 1980 and his seedlings, raised by the author, produced plants with deep blue flowers. One has been named *C. heracleifolia* 'Manchu'. Seedlings raised from this selection have given yet again different blue forms from their parent, proving once more that such a great deal of selection work has to be done with plant introduction from the wild.

Another good re-introduction by Roy Lancaster from China is *C. chrysocoma*. This has been grown for many years in gardens but the true species had been lost to cultivation. Its stunning white flowers have yellow anthers.

C. kirilowii, a species native to the Beijing area of China, was found during my 1984 visit. Its 2.5cm white flowers, produced in great abundance, make it a welcome introduction to the range of garden clematis.

C. florida sieboldii (syn. *C. florida* var. *bicolor*) was introduced to England from Japan via The Netherlands in 1837, soon followed by its sport, *C. florida 'Alba Plena.'* Neither of these plants have been widely grown until recently because of propagation difficulties. The great excitement that recently occurred is that *C. florida* sported, or reverted back to the true *C. florida* 'Alba Plena' in our Guernsey nursery in mid-July, 1988. If we are able to propagate from this stem, we shall once again have the true *C. florida* in cultivation, a plant used by the old hybridists of China and Japan long before we in Europe knew of the existence of large-flowered clematis species. This will give us the opportunity of re-creating many of the old crosses which produced the large-flowered clematis of today.

HIGH ALTITUDE TASMANIAN PLANTS WITH HORTICULTURAL POTENTIAL

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The State of Tasmania lies in the equivalent latitudes of northern Portugal and northwest Spain. The climate of the lowland areas, by British standards, is in fact very mild and pleasant with few extremes of temperature.

Tasmania is a small island of slightly more than 64,000 square kilometres (roughly the size of Ireland), lying in the path of moisture laden westerly winds. On reaching the west coast these are forced up by the mountains (1200 to 1600m), thus depositing much of their moisture. There is a marked rainfall gradient from over 4000mm in the mountains of the west to 560mm on the east coast. Much of the landscape is dominated by rugged mountains and even today many areas have not been fully explored.

Altitude has a great influence on temperatures, with some coastal regions experiencing only light frosts. However above 1000m frost can be experienced at any time of the year and snow lies for long periods in the winter months. The vegetation of these high and cold regions is restricted to shrubs and low growing species that can survive under severe conditions. Soils at these altitudes range from shallow, heavily leached podzols to deep, wet blanket bogs, and all are invariably low in nutrients and acid in reaction.

The term alpine and sub-alpine is often applied to these regions but they are in effect more like the wet western hills of the British Isles.

At the present time about 2000 species of flowering plants are known to occur in Tasmania, either native to the State or as naturalised introductions. More than 200 species are endemic. Some Tasmanian native plants have been introduced into horticulture within the State and a few have even reached the British Isles. However most of the highland plants are unknown to the gardening public even in Tasmania, where there has been an upsurge of interest in the growing of native plants in the last two decades.

The principal reasons for this are: *all* Tasmanian gardens are at low altitudes thus are warmer than the mountains and more prone to drying out in the summer. Until recently exotic plants were more popular and their conditions of culture better known; most of the highland plants do not grow well in rich soils and applied nutrients (particularly phosphorus) can be lethal; very fresh seed is needed for propagation. Some species require special techniques for vegetative propagation. Nevertheless I am convinced that many Tasmanian plants offer exciting possibilities for introduction into

cool temperate gardening. Indeed some of the low altitude species are probably ideally suited to the conservatory or the cool greenhouse.

I wish to consider a few of these Tasmanian high altitude species. The choice of plants is by no means comprehensive and is essentially a reflection of my own interests. Those who wish to gain a fuller understanding of this unique flora I would recommend that they refer to Cameron (1984) and Corbett (1984).

Tasmania has 11 conifers, 8 of which are endemic. The most well known are the *Athrotaxis* species, with *A. cupressoides,* ('pencil pine') being found commonly on the banks of highland streams and lake shores. Not so well known are the prostrate conifers, represented here by *Diselma archeri* and *Microcachrys tetragona*. Both of these species are common on the highest peaks, often in very exposed situations. The latter is most striking when the large red fruits appear on the female plant in summer, hence the common name, strawberry pine.

Ground-hugging plants are common on the exposed ridges where the peaty soil is usually shallow and dries out quickly even after heavy rain. *Pernettya tasmanica,* which is already fairly well known in the British Isles, is often found growing alongside *Epacris serpyllifolia, a species which forms carpets of white during the* summer months. Among the daisy-like white flowering plants in this situation, the most common are *Helichrysum milliganii,* with its large, papery inflorescences, and *Olearia ledifolia,* with its showy, solitary flowers.

Geum talbotianum, with its large single white flowers and ground hugging leaves, is restricted to a few wet mountains of the southwest. Also a typical inhabitant of these high exposed moors is *Isophysis tasmanica,* a member of the Iris family and endemic to Tasmania. The flowers are up to 8cm across and, although mostly a dark, purple-red, occasionally pale yellow forms are found.

On slightly wetter sites the Australian gentian, *Gentianella diemensis* is often found growing alongside *Anemone crassifolia,* both producing their prominent white flowers during the height of summer. One of the most elegant of Tasmanian plants is the Christmas bells, *Blandfordia punicea*. This spectacular member of the lily family occurs in wet heaths, on moors, and hillsides throughout the high rainfall area and its robust orange-red blooms are very showy.

Also endemic and equally striking is the mountain rocket, *Bellendena montana*. It is a small shrub growing to 40cm and is covered with creamy white flowers in summer and, as autumn approaches, these are replaced by spikes of spectacular, red coloured seed capsules which last well into winter. Although difficult to grow from seed it has proved suprisingly easy to propagate from cuttings.

Space does not permit an account of all the magnificent shrubs that are found in the Tasmanian highlands but here are some of my favourites. Members of the genus *Cyathodes* have small white-bell flowers but their main virtue is the profusion of colourful, pinkish-red fruit which remain on the plant for many months. *C. straminea* is common on the highest moors. There are 10 species in the genus, all of which exhibit horticultural potential, and nine are endemic to the island.

Leucopogon collinus (bearded heath), *Lissanthe montana*, and *Phebalium montanum*, are all found throughout the high altitude area. Usually they are small shrubs growing to about 50cm, but in windy exposed situations they also become completely ground hugging.

Boronia citriodora (lemon-scented boronia) has very aromatic foliage and the pale pink flowers persist for a long time. It grows alongside *Orites milligani* which is also found on the very highest mountains. This latter shrub has holly-like leaves and creamy-white flowers in terminal spikes.

On rocky exposed ridges, *Coprosma moorei*, with its persistent bright blue fruits, is common amongst the boulders. On these same ridges *Dracophyllum milliganii* is a very small shrub to 50cm in height but in deep sheltered gullies it can reach 4m and produces a huge inflorescence.

In a similar fashion *Eucalyptus vernicosa* (varnished gum) is variable in height depending upon its landscape location.

In the flatter areas bordering swamps or near mountain summits where snow lies for several months the cushion plants are to be found. It is here that *Abrotanella forsteroides, Chionhebe ciliolata, Donatia novae-zelandiae, Dracophyllum minimum, Mitrasacme archeri* and *Pterygopappus lawrencii* form extensive colonies. These intriguing plants have enormous horticultural potential not only for their unusual form and foliage, but also for their brilliant floral display. There has been some success in introducing them to cultivation but only where the growing conditions simulate their natural environment. While propagation from seed is possible, all can be readily established by cuttings or division. They all clearly have potential for the wet alpine or bog garden and are worth trying out as container plants.

No discussion of Tasmanian plants would be complete without mentioning *Telopea truncata* (Tasmanian waratah). Not only does it have a long flowering period but also its foliage is attractive at all times of the year. There are I believe some very fine specimens to be found in southwest Ireland and this would encourage me to look at plants from the highest elevations in Tasmania to find greater adaptability to even cooler conditions.

Finally I wish to introduce you to two species that illustrate the principle of selecting the most suitable ecotype. *Banksia marginata*

(Tasmanian honeysuckle) and *Melalouca squamea* are both found at sea level in the State and introductions from that source would be most unlikely to survive outdoors in the British Isles. However, *Banksia* can grow at 1100m in an area that is exposed to very cold weather and *Melaleuca* can be found at 1350m on the edge of a highland bog. I would be very surprised if either of these ecotypes had ever been introduced into cool temperate gardens and, without doubt, this is where the source of increased cold hardiness lies.

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THE FLOOD OF AMERICAN HYBRID RHODODENDRONS: AN EVALUATION

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Rhododendron hybridising started in Britain about 1800 when some of the European and North American species were first crossed. Important breakthroughs occurred with the introduction of red flowers from *R. arboreum* and the first group of what is known as the hardy hybrids were raised by the great Victorian nursery firms such as Waterers at Bagshot and Knaphill, and at Cunninghams nursery in Edinburgh.

Among the best known hybrids of this period, are 'Cunningham's White', 'Gomer Waterer', 'Christmas Cheer', 'Purple Splendour', and 'Cynthia'. The next phase was marked by the introduction of more Himalayan species such as the enormous flowered *R. griffithianum* and later, the yellow species *R. campylocarpum* and *R. wardii*. In German and Dutch nurseries, breeding was being carried out from 1890 until World War II, with the Dutch hybrids such as 'Britannia', 'Betty Wormald' and 'Kluis Sensation' becoming popular wherever rhododendrons were grown.

The Edwardian and Georgian eras in Britain saw the hybridising mantle being taken up by the aristocracy and gentry. Lord Aberconway, Lionel de Rothschild and several others directed armies of gardeners raising thousands of seedlings made from crossing the new species as they were introduced by Forrest, Kingdon-Ward, and others. Among the hundreds of worthless named hybrids many important breakthroughs were found and this

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group of hybrids still provides the largest scope for the rhododendron hybrid enthusiast who would rarely be without 'Elizabeth', 'Loderi', 'Lady Chamberlain' 'Crest', and 'Fabia', etc.

After the war, many of the great gardens and nursery firms went into decline, and the flood of new hybrids appearing at London shows slowed to a trickle. With the exception of the Waterer and Hydon *R. yakushimanum* hybrids and some new dwarfs from Glendoick and elsewhere, very little useful hybridising has been done in the U.K. since 1945. In West Germany, D. Hobbie, H. Hachmann and others have been active, while Australia and New Zealand have also seen a considerable amount of breeding activity. But all this is dwarfed by the hybridising that has taken place in the U.S.A.

Starting on the East Coast in the 1920's an assortment of enthusiasts such as the industrialist Charles Dexter, the nurseryman Tony Shamarello, and Joe Gable began crossing rhododendrons. Many important hybrids were raised, many of them particularly suitable for the extremes of heat and cold found along the U.S. East Coast. These pioneers were succeeded by many keen nurserymen and amateurs and there are now hundreds of named hybrids bred from Nova Scotia to Georgia, and from Cape Cod to Indiana. The best known of these include 'Dora Amateis' and 'Scintillation'. It is the West Coast, however, that has produced the most suitable hybrids for the U.K. The most populous parts of Oregon and Washington have a climate very similar to that of the U.K. and, soon after the first importations of rhododendron species and hybrids from Britain, breeding programs were begun. Nurseries run by Whitney, Lem, Van Veen, Greer, and many amateurs have been making thousands of crosses each year and over the last two decades we have been collecting and evaluating some of the fruits of these labours at Glendoick. Many of the hybrids we have received from across the Atlantic are better than anything raised in Europe, and we have been propagating and distributing many of them for many years. In last year's new entries to the International Rhododendron Registry, less than 10 percent of the new hybrids were British. Germany, Australia, and New Zealand accounted for 20 percent and the USA and Canada for the other 70 percent. There is no sign that this trend will not continue in the future.

The recent progress in micropropagation of rhododendrons in the U.S.A. and Europe has, during the last few years, seen many excellent new American hybrids on the market here for the first time in large quantities. The most important advantage of this method of propagation is the speed of introduction of new species and cultivars, and their international distribution. Tiny plantlets in sterile medium can be brought into this country at a fraction the cost of the traditional methods.

At last the Chelsea Show may actually have some new rhodo-

dendrons to make headlines in the horticultural press, in the same way that newly named roses do. This is a time to promote all that is new in rhododendrons, from the smallest creeping types for the rock garden, up to the enormous blowsy giants.

Unfortunately, with the advantages of the new technique have come several largely avoidable but nonetheless worrying problems.

The first is that of what is available. Some of the best hybrids are now indeed in tissue culture, but many are not, and a large proportion of those being offered for sale in the U.K. really are not suitable. Many have been bred for harsher climates than our own, and their ornamental value is only to be appreciated in areas where the tenderer types will not survive. If new hybrids are blindly distributed, the whole chain from wholesaler to retailer and customer is going to feel disappointed and deceived.

The second problem ties in with this, in that micropropagation allows new introductions to be made very quickly. Once a small shoot is successfully multiplied in a test tube, theoretically there is no limit to the number of young plants that can be produced in a short period of time. This allows untested hybrids to be churned out, with their short-comings only discovered later by the unfortunate customers. The worst example amongst rhododendrons has been 'Pink Petticoats', one of the worst commercial hybrids I have ever seen, with appalling hanging foliage. In exceptionally favourable conditions, it can produce a reasonable show, but it is hardly the cultivar for the mass market.

There are other similarly poor choices in tissue culture in Britain and in the U.S.A. and hopefully the companies concerned will have the foresight to destroy worthless material, preventing it from spoiling the market. The new *Kalmia latifolia* cultivars are a case in point, where the nurseries producing them had not even seen them flower, let alone tested them. We had several utterly worthless hybrids, which have subsequently been discontinued, but I see no reason why we should have to do the selecting.

The third problem that we have encountered is that of naming. We know of at least 23 instances of incorrectly named rhododendron cultivars from tissue culture batches from the main U.K. and U.S. labs. Not all the plants of one cultivar are necessarily wrong, although sometimes this is so. We have all the resourses available to identify rhododendrons at Glendoick, but we cannot be expected to recognize hybrids we have never seen. Often the plants flower for the first time after the age at which they are sold to our customers, and for us this means considerable financial inconvenience as well as a compromising of our reputation. Many other nurseries, through no fault of their own, have been and will be distributing hundreds of wrongly named hybrids.

There are several reasons for the naming mix-ups. Micropropagules look much the same from one cultivar to another,

usually not developing recognizable characteristics until they are a year or so old. For various reasons microprop nurseries tend to label their test-tubes with codes rather than names, and it only takes one wrong digit in one of the many transferrals from tube to tube, and the wrong name may later be applied. But of course it is new hybrids which no one has seen before which are most likely to be confused.

Apart from general vigilence and more skilled staff, there is a limit to what can be done. I feel that it is up to the micropropagation laboratories to compensate for some of the value of the stock at the time the mistake is noticed, even if this involves three to five year-old plants. It costs us a fortune in postage to replace wrongly named plants, especially if they have been distributed in hundreds, or sent to Japan.

EVALUATING HYBRIDS

Having made general comments about new hybrids, it seems worthwhile to summarize what criteria we use to make judgments in evaluating them.

1. **Flowers.** Not as important as might be expected, flowers must be of an acceptable standard, but commercially we would always prefer a hybrid with, say, pale yellow flowers, if it was easier to produce commercially. Yellows is probably the most important area for breeding, as a really satisfactory larger hardy hybrid for general cultivation has yet to be produced. Things are improving though. Texture of flowers and how long they last is important especially to garden centre sales. Early and late flowerers have a novelty value but more work needs to be done to breed free-flowering late hybrids.

2. **Habit and foliage.** For garden centre sales, this is very important. Healthy deep green leaves on a dense, bushy plant are always sought after. *Yakushimanum* hybrids are amongst the best, although they are rather slow-growing. Novelties such as variegation and red leaves are also popular.

3. **Hardiness.** Not only winter-hardiness, but the hardiness of opening buds, the weather-resistance of foliage, and a self-preservation attitude towards growing, i.e. does not grow in a mild spell in March-April, and doesn't shoot up soft new growth in September which is clobbered by the first frosts.

4. **Tolerance of commercial conditions.** This is really the bottom line, of course. A beautiful hybrid, ideal for a woodland garden with a patient owner is often totally unable to withstand the rigours of mass-production, particularly in the area of container tolerance. Rhododendrons are hard to grow well in pots, and they are among the most reluctant of ornamentals to thrive in this way. Soil temperature and pH, fertilizer levels, and many other factors are critical. To be a successful commercial plant for garden centre

sales, the most important requirements are:

- budding up at a 3 year plant or less (2 years for a dwarf).
- takes a standard amount of fertilizer
- vigorous, forming a large enough bush in the given time
- pest and disease resistant, and easy to keep healthy. (A new powdery mildew has begun to affect rhododendrons over the last few years, and some new American hybrids are unfortunately very susceptible.)
- looks good in a pot.
- attractive name; 'Scarlet Wonder' sells better than 'Gartendirektor Glocker'!

NEW AMERICAN HYBRIDS—A BRIEF SURVEY

Dwarfs. Not many American hybridisers have concentrated on dwarfs, but several excellent ones have been raised. 'Anna Baldsiefen' is a tight upright plant with masses of bright pink flowers. Very free-flowering and hardy anywhere in the U.K. but rather early flowering. Later, and equally hardy, is 'Dora Amateis', now well-known, which has very fine white flowers. 'Ginny Gee' is one of the freest flowering hybrids ever raised, with masses of pink and white flowers on a compact plant. It is sure to become a standard. From the same hybridizer, Warren Berg, comes 'Patty Bee', a large-flowered pale yellow type, and the two-tone pink of 'Too Bee'. Warren has found an excellent parent in his own introduction from Japan, of a very dwarf form of the species *R. keiskei*. We have also found this a good parent at Glendoick, and there are sure to be many more hybrids produced from it.

For something more unusual, try the daphne-flowered 'Maricee' (alas no scent), or one of the bi-generic hybrids 'Arctic Tern' with ledum-like flowers, or 'Brilliant' with waxy red flowers, and red new growth. Other good-doers include the upright pale pink 'Flip', the deep yellow 'Goldilocks' and the ironclad 'PJM' group with rosy purple flowers in early April. We also think highly of the early flowering 'Snow Lady', a slightly less vigorous version of 'Cilpinense', but with purer white flowers. It flowers in March–April so is vulnerable to frost, but worth a gamble.

Medium growing hybrids. Medium-sized hybrids are becoming the most important and popular group of rhododendrons in the U.K., mainly due to all the new *R. yakushimanum* hybrids. Hybrids growing 3 to 4 ft tall and wide in 10 years are an ideal size for the suburban garden, and the American hybridizers have produced many fine plants of this size.

'Bruce Brectbill' is a sport of the well known pale creamy-coloured English hybrid 'Unique'. 'Bruce Brechtill' is identical in habit and foliage but with showy pink flowers that we prefer to those of 'Unique' itself, and we have no doubt that it will become a

commercial standard in the U.K. 'Cupcake' is one of the few good "yak" hybrids from America and we like this especially for its precocious budding, its deep green foliage, and for the fact that it opens its flowers a week or so earlier than most of the other "yaks", so stretching the season. The colour is an apricot salmon, fading to pale pink.

Of similar colour is 'Jingle Bells', a larger grower with lax trusses of unusual orange and yellow. 'Ken Yaneck' is close to the species, *R. yakushimanum* but with flatter-faced, pinker flowers. The plant under this name released in tissue culture in 1985/86 was 'Yaku Princess', a similar but inferior plant.

'Molly Ann' would be our tip for the perfect commercial medium grower with its glossy rounded leaves, neat upright habit, and its carmine red flowers but, unfortunately, it seems to be very susceptible to powdery mildew. 'Riplet' is one of our own particular favourites with red flowers fading to near cream. Too early and a little tricky for container production, we anticipate the German hybrid 'Lampion' will fill the market for a commercial hybrid in this colour. A potentially very successful curiosity is 'Cream Chiffon', a white double-flowered compact grower. The flowers look like gardenias, and we find the plant free-flowering.

Larger hybrids. These are traditionally the mainstay of the rhododendron nurseries, and form the public perception of what a rhododendron is supposed to look like. Despite the fact that most of these will eventually grow too big for all but the larger garden, they are planted in huge numbers everywhere.

In the U.S.A., the Massachussettes industrialist, C. Dexter used the very hardy, tall, vigorous *R. fortunei* as a parent, producing the now well known 'Scintillation', which has brownish pink flowers, and deep shiny foliage. This is one of the most versatile hybrids ever raised, being tolerant of extremes of heat and cold, and never likely to be damaged in a U.K. winter. 'Ben Moseley' [reddish-purple flowers, blotched deeper] and 'Brown Eyes' [pink with a very striking brown flare] are two of the best Dexter hybrids at Glendoick.

Among the reds, are some outstanding plants for the enthusiast: 'Grace Seabrook' and 'Taurus' have tall, upright, conical trusses of deep waxy red, of a fine pure colour. Both have excellent deep green foliage, on very vigorous plants. They are rather slow to bud up, however, usually at approximately 5 years, and their flowering in late April, probably means that they will not be suitable for the mass market.

'Markeeta's Prize' and 'Halfdan Lem' have flowers of a more translucent and less rich colour, but they have larger flowers than the 'Britannia' type Dutch hybrids.

The finest red flowers of all are on 'Captain Jack', but this is a stubborn plant, hardy enough, but slow to flower, inclined to have

poor foliage and hard to root. A first class enthusiast's plant, but not for the mainstream.

Among the yellows, 'Hotei' (named after a Japanese God) is the best known. Really deep yellow flowers, in tight trusses on a compact, tidy bush. Slow to bud up, fastidious about drainage, and hard to keep growing well, especially in a container. I fear that it is not suitable for the garden centre trade or for general planting. Hopefully some of the many 'Hotei' hybrids coming on the market will not suffer from the same problems.

'Golden Star' is a much easier, more robust plant, but with much paler flowers. Again, as with most yellows, not free-flowering until four to five years of age, but easy to please and one of the hardiest of this colour. Hard to root, but now it is in tissue-culture, so hopefully will become better known.

'Frontier' is paler still, pale pastel pink, fading to cream, ideal for lovers of 'Laura Ashley'. Free-flowering, and with good foliage, but has had some mildew problems with us in Scotland. Another fine pale yellow is 'Odee Wright', which opens with some pink and bronzy tints, fading to pale yellow, in large full trusses. Free-flowering from a young age, and a slow-growing compact plant with deep green shiny leaves. One of the best all round commercial plants in this colour, and sure to become widely grown.

Multicolored hybrids. The most important lines of breeding to come from across the Atlantic will probably turn out to be the multi-coloured hybrids. Tastes in colour are always changing, but the current fashion seems to be for these combinations of yellow, pink, apricot, peach etc, and we find once seen in flower, they are much sought after.

'Tidbit' is a combination of straw yellow and red, on a neat bush with glossy pointed leaves. Not for the coldest gardens, but generally rugged and easy to please, and one of our favourites.

'C.I.S.' has a peach, pink and reddish combination, giving a marvelous display in flower. Unfortunately, its drawbacks are rather numerous, being hard to root, slow to bud up, mildew prone, rather sparse, and often having poor foliage. Its flowers are so fine, that it is definitely worth growing, but is is not a plant for mass distribution in microprop, and I expect that those U.K. labs that have it will probably discontinue it.

'Virginia Richards' is an all-round finer plant and, in our opinion, one of the finest hybrids ever raised. Opening salmon pink, fading to cream with a red blotch, on a compact bush with good foliage, budding up young, and very hardy. Alas, it is very susceptible to mildew and unless a satisfactory control is developed, it will remain only an enthusiast's plant. The crème de la crème of the multicolours is surely the magnificent 'Lem's Cameo', with enormous frilly pink and cream flowers blotched red. Hard to propagate, and requiring masses of fertilizer to avoid chlorosis, it

may only be a specialist's plant. As yet not in microprop, and perhaps should not be put onto the mass market.

A further group of fine American hybrids is the 'Wallopers', a group of sturdy giants with massive conical trusses from white and pink to light red. The best in our opinion are the pink and white 'Lem's Monarch' and the light red 'El Camino'. These take a while to bud up, but they are so striking, that most people are prepared to wait.

My survey could go on and on; there are probably close to 2000 different named American hybrids in some stage of commercial production in the USA and Canada, and the numbers look certain to increase more and more. With this flood of material, nurseries must be ruthless. Do not take on a new plant unless you are willing to admit that it supersedes an older one, and then cease distributing the older one. Cultivar preservation is one thing, but proliferation of cultivars only confuses the customer.

Most importantly, the tissue culture laboratories need feedback, and should be held responsible for what they are producing; ask questions, request photographs of new cultivars, and demand compensation for incorrectly named plants. Lets take a leaf out of the rose business' book in launching new hybrids with sound commercial and marketing practices, exploiting the advantages that we can get from micropropagation, to offer the public what they want.

There is a potential market for far more rhododendrons, and this can only be realised by providing the right plants for the right situation.

UNUSUAL AND WONDERFUL HEBES

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INTRODUCTION

The genus *Hebe* belongs to the family Scrophulariaceae, and was once part of the genus *Veronica* which still contains the deciduous plants. The difference is that seed capsules of veronica split vertically and those of hebe horizontally. Hebes also have a larger number of chromosomes than veronicas. *Parahebe*, the other closely allied genus, is semi-woody in character. Most hebes come from New Zealand, although members of the genus also come from Australia, Tasmania, New Guinea, South America, and the Falkland Islands.

There are about a 100 species but they are a promiscuous lot and hybridise readily so there are as many as 200 cultivars.

As shrubs they are of great garden merit being outstanding flowering plants, most of which produce axilliary or terminal racemes of either white, pink, red, violet or blue flowers. The main flowering periods are May, June, July to September.

There is great diversity of foliage—many produce deep glossy green elliptical leaves, others produce tiny scale-like leaves such as the "whipcord" types. The foliage can also be green, golden, purple, grey and, of course, variegated. They are all evergreen. Hebes vary greatly in height some, suited to the rock garden, are as little as 7cm, others are up to a height of 2.5m.

Hebes grow best in an open sunny site, although some will tolerate a little shade. The soil needs to be well drained, moderately acid to moderately alkaline. They will withstand drought well and grow well in sites subject to exposure from the sea. One problem which needs more research is a specific replant disease. On some sites at Cannington it has been difficult to re-establish hebes where they have been killed during very cold winters. A number of species are quite hardy, particularly those with grey foliage, the "whipcord" types, and those with small leaves. Those which come from the North Island, New Zealand, are less hardy so they should be planted in a sheltered position. To ensure regeneration of growth after a hard winter, tender hebes should be planted more deeply and mulched to protect the basal buds from frost and cold winds.

Pruning is only required when the plants either become leggy or are damaged by frost. The pruning technique for either problem should be in two stages, cutting back half the growth in the spring and waiting for regrowth before completing the job. In my experience where the plants have been damaged in a very cold winter they

will not regenerate satisfactorily and will need replacing.

Propagation can be done by tip cuttings taken from the current season's growth in September.

Hebes can be used in the garden in a great number of ways—as ground cover and mass planting, hedges in milder locations, in formal bedding schemes, and as pot plants.

As well as taking into account size and shape, colour and texture of the foliage of the plants, the overriding factor in my opinion, is hardiness. Indication of hardiness and use can be dealt with by looking at their botanical groups.

BOTANICAL CLASSIFICATION

Hebes can be divided into roughly 11 groups, 10 of which are used by Dr. H. H. Allan's "Flora of New Zealand" for classifying the species and naturally occurring hybrids. The eleventh group is used for the hybrids of unknown or garden origin, which I am sure with a bit of botanical work could be fitted into the previous 10 groups.

These groups are as follows:

1. Subdistichae Most of these have relatively small to medium sized leaves; they are fairly hardy and vary in height from 30cm to 2m tall. Three best known species/cultivars are: *H. brachysiphon*, *H. colensoi*, and *H.* 'White Gem'.

2. Apertae Most are medium to large-sized shrubs and are generally not very hardy. There are a number of coloured-leaved cultivars. *H.* × *fransicana* cultivars include 'Variegata'; hybrids with *H. speciosa* parentage include 'Amy'; hybrids with *H. salicifolia* parentage include *H.* × *andersonii* 'Variegata' and 'Midsummer Beauty'.

3. Occlusae Inflorescences in lateral racemes, mixed hardiness, height range from 30cm to 80cm. Most common species and cultivars: *H. parviflora*, with a number of hybrids including 'Bowles' Hybrid' and 'Mrs. Winder', both fairly hardy; *H. glaucophylla* and cultivar 'Variegata', also hardy.

4. Subcarnosae Many are small-leaved, grey in colour, very hardy and tolerant of dry conditions so can be used on rock gardens and for ground cover. Examples include *H. albicans*, *H. pinguifolia* 'Pagei', *H. carnosula*, and *H. pimeleoides*.

5. Buxifoliatae Leaves are small and stiff and the plants are hardy. Most are short, up to 50cm. The most common species is *H. odora*—known in Britain as *H. buxifolia*.

6. Flagriformes These are the whipcord hebes—all are hardy. The most well known species and cultivars are: *H. hectori*, *H. lycopodioides*, *H. armstrongii*, *H. ochracea*, *H.* 'James Stirling' and *H. cupressoides* 'Boughton Dome'.

7. Connatae These have overlapping leaves, the leaf bases are joined; they are compact plants that are hardy. None are particularly well known; an example species is *H. haastii*.

8. Paniculatae Flowers are carried in terminal panicles and the leaves have petioles. They are moderately hardy. The most well known species is *H. hulkeana*.

9. Grandiflorae Leaves have petioles and are toothed. The plants have large flowers and are hardy. The best known example is *H. macrantha*.

10. Semiflagriformes These are small whipcord or semi-whipcord plants and are not very common. They are fairly hardy. *H. ciliolata* is an example.

FOLIAGE EFFECTS

Purple. *H.* 'Amy', *H.* 'Eversley Seedling', *H.* 'Mrs. Winder', *H.* 'Purple Glory', *H.* 'Sapphire', and *H.* 'Simon Delaux'.

Grey. *H. albicans, H. carnosula, H. colensoi* var. *glauca, H. pinguifolia* 'Pagei', *H.* 'Pewter Dome', *H. pimeleoides,* and *H.* 'Wingletye'.

Variegated

Cream and green. *H.* 'Amanda Cook', *H.* × *andersonii* 'Variegata' and 'Aurea', *H. darwiniana* 'Variegata', *H.* × *fransicana* 'Variegata', *H. glaucophylla* 'Variegata',

Cream, green and plum. *H. speciosa* 'Tricolor'

Whipcord "conifer-like"

Green. *H. cupressoides, H.* 'Edinensis', *H. hectori*

Yellow/bronze. *H. armstrongii, H.* 'James Stirling', *H. ochracea*

Glaucous. *H. cupressoides* 'Glauca'

Yellow green or yellow tipped. *H. buxifolia, H. brachysiphon* 'White Gem', *H. rakaiensis, H. rakaiensis* 'Golden Dome'

LANDSCAPE USE

Small rock garden and troughs

H. cupressoides 'Boughton Dome'
H. buchananii
H. canterburiensis
H. 'Colwall'
H. loganoides
H. macrantha
H. pinguifolia 'Pagei'
H. prostrata
H. willcoxii

Large rock gardens and fronts of borders

H. albicans
H. amplexicaulis
H. boscawenii
H. 'Caledonia'
H. 'Carl Teschner'
H. carnosula
H. colensoi 'Glauca'
H. lavaudiana
H. 'McEwanii'
H. pinguifolia
H. vernicosa
H. 'Wingletye'

Ground cover

H. 'Carl Teschner'
H. carnosula
H. 'County Park'
H. decumbens
H. rakiensis

Hedges up to 1 m

H. 'Autumn Glory'
H. buxifolia
H. edinensis
H. × *franciscana* 'Variegata'
H. gracillima
H. rakaiensis
H. × *warleyensis*

Hedges over 1 m

H. angustifolia
H. cupressoides
H. 'Great Orme'
H. 'Jewel'
H. 'Killiney'
H. 'Midsummer Beauty'
H. 'Waikiki'

Hebes for background screening

H. brachysiphon
H. 'C. P. Rafill'
H. 'Miss E. Fittall'
H. salicifolia
H. 'Violet Wand'

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PLANTS FOR WIDER PROPAGATION: SOME HERBACEOUS TREASURES, BAMBOO MAGIC, AND OTHER SURPRISES

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Obviously, no nurseryman wants to be caught raising a large stock of some esoteric plant of which he will eventually sell only two or three. I should like to point out, however, that communications between grower and customer have been greatly improved since Chris Philip and Tony Lord, under the aegis of the Hardy Plant Society, have produced *The Plant Finder,* a mine of information on how to locate a whole range of hardy stock.

In general, there are plenty of businessmen around in the nursery trade with a sensitive nose for ratings, but plantsmen are few and far between or, if present, uninfluential. A plantsman is always supposed to have his head in the air and to be blissfully unaware of market forces. Peter Catt, whom we met on his nursery during the conference tour, is exceptional in being a combined plantsman, propagator, and businessman. The result of having so few plantspeople either at the propagating end or the selling end of the production line is a dismal uniformity. The public is in part to blame because a large part of them do not notice anyway.

But a large part of the British gardening public is remarkably well informed. In my garden, which is constantly open to the public but is totally unlabelled, I am made aware of this fact all the time. To a large extent they know what they are looking at or recognize what is different. The best plantsmen, therefore, are the amateurs, which doesn't say much for *us.*

The sort of plants that need producing and promoting are not necessarily new at all. In the herbaceous field, the old-fashioned single white Japanese anemone is constantly in greater demand than supply. This is the flower that I call *Anemone japonica* 'Alba', though it may be more correctly, *A.* ×*hybrida* 'Honorine Jobert'. It is *not* 'Luise Uhink', wherein the flower is fussed up with a lot of narrow petals. In 'Alba' they are broad and set off by a ring of yellow stamens and a green eye.

Arundo donax, the giant reed grass, grows three to four metres in a season from scratch, but its growth and foliage is well spaced. You can see through and past the plant, which allows it to be placed as appropriately at the front of a border as at the centre or back. American visitors sometimes annoy me a little by saying it looks like corn, their name for maize. Admittedly both are grasses, but the giant reed grass has beautiful glaucous foliage and great style.

Hakonechloa macra 'Aureola', another grass, is fairly widely distributed but young plants take a while to make any impression.

At most its height is 30cm. With its gold and green striped foliage its season extends from spring to autumn, when it flowers, and right into winter, when its dead stems and leaves still look good. It is a marvellous plant once established.

Yet another grass, *Imperata cylindrica* 'Rubra', seems the ideal companion for the black-leaved *Ophiopogon planiscapus* 'Nigrescens', a plant for which it is not easy to find a good team-mate. The grass grows stiffly to 30 to 40cm tall and its red foliage in autumn shines like rubies when back-lighted by the sun.

Hellebores are excellent plants in garden centres for extending the selling season but seedlings are unreliable. We desperately need to be able to clone up the new hybrids which Helen Ballard and others have been breeding. I had hoped to hear, at this Conference, that micropropagation might provide the solution, but is seems not. The numbers of any one clone required by the hardy plant trade are too small to justify the high production costs of this expensive propagation method.

Kniphofia caulescens has an imposing presence with broad, glaucous strap leaves similar to if not quite as good as a leek's. But the kniphofia is evergreen. It makes a bold feature in paving or on a promontory in such a position where the leathery old *Bergenia cordifolia* is normally used.

The kniphofia has, on account of its tropical appearance, always been supposed to be tender, but is remarkably hardy in such gardens as Wallington, Northumberland, and Crathes Castle near Aberdeen. The plant is slow to propagate by division and the clone in general cutivation flowers too late, in September, to set and ripen seed. However, Dr. Jack Elliott has a clone which flowers in August and ripens generous seed crops, so future prospects are brighter.

Polystichum setiferum 'Bevis' is a most desirable fern with elegant fronds that taper to fine points. But it is sterile and the dense crown that it forms is not easily pried apart. But how many have seriously tried?

At Sissinghurst Castle it combines with and cools off a large planting of *Dactylorhiza* × *grandis*. The hardy dactylorhizas, such also as *D. foliosa* and *D. elata,* have gone in and out of nurserymen's lists, including Bloom's, over the years. They are first rate garden plants with quite a long flowering season. Furthermore their roots multiply readily, unlike the genus *Orchis* in which the crowns generally remain single.

Aralia cachemirica is a herbaceous member of the genus, making 2.5 to 3.0m of growth in a season when well established in moist soil. It is an imposing plant to use as a specimen, not colourful but hard to pass by. The large pinnate leaves are surmounted by umbels, combined in panicles, of small white flowers which soon become deep purple fruits; the subtending pedicels also purple. A handsome plant, easily raised from seed sown in autumn and

allowed access by frost. Germination is free in the following early spring.

Paris polyphylla, again, is discreet judged by the notion that flowers should be colourful and only the leaves green. But its inflorescence has a splendid structure retained right through the summer until the capsule of vivid orange or yellow seeds opens out. Ther must be an easy way to germinate these seeds. It has been done but not by me.

Euphorbia schillingii was introduced by Tony Schilling from Nepal and was thought at first to be a form of *E. sikkimensis*. In fact it belongs to a different group of euphorbias and was found to be a so far undescribed species. Unlike *E. sikkimensis*, which suckers inconveniently, *E. schillingii* is a sturdy clump former, a metre tall, flowering at a usefully late and prolonged season from mid-July for two months. It can be raised from seed, which germinates directly from a spring sowing, or from cuttings of basal shoots taken early.

Geranium 'Anne Folkard' is a sterile hybrid between *G. psilostemon* and *G. procurrens*. It combines the virtues of both parents without inheriting their faults. The young foliage is yellow green, which is a worry until you realise that it is healthy and natural, after which you advertise it as a great asset. The bright purple flowers are borne unceasingly from May to October on a rambling, weaving plant and it is invaluable for binding a border's contents together. In winter it dies back to the crown. Stem cuttings need to be taken early in order to establish plants that will overwinter.

I should like to bring in clematis, since my name has at times been associated with the genus. Some old favourites, greatly in demand, are hopelessly underproduced. Raymond Evison tells me that he has taken 2000 cuttings this year of 'Perle d'Azur' and his is the largest European clematis nursery. 'Perle d'Azur' is by far and away the most prolific and showy blue clematis for late July. At Sissinghurst it makes a great curtain of blue against a concave wall. Everyone wants it but it is always in short supply.

So is 'Alba Luxurians', a viticella hybrid which finds itself difficult to decide whether it wants to be leaves or flowers. The first blooms are entirely green, the last entirely white, but in the main flush it is characteristically white with green tips to the sepals. It has great public appeal.

Bamboos were, as I wished them to be, included in my subject title. Nurserymen are most unadventurous in the range offered. Of the larger, specimen-forming kinds, the commonest is *Pseudosasa japonica* [syn. *Arundinaria japonica*], which is invariably scruffy and always subsiding into a partial flowering condition. *Sinarundinaria murielae* and *S. nitida* are good but nowhere near as distinguished as a whole range within the genus *Phyllostachys*, such as *P. aurea*, *P. viridiglaucescens*, *P. bambusoides*, and *P. nigra*

in their several selected clones.

These bamboos have shown little inclination to flower, at least in my lifetime. And in our climate they are compact in habit, not running about as they do where summers are warmer.

As a genus, they have far greater presence than the majority of bamboos, yet when the Award of Garden Merit Committee was sitting a few years ago, reviewing the lists of plants deserving this award, not a single phyllostachys was included. The nurserymen represented just did not want to know about them.

LESSER KNOWN AND UNUSUAL SHRUB SPECIES AND THEIR PROPAGATION

NORMAN S. STANDBROOK

Hinton Nurseries
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These days people are constantly asking nurseries for something out of the ordinary. This paper contains a few suggestions that may be of interest to the discerning gardener.

The Moroccan broom, or *Cytisus battandieri,* with its pineapple scented flowers, is usually grown from seed, but this method is not really satisfactory as the plants do not flower until quite mature. Micropropagated plantlets are sometimes available, but there are still problems with successfully establishing the plantlets.

The best results are from cuttings which, although not easy, are a good source of supply. The wood must be semi-ripe and taken rather late in the year, October or November. Our greatest success has been from plants kept in a poly-tunnel and the growing shoots taken when about 10cm long and quite whippy to the feel. They are then dipped in Synergol rooting hormone, at the rate of one part to six of water and inserted into individual pots of Cornish grit/peat, 3:1.

The pots are then placed in a carrying tray and put on the mist bed, with a base temperature of approximately 65°F. The mist is kept to minimum levels during the day and turned off at night as this species thrives best in a dry atmosphere. Rooting usually takes place in about 3 to 4 weeks, when the young plants should be carefully potted on into suitable containers. Care should be taken to avoid any root disturbance. This method produces a good quality plant that will generally flower during its first year.

Grafting, using laburnum as an understock, is not generally regarded as being ideal as the resulting growth is too lush and the plant is not long lived.

Climbing hydrangeas and relatives. While there seems to be a plentiful supply of *Hydrangea anomala* subsp. *petiolaris,* there

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Climbing hydrangeas and relatives. While there seems to be a plentiful supply of *Hydrangea anomala* subsp. *petiolaris,* there

should be more thought given to some of its near relations, especially the schizophragmas. These plants, although deciduous, are a useful addition to the garden for covering walls and fences.

Propagation is usually by cuttings taken from wood of the current season's growth, about 10cm long. The leaves of *Schizophragma integrifolium* may be halved to lessen moisture loss through transpiration. The cuttings are dipped in a Synergol solution of one part to three of water; they root in about three weeks. *Schizophragma hydrangeoides* is treated in a similar manner, although the need to reduce the leaves does not apply as they are somewhat smaller.

A near relation of this species is *Pileostegia viburnoides* and, although best grown in milder areas, it has survived temperatures of minus 12°C at our nursery on the south coast of England in the winter of 1986–87. This shrub is a good evergreen and, although rather slow growing, is a superb plant for covering a wall and has large bracts of creamy yellow color during the late summer. Propagation is quite easy, with cuttings being taken in late August and September; they root freely from all types of wood.

Although very similar in appearance to *Pileostegia, Hydrangea seemannii,* from mountains in Mexico, is a more recently introduced plant. It is a good evergreen with a large head of faintly scented white flowers, although as yet I have not seen these for myself.

For some colour early in the year, I would suggest *Prunus mume* or the **Japanese apricot.** Although usually grown as a wall plant, it makes an attractive warm border bush. A wall-grown specimen can well exceed 20 feet in height. Although there are numerous cultivars grown in the Far East, the ones most usually found in Great Britain are 'Beni-Shidori', a very good fragrant single pink, and 'Omoi-No Mama', a semi-double white. The form, Pendula, can also be found, but it would appear not to be very vigorous. At Hinton we propagate the above cultivars by means of bench grafting onto *P. cerasifera* in early February, just as the flower buds start to show. By this method we produce a good plant of 60 to 90cm, and of bushy habit, by August or September of the same year.

We have also had some success with rooting shoots of the current season's growth inserted during July, but the resulting plants are usually quite weak. Another method of propagating this species is by chip budding in late July and August on stocks planted in the open ground. Although not long lived, it is an excellent plant as it does provide a splash of colour in the dull early months of the year.

A plant which still gives propagators a few problems is ***Romneya coulteri.*** This good border plant is becoming more widely grown at last. Romneya, sometimes known as the California tree

poppy, is a semi-shrub plant with succulent herbaceous stems that grow to 1.5 to 2.0 metres. The flowers have satiny white petals with a rounded boss of golden yellow stamens at the centre. This is essentially a suckering shrub that can be grown in most locations, although a nice sunny position next to a warm wall would be an ideal place for it.

Propagation is best performed by means of root cuttings taken during late January to early February. It is essential that roots of the current season's growth only are used. Old roots do not regenerate. Sections of these new roots should be cut into lengths of about 4 to 5cm, placed in pots of a sandy mixture and put into an open frame with gentle bottom heat of about 15°C. It is important to stress that the roots should be placed no more than 1.5cm beneath the pot surface and when watering, great care should be taken to ensure that the pot is not over-wet, although as the root is near the surface, it must not be allowed to dry out. As a rule, the roots will produce shoots quite quickly, usually within three to four weeks of planting.

In April or May, when the small plants are about three months old, potting on must be done with great care as the new roots do not take kindly to being disturbed. This has been the method that we have found to be most successful, although soft cuttings taken in late June can be attempted. These do, however, produce problems of establishment which are more difficult to overcome. Seed of this species also offers a way of propagation, but it is often unreliable.

At our nursery, we have planted a nursery stock bed to give us sufficient roots. This stock bed is completely renewed every year with a number of new young plants selected for their health and vigour. During any severe weather we cover them with a 15cm mulch of peat to keep out the worst of the weather.

Another interesting species is ***Fabiana imbricata*** and the violet blue form, 'Violacea'. This could be grown far more widely in the more favoured milder areas. Fabiana is very often mistaken for a tree heath, but has a very distinct habit of growth, mainly vertical, but sometimes issuing out branches at unusual angles. It will attain a height of some two metres and the flowers are either white or violet blue, appearing during June and July and looking very like a tropical heath.

Propagation is best achieved by cuttings that root freely during late summer, if taken with a heel. Care must be taken not to damage the stem when stripping the lower portion of the cutting, as any damage will allow rotting to occur in the boxes. Rooting usually takes place after four to five weeks when placed in a mist house or closed frame with gentle bottom heat. This species was subjected to temperatures of minus 14°C during the winter of 1986–87 but came through unscathed. It would appear that if you can protect these so-called borderline hardiness plants from the prevailing winds, so that

the foliage is not desiccated they may well survive.

Cornus controversa 'Variegata' is a most elegant small tree or shrub which is not very freely available, probably because it is not the easiest plant to reproduce. It is very striking in its habit as it grows and produces its branches in tiers rather like an open umbrella, with one tier upon another, ascending upwards. Propagation to date has been by means of grafting the striking variegated form onto a *C. controversa* seedling. As yet, I have been quite unsuccessful with any other means of propagation, although a near relation, *C. alternifolia* 'Argentea', seems to root from softwood cuttings taken in July.

Obtaining seed or seedlings of *C. controversa* does sometimes present a problem, as the seed often takes a long time to germinate and in some seasons is not always viable. We have found that the best time to graft the species is rather late in the season when the scionwood is starting to harden, about early September or even a week or so later. Any earlier and the soft tips of the scion will keel over and the growing buds would be lost.

With the seedling stocks of about pencil thickness, or a little less, established in small pots, they are allowed to dry out for a few days before grafting. The scionwood is selected from strong growing tips of about 10 to 15cm in length and the leaves reduced by half to prevent excessive moisture loss. The stock and scion are then bound together in the traditional manner as low down as possible and the joint waxed. Callusing should normally take place quite quickly if the plants are placed in a closed frame with a gentle bottom heat of about 60 to 65°F. It is essential that the frame be shaded, especially on very warm days which sometimes occur during the early autumn. After about four weeks, the head of the stock should be removed and the cut waxed over. This is very important as, if it is left, the stock will sometimes bleed and infection will set in. After a further hardening-off period of 14 days or so, the plants can be kept over winter in a frost-free greenhouse ready for potting on in the following spring.

As an experiment, some 10 years ago, I grafted *C. controversa* 'Variegata' onto cuttings of *C. alba*, ensuring that all the eyes were taken off before grafting. Today I have some good sized specimen plants about two metres high from which I obtain my scions. However, I do not know if they will be very long lived.

Another good evergreen genus is ***Trachelospermum***. These plants are particularly good for cladding a wall or fence as they have very fragrant flowers during the summer months and must surely be rated as one of the best climbing plants available. At my nursery in Hinton, all cultivars have withstood the recent hard winters protected from the easterly winds.

Probably the most favoured species is *Trachelospermum jasminoides* with its white, scented flowers and bright evergreen

foliage. We also cultivate the variegated form, which is very attractive. *Trachelospermum asiaticum* has rather small leaves and pale apricot-yellow flowers which are also scented and perhaps a little hardier than *T. jasminoides*. Propagation of all the forms is by cuttings of semi-mature growths taken during August and September. When cut, the shoots will exude a milky white sap, which should be stopped by dipping the cuttings in a rooting powder while preparing for insertion into boxes containing sand/peat, 3:1. Rooting should be well under way in less than four to five weeks. By this method a good, saleable sized plant can be obtained in about 12 to 15 months.

A genus that is regarded as being very common is ***Buddleia***, especially the hybrids of B. davidii but, in fact, there are numerous species, some of which should be, in my opinion, more widely grown. One in particular is *Buddleia crispa*. This is a shrub of neat bushy habit, growing to about 2 to 3 metres in height with a most striking silvery appearance, the leaves and stems being covered in a downy felt. The flowers are a soft lilac and very sweetly scented.

A good, partially evergreen, species is *Buddleia salviifolia*, with its square stems and browny-red down on the underside of the leaves. The flowers are very fragrant and the colours range from white to purple. This plant is quite vigorous and will grow to about five metres in height in good conditions.

Although *Buddleia alternifolia* is very popular, a much more striking plant is *Buddleia alternifolia* 'Argentea', with its delicate silver foliage giving the long sprays of purple flowers a perfect foil. Lastly, I must mention *Buddleia auriculata*. Although essentially a cold greenhouse or conservatory plant, it is an evergreen well worth growing for its superb scent during the dull days of winter when there is little else in flower. The flower is not particularly striking, being of a creamy white colour, but the honey-like scent can sometimes be overpowering in an enclosed situation.

Propagation of the buddleia species is generally regarded as being quite easy, either from softwood cuttings taken during July or from hardwood in November. Some of the species, especially the furry-leaved ones, can be a little more difficult to root. The secret, we have found, is to keep the foliage as dry as possible, while still maintaining a humid atmosphere. We generally use a closed frame technique, with gentle bottom heat and heavy shading during very sunny days.

Finally, in conclusion, I would stress that the hardiness of all the species I have mentioned is open to question, while growing in pots. Once planted in the open ground and having made a reasonable amount of growth, most, if not all, will survive the average British winter. I would suggest, therefore, that perhaps we should be a little more adventurous in offering the gardening public what it seems to want . . . something a bit different!

PROPAGATION OF PAPAVERS BY ROOT CUTTINGS

PETER J. CROSLAND

Howard & Kooij's Nurseries
Wortham, Diss, Norfolk

Papavers are worthy plants with bright bold colours for the herbaceous border. They do best in a sunny position in a deep dry soil. *Papaver orientale* hybrids, which are common in cultivation today, were raised by Amos Perry of Enfield, Middlesex in the early 1900's. With a few exceptions these cultivars must be propagated by division or root cuttings.

To obtain suitable propagation material papavers should be field-grown, not container-grown, as the restriction of root growth causes a more fibrous root system to be produced.

The stock plants are planted in May or June and left undisturbed, apart from keeping them weeded, until November or December. At this point they are carefully lifted from the ground using a normal garden fork so that the roots are not damaged. As the cuttings will not be inserted until February or March the roots must be stored, there are two ways this can be done:

1) the complete plant is plunged in peat

2) the roots needed are removed, laid in boxes and covered with peat; it is most important that they are kept facing the same way to maintain correct polarity for planting. The original plant can then be plunged in the open ground ready for replanting in the spring.

The roots are then stored dry and frost-free until they are required for propagation. This is very convenient because they can be stored for up to two months. The actual time of preparation of the cuttings is flexible but ususally they are prepared in February when bad weather may mean that outside work is impossible.

The cuttings should be 50 to 60mm in length with straight cuts at both ends, the best diameter is 3 to 7mm; they should be inserted into trays the same day they are made.

Usually trays 600 × 400 × 180mm are used with peat 30mm deep spread on the bottom of the tray. A strip of peat 30mm deep is then put at one end of the tray so that the cuttings can be placed against it. The cuttings are stood upright across this strip of peat; when the row is completed they are covered with more peat and another row of cuttings can be placed in the tray.

When the tray is full a thin 2mm layer of peat is spread over the top of the whole tray. It can then be lightly watered in and stood in an unheated polythene tunnel or cold frame. The roots are of a fleshy nature, therefore they can be easily damaged by frost; this can be reduced by not letting the peat get too wet.

I have been experimenting with other materials instead of peat because of its water-holding capacity and have had some very good

results using a 50:50 perlite-sand mixture.

The cuttings usually start to shoot in April and as the temperatures rise more frequent watering will be required; during May and June the trays can be removed from the polythene tunnel and placed outside for hardening off before planting or potting. This should be done before the roots have started to produce their own fibrous root system. As this is very easily damaged a better plant is produced if the new roots can grow straight into the container compost or the soil. The plants are then left to grow until they have reached a saleable size in containers, this is usually July and August; the field-grown plants are sold from September onwards and the cycle can begin again.

PLANT FAMILIES IN NEED OF TENDER LOVING CARE[1]

R. A. W. LOWE AND G. A. PATTISON

"The Pines", Royal Horticultural Society Gardens
Wisley, Woking, Surrey. GU23 6QB

The National Council for the Conservation of Plants and Gardens was formed some 10 years ago, following a conference organised by the then Director of Wisley, Mr. C. D. Brickell, now Director General of the Royal Horticultural Society, because of his concern at the rapidly decreasing number of garden plants available to the gardener and horticulturist. The NCCPG, by which initials I shall now refer to us, is as much of a mouth-full as the full name. We are, in fact, an independent charity with offices within the Royal Horticultural Society Gardens at Wisley.

Work on the wild endangered flora of many countries is well underway, co-ordinated by the International Union for the Conservation of Nature and Natural Resources (IUCN), but little or no work has been done on the garden plants of British Gardens. Some work has been done by Dr. E. C. Nelson on Irish garden plants and, in particular, cultivated plants.

The main aims of our organization are:

a. to encourage the conservation of uncommon plants that are valuable because of their historic, aesthetic, scientific, or educational value by propagating and distributing them as widely as possible,
b. to list plants held in important collections and gardens,
c. to encourage the widest possible cultivation of uncommon and endangered plants by arranging conferences, exhibi-

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tions, discussions and visits to gardens, specialist plant collections and nurseries,

d. to encourage the re-introduction and distribution of uncommon and endangered plants, and

e. to establish and support National Collections of specific genera, part genera, and other defined collections of plants, for the enjoyment and information of the public and the benefit of science.

NCCPG is basically split into two closely inter-related parts, the Membership and the National Collections Scheme. The former consists of 34 autonomous county-based local groups with a total membership of some 5 to 6,000, who organise their own events and activities. These include lectures, propagation, plant sales, garden and nursery surveys, etc. Secondly, there is the National Collections Scheme with which I shall deal in more detail. These collections have been built up over the last six years from a total of 33 in 1982 until today when we have over 400. The existence of these collections should make it possible for a unique resource to be established in these islands which can be conserved, assessed, improved, and exploited as follows;

a. Horticulturists will be able to view the wide variety of plants within a genus that can be grown, to assess their qualities, and to encourage their propagation, hybridisation, and distribution.

b. Efficient scientific and horticultural research can be carried out because a large representation of any target group of plants is available in one location.

c. Taxonomic research can be carried out to the benefit of horticulture in general. This essential work is at present hampered by dispersion and lack of coherent inventories of our plant resources. As collections grow, they become authoritative sources for the correct identification of hybrids and cultivars and to some extent species.

d. Authentically named stock plants can in some cases be provided for the horticultural industry.

e. These collections concentrate on cultivars and will therefore supplement the major collections in botanic gardens, which are predominantly of species.

Of the 400 collections that are in existence today some 60 are duplicated. In two cases the collections represent plants introduced by eminent nurseries, i.e. Jackman's and Slieve Donard.

The custodians of the collections are divided as follows: 28 per cent in private hands; 24 per cent with trusts and societies, including some held by NCCPG local groups; colleges of horticulture and

other schools have 18 per cent; government bodies 14 per cent, and nurseries 16 per cent.

Today one or two of the collections are nearing definitive status such as *Azara*, *Crocus* and bamboos. The next stage here, if not already started, is to take herbarium specimens of each with a photographic record and descriptions using RHS colour codes.

The correct naming of the plants within the collections is one of our biggest nightmares and I am sure you, the nursery industry, could be of assistance when we come to trying to sort these out. I know that at a recent meeting with some Surrey nurserymen they showed interest in assisting us, but it must be remembered that this will be a slow exercise, although hopefully the botanist and the nurserymen can come to a consensus.

Material is now used for Ph.D. work as well as medical research, as with Nottingham University that has used the *Linum* collection in their research into anti-cancer drugs.

It will be noted that several colleges have collections that are being built up for use as educational tools hopefully to widen the field for future students so they are aware of the variation within a genus and therefore will use a wider selection of plants. This may avoid future comments like those in the horticultural press warning us of the dangers of "monocultures" within certain genera when used for landscaping, with all the dangers associated with this.

Notcutts hold some 24 different taxa of *Hibiscus syriacus*, and Webbs some 30 taxa of *Forsythia* and *Potentilla*. Norfolk Lavender is the centre of the lavender growing industry, it is only fitting that it should hold the *Lavendula* collection. At the other side of the country, Paul Picton, son of the famous Percy Picton, holds one of the duplicate collections of Michaelmas daisies, including some of the early cultivars raised by Barnard.

North of the border we have, at Glendoick Gardens, *Kalmia* and *Enkianthus*, with a duplicate collection of *Kalmia latifolia* cvs. and *Cornus florida* cvs. at Secretts down in Surrey.

National collections can be used as a bank. Nurseries, which for various reasons, stop selling a particular cultivar can give stock plants to collection holders. Conversely stock held by the collection holders may be of use to the trade and I am sure arrangements for exploitation can be made. It must be remembered that we are a charity and always trying to save ourselves from becoming extinct.

Local authorities also play an important role as holders of collections, from Brighton who holds the internationally registered *Syringa* to Leeds, holding some 10 collections including *Philadelphus, Phlox, Delphinium*, and *Dahlia*, to name but a few. It must, of course, be remembered that holding a National Collection is not an easy way out of the government's privatisation bill because these are scientific collections which have to be researched and

recorded, and to contain as comprehensive a collection of a genus as is possible.

Now we come to the question which is the title of the talk—which genera need adoption?

If we look at the list of those collections in existence we will find there is a predominance of herbaceous groups which, in fact, in most cases, occupy the least amount of space and are therefore obviously the first to be taken up.

We are mainly in need of sites for the shrubs and trees but also some more herbaceous groups. It is always difficult to say exactly which genera because of variation in particular sites or the interests of individuals or nurseries, but we are always open to suggestions from interested parties. It must also be remembered that collections, like plants, may lay dormant while ground work is being done and therefore take time to mature. Lists of National Collections are available at the minimal cost of £1.00.

The National Collection scheme is actively supported by the Royal Horticultural Society, Royal Botanic Gardens at Kew, International Union for the Conservation of Nature and Natural Resources, and several overseas countries that are liaising or thinking of setting up similar schemes, e.g. New Zealand, Australia, Holland, and the United States.

CAREERS: ACADEMIC TO HORTICULTURIST

NEAL WRIGHT

Micropropagation Services Ltd,
East Leake, Leicestershire

Abstract. A personal view of various aspects of micropropagation. The costs of developing a commercial production process for a new subject. How can these costs be financed? The Heath Robinson approach. The need for follow-up development beyond the laboratory.

My first view of micropropagation was as an academic, when I was studying at the Nottingham University School of Agriculture for my Ph.D. During this time I began to realise the potential of microprop. and that it was not then being exploited commercially, or not in what I consider as the right way from a horticultural viewpoint.

The average "tissue culturist" is a scientist who considers that, in theory, anything and everything can be propagated using tissue culture. He can point to published research papers that list procedures for the micropropagation of plants X, Y, and Z, and which often describe how plants were transferred to compost, even if it was only 10 plants!

In our laboratories we, too, started trying to propagate every-

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In our laboratories we, too, started trying to propagate every-

thing that we were asked to try. We were asked to propagate many different types of plants—ones difficult to propagate as well as easy-to-root subjects. We succeeded in getting some subjects to grow in culture such as: *Prunus tenella, Saintpaulia,* and even tulip. Some subjects we even got into compost such as: strawberry, rubber plant, cherry, Boston fern and gerbera. It was not long, however, before we realised that few plants grow in culture as well as Boston fern and that developing commercial systems from research papers was not that simple. Successful development would require a lot of "Academics". The only problem with this is that such scientists are costly. The cost of setting up a microprop. laboratory has been well documented, but the major cost, the personnel, has often been ignored.

The costs of research and development (R & D) can be very high. The cost of developing a microprop procedure for a new plant type, even when there are relevant research papers published, can be approximately £3,000 and it can take two or more years. It is necessary to sort out not only basic techniques, but also the whole management of a new subject so that production can be efficiently planned to enable the regular production of plants at the right time and in the right quantities. This requires considerable knowledge of the subject in terms of how it grows in culture and its relation to changes such as temperature, handling method, rate of multiplication, etc. Even after all this development work and expense it may not be economically viable to produce the subject.

It can even be costly to introduce a new cultivar of a subject already in routine commercial production, e.g. for new rose cultivars approximately £250. The initial slow build-up of stocks of a new culture and the need for an initial cleaning-up period for the material means that it can take up to 18 months for a new cultivar to come on line.

Given all this development cost it is not very suprising that so many companies in microprop. have approached venture capitalists for finance.

Venture capital would at first sight appear to be the answer. Venture capitalists are keen to invest in "Hi-Tech" areas, are not expecting an instant return, and will provide money in high risk situations where banks panic. Microprop. is considered a high risk investment because it is considered a "non-proven" technology. The venture capitalist therefore requires: (1) high growth (looking for growth of a minimum of three to five fold over five years), and (2) high return (profit margin of say 25 per cent to 40 per cent). They will also want to be sure that there will be someone willing to buy them out so that they can realise their investment.

If we look at figures published in July, 1988, for the growth and profitability of horticulture overall (Table 1) neither of these requirements could certainly be met. However, in terms of growth rate

microprop. can meet the desired levels, but I do not believe that it can do so in profitability terms and certainly not in the short term if past figures are anything to go by (see Table 2). The figures up to 1986 for the independent microprop. labs show an overall loss with few exceptions.

Table 1. General horticulture profitability & growth.

	Profit Margin	Average Growth
GROWERS (Average of 47)	2.7%	5.6%
GARDEN CENTERS (Average of 14)	2.9%	14.9%

Table 2. Financial history of micropropagation.

Year	Turnover (£)	Growth in Turnover	Loss (£)
1984	999,100	—	355,883
1985	1,683,900	1.7 fold	810,153
1986	4,323,026	2.6 fold	895,287

Totals for all independent micropropagation companies where information is available

My personal view is that in the short term (and probably in the long term as well) microprop. can only be successful if it employs the same approach as many industries including much of horticulture—i.e. companies must specialise. Much of horticulture is already specialised either by function: propagator, liner producer, container producer, field grower, garden centre, or by plant type: bedding, conifers, herbaceous, heathers, rhododendron, roses, trees, etc.

There are three main reasons why it is important to specialise:

1. To 'master the specialism' rather than being a jack-of-all-trades and to concentrate resources in a limited area.
2. Economy of scale—the efficiency of an operation can be improved simply by doing more with the same overheads and it becomes easier to justify the R & D costs when spread over a larger volume.
3. It is possible to provide better customer support by making use of accumulated knowledge. These days it is not good enough to sell a brand new product, take the money and walk away. If you want to develop repeat business you need to make sure the customer has the back-up to enable him to grow a good product which he can sell at a good price.

Our approach has been to specialise and to rely on banks for finance, even though their view of microprop. is somewhat nervous. By specialising it is possible to establish a profitable business and in our case we are now able to consider diversifying into

woody plants other than roses.

With restricted capital we have had to be a little 'Heath Robinson'. This is an approach used by many other growers and propagators—find alternatives to scientific apparatus and don't spend £5 if 50p will work.

Like many other labs we use honey jars instead of expensive flasks or test-tubes, and our media is poured with a jug instead of a hi-tech media pourer—not so accurate but for production work quite adequate and quicker. Our media "cook" can fill 1600 jars in a couple of hours. Our lamina flow cabinets are made from kitchen units (obviously with high efficency filters) and have the added advantage of costing approx 80 per cent less than their scientific counterparts!

An important area largely neglected by the microprop industry is the follow-up once the plants come out of the lab. This does not include just the weaning, the light levels, humidity etc. (much of this has been looked at by various experimental stations such as Brogdale and Efford) but also the subsequent growing on. The compost required for potting, the optimum stage of potting on, how long it will take to produce saleable plants. We have been very fortunate that Luddington E. H. S. has done extensive trials on microprop roses and have produced recommendations for container compost controlled-release fertilizer etc. (See Table 3).

Table 3. Recommended compost formulations: free draining, coarse structure, with slow release fertilizer.

STAGE I—LINER		
Container Size:	7cm(2½") square or 9cm(3½") round or similar	
Compost recommendation	Irish moss peat	75% (3 parts)
	Cambark, fine	25% (1 part)
	Fritted trace elements	0.3 kg/m^3
	Ground magnesium limestone	2.4 kg/m^3
	Ammonium nitrate	0.25 kg/m^3
	Osmocote, 5–6 month, or	4 to 6 kg/m^3
	Ficote 140	6 kg/m^3 (with single superphosphate 1.4 kg/)
STAGE II—FINAL CONTAINER		
Container:	Usually 3-litre rigid (2-litre pot may suit requirements for miniatures)	
Compost recommendation	Irish moss peat	67% (6 parts)
	Cambark, 100	22% (2 parts)
	6 mm grit	11% (1 part)
	Fritted trace elements	0.3 kg/m^3
	Ground magnesium limestone	2.4 kg/m^3
	Ammonium nitrate	0.25 kg/m^3
	Osmocote 12/14 month, or	6–8 kg/m^3 Osmocote
	Ficote 140	(6–8 kg/m^3 Ficote) (with 0.75 kg/m^3 single superphosphate)

Specialising in roses has allowed us to put a lot of time and effort into determining the precise requirements for growing on the crop and into sorting out some of the problems. It has also enabled us to give technical back-up to our customers to help them grow a quality crop. In fact we now even circulate a regular information sheet to all our customers to suggest what they should be doing each month. It also includes information about problems they might meet and those previously met by others—so hopefully they can avoid them. We hope that by giving this back-up we can help our customers produce quality plants which will establish well in the garden of the final consumer and thereby create further demand for micropropagated plants.

PROPAGATION SYSTEMS IN THE 1980s: A PERSPECTIVE ON THE BEST AVAILABLE

KEITH LOACH

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The aftercare of newly micropropagated plant material and the rooting of conventional cuttings share similar environmental requirements. Specifically, these are:

1. The need to conserve water in the plant tissues, since cuttings, whether from *in vitro* or conventional sources, readily suffer water deficits because they have no roots. In microplants already rooted *in vitro,* the roots often function poorly; their leaves, having developed in high humidities, have thin cuticles (1), little surface wax deposition (4), and relatively few stomata (5) with imperfect stomatal control (3).

2. It is nevertheless important to avoid excessive wetting of the plant material. In the case of micropropagated plants, the weight of water droplets can be physically damaging. In conventional cuttings there is need to avoid waterlogging of the basal stem tissues, which occurs especially in winter conditions and results in rotting.

3. Irradiance conditions must allow for the gradual redevelopment of autotrophic nutrition in micropropagated plants which have relied on sugars in the medium while in culture. Conventional cuttings of many woody ornamentals apparently require only low irradiance until they develop roots and begin to grow actively (10).

4. Temperatures should be moderate (18 to 25°C) but not excessive, i.e. below 40°C.

Specialising in roses has allowed us to put a lot of time and effort into determining the precise requirements for growing on the crop and into sorting out some of the problems. It has also enabled us to give technical back-up to our customers to help them grow a quality crop. In fact we now even circulate a regular information sheet to all our customers to suggest what they should be doing each month. It also includes information about problems they might meet and those previously met by others—so hopefully they can avoid them. We hope that by giving this back-up we can help our customers produce quality plants which will establish well in the garden of the final consumer and thereby create further demand for micropropagated plants.

PROPAGATION SYSTEMS IN THE 1980s: A PERSPECTIVE ON THE BEST AVAILABLE

KEITH LOACH

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The aftercare of newly micropropagated plant material and the rooting of conventional cuttings share similar environmental requirements. Specifically, these are:

1. The need to conserve water in the plant tissues, since cuttings, whether from *in vitro* or conventional sources, readily suffer water deficits because they have no roots. In microplants already rooted *in vitro,* the roots often function poorly; their leaves, having developed in high humidities, have thin cuticles (1), little surface wax deposition (4), and relatively few stomata (5) with imperfect stomatal control (3).

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4. Temperatures should be moderate (18 to 25°C) but not excessive, i.e. below 40°C.

THE IMPORTANCE OF WATER BALANCE

The requisite balance between maintaining turgor in the plant material and avoiding waterlogging changes with the season. For example, when softwood cuttings of 6 species were rooted in 3 different systems in summer (Figure 1a), best rooting occurred in the system which gave greatest gain in water content, i.e. enclosed-mist (mist operated within a clear, polyethylene tent). Poorest rooting was in open mist, where cuttings showed a net loss of water after insertion. In winter, with shorter days and lower irradiances, the water balance was more easily maintained, though the systems behaved in the same relative fashion in this respect (Figure 1b). However, rooting in winter was poorest in enclosed-mist because the stem bases were often waterlogged. In such conditions, alcohol rapidly accumulates in the basal tissues, suggesting that oxygen availability is reduced (R. S. Harrison-Murray, personal communication).

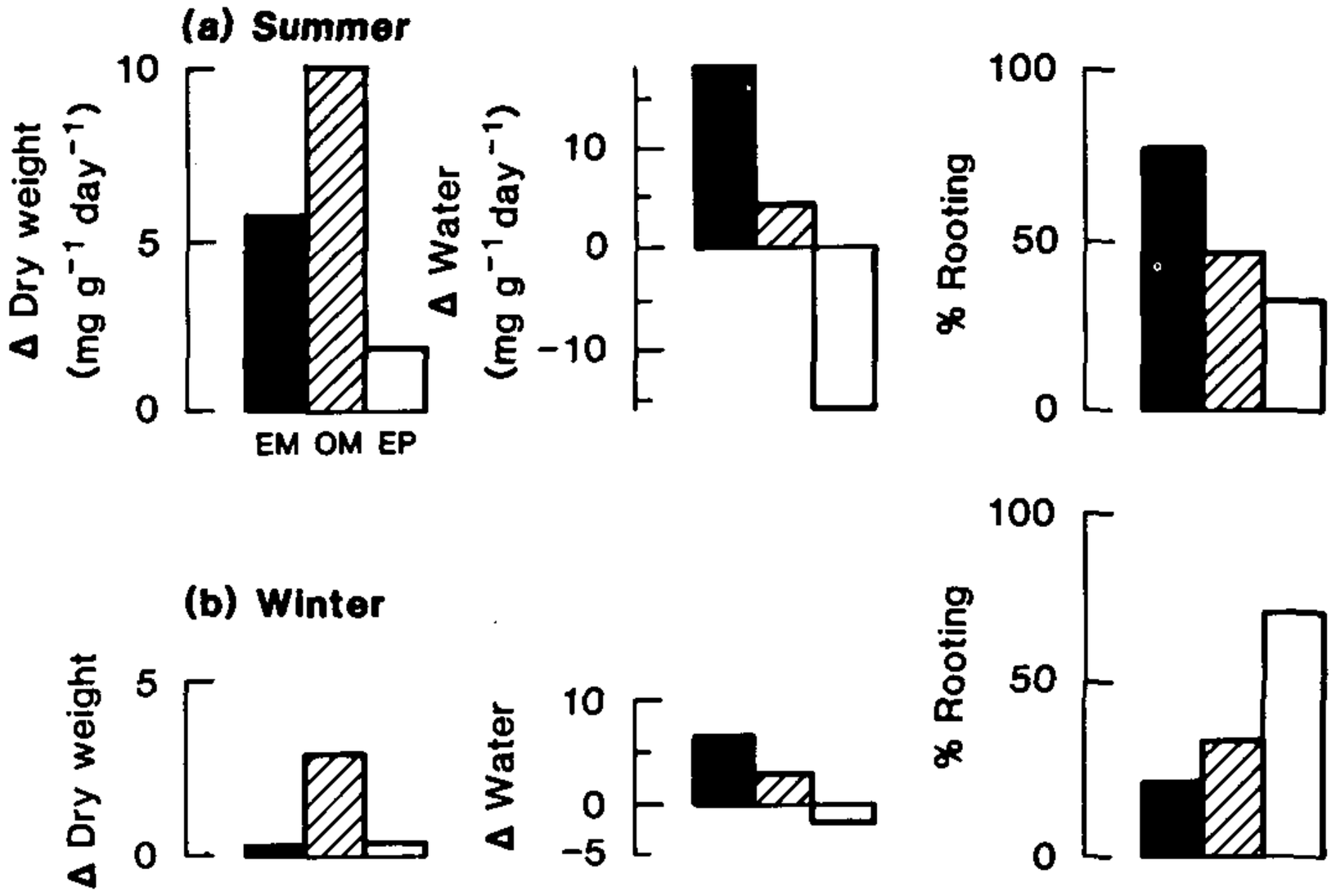

Figure 1. Changes in dry weight and water content of cuttings in open mist (OM), polyethylene-enclosed mist (EM), and a non-misted polyethylene enclosure (EP), measured over 2–4 weeks after insertion, and the eventual rooting percentages.
(a) Means for 6 species in summer.
(b) means for 4 species in winter.
Changes are expressed relative to water content and dry weight of cuttings at insertion.

These principles were further evident in experiments using a fog tunnel. Cuttings of 21 species were inserted in a clear polyethylene enclosure, 8.4m long × 1.7m wide × 0.9m high, with a single sonic fogging nozzle at one end. This allowed a simultaneous comparison of a range of propagation environments at 10 equally-spaced locations away from the nozzle. Nozzle operation was con-

trolled by a psychrometric controller set at 97 per cent relative humidity, positioned 3.4m from the nozzle. Figure 2 shows that for 4 species rooted in July, when maintenance of turgor is the prime consideration, rooting was best close to the nozzle. For 4 species in winter conditions, rooting was best at location 7. Note, however, that different species were used in July and October and subsequent evidence suggests that the differences may have a species as well as a seasonal component (see Figure 4). The remarkable feature of these results is the very evident sensitivity of rooting to environment, considering that the locations are only 0.84m apart and mean daily relative humidities ranged from 100 per cent at the nozzle to around 90 per cent at the far end. It would be instructive to carry out similar studies using cuttings and plantlets from *in vitro* sources.

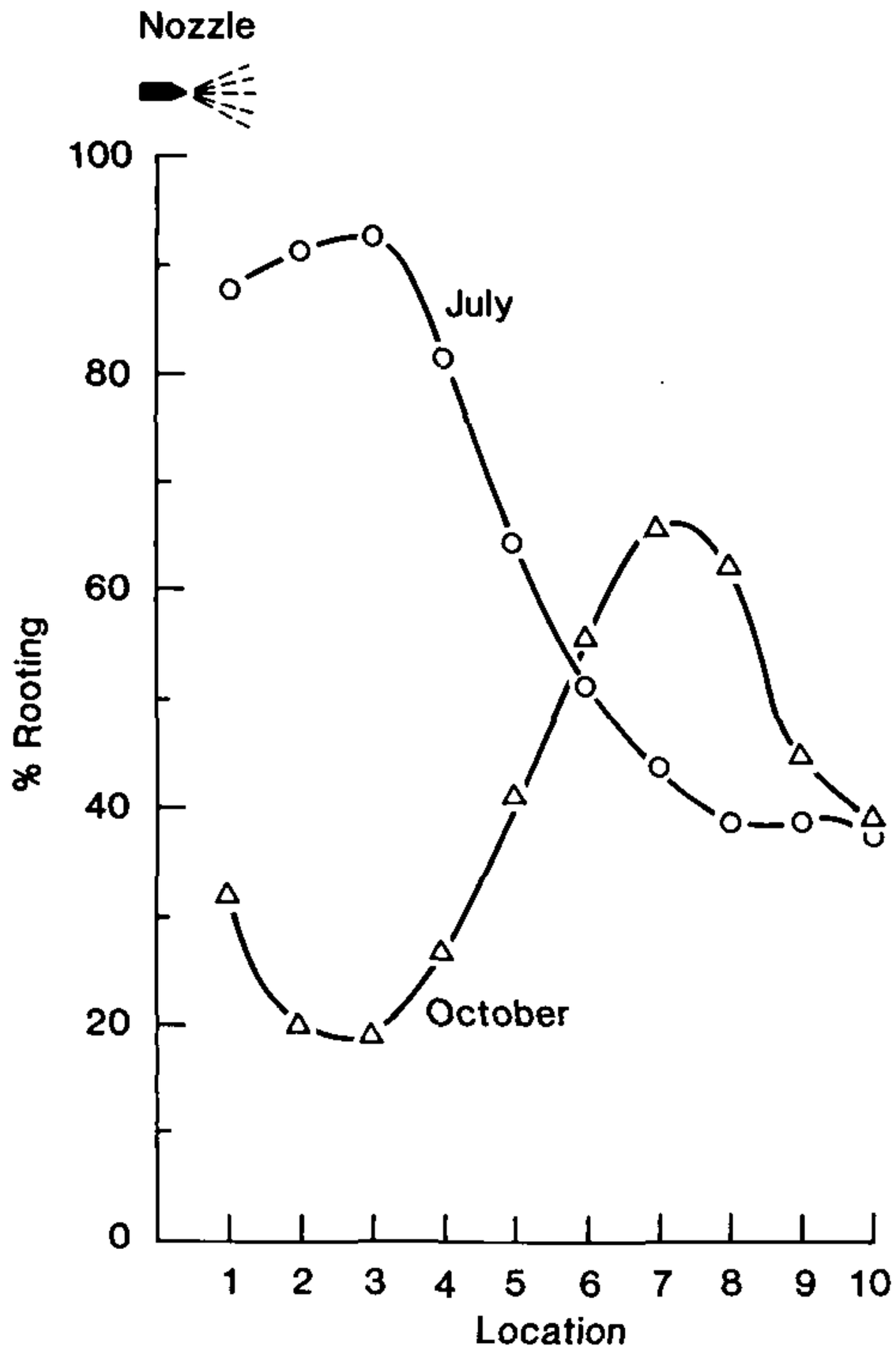

Figure 2. Mean rooting percentages for 4 species inserted in July and 4 in October, at 10 equidistant locations (0.85 m apart), from a single fogging nozzle in a clear, polyethylene enclosure.

Available systems. Propagators are thoroughly familiar with the use of polyethylene tents and conventional open mist, which need not be described here. Enclosed-mist is used less frequently, probably less then it should be. In U.K. conditions it has the advantage of providing a useful temperature rise relative to open mist (8).

It also maintains higher humidities than occur in a non-misted tent and the mist-wetted leaf surfaces provide insurance against tissue water loss. As shown in Figure 1, enclosed-mist can be over-supportive in winter, particularly with conifers. Nevertheless, with appropriate shading and regulation of the misting frequency, it can be very effective at all times of year (7).

We have limited experience in the use of enclosed-mist for weaning micropropagated material but 100 per cent survival of unrooted lettuce microplants has been achieved in March. For this purpose, the enclosed-mist was shaded to reduce an average 11 $MJ/m^2 \cdot day$ outdoors (total short-wave) to 3 $MJ/m^2 \cdot day$ in the enclosure. Misting frequency was controlled by a radiometer during the day to provide a two sec burst for every 0.12 MJ/m^2 of radiation and by timer at night to produce a two sec. burst every 60 min.

Fog presents potentially the most effective means of regulating the propagation environment. Fog generators produce very fine water droplets (<20 μm) which remain airborne for a long time, have a large surface to volume ratio, and so evaporate readily to humidify the air. Fog is favoured for delicate, micropropagated material because less foliar wetting occurs than with mist. It is also valuable to provide cooling of glasshouse air, again because fine droplets evaporate easily. However, because transpiration into a humid atmosphere is restricted, little of the energy absorbed by leaves is lost through evaporative cooling and leaf temperatures can be relatively high and even damaging. Shading is therefore essential to reduce the incoming irradiance and avoid water stress in the cuttings (2).

An extensive range of fogging equipment is now available and employs one of three basic principles:

1. **Centrifugal systems,** which use centrifugal force to atomize water. Outputs range from 1 to 190 litres per hour but the larger models produce a wide range of droplet sizes, resulting in fall-out close to the units, so making them less suitable for micropropagules.

2. **High pressure water nozzles,** which are similar to mist nozzles but with ultrafine orifices, and operated at high pressures up to 1000 psi (6.9 MPa). Typical outputs per nozzle are 5 to 8 litres per hour and arrays of these relatively inexpensive nozzles can be used to produce a large and evenly distributed fog output.

3. **Pneumatic nozzles,** which use compressed air and water. Recently developed "sonic" nozzles generate a field of high-frequency sound waves at the tip of the nozzle, which disrupts the water into uniformly fine droplets. They can produce up to 55 litres per hour of fog (more typically 15 to 20 litres per hour). The individual nozzles and associated air compressors are relatively expensive.

The merits of different fogging systems are compared in a sub-

jective fashion in Table 1. These must be considered in relation to the individual application, e.g. for micropropagules that require minimal foliar wetting and a spatially uniform fog distribution, sonic nozzles, or a high pressure water system are probably better than most centrifugal generators. For effective glasshouse cooling, the large capacity and low cost of centrifugal foggers may be attractive.

Table 1. A subjective comparison of fogging systems (*** = highest rating).

	Sonic nozzles	Centrifugal generators	High-pressure water nozzles
Low price	*	***	*
Capacity/unit cost	*	**	***
Effectiveness for ventilated cooling	*	***	**
Spatially uniform distribution	**	*	***
Uniformly fine droplets (minimal fallout)	***	*	**
Uniform air flow	**	*	***
Low maintenance requirement	***	**	**

Uneven spatial distribution of fog is a common complaint in many propagation installations. The ill-effect on rooting can be judged from Figure 2. It is helpful to install ancilliary ventilation fans to gently move the fog around the glasshouse. If ventilation is too vigorous, droplets coalesce and may fall-out out of the air.

FUTURE DEVELOPMENTS

The experiments in the fog tunnel clearly show that rooting of cuttings is very sensitive to environmental variations. As already noted, this sensitivity derives from the simple fact that cuttings, whose water uptake is restricted through lack of roots, are especially prone to tissue water deficits. Conversely, if transpiration is too restricted by environmental conditions cuttings suffer basal waterlogging. These observations raise the interesting challenge of characterising the narrow optimal range of conditions for rooting and controlling the propagation environment within this range.

It has proved possible to characterise propagation environments either by using sensitive evaporimeters (6) or by calculating from measurements of temperature, humidity, and leaf wetness, a "water stress index" (WSI) for the environment. The WSI is a measure of the accumulated leaf-to-air vapour pressure difference during the day (i.e. the summed driving force for water loss from the leaves), adjusted to accommodate the effects of any surface wetness of the foliage.

Calculation of the WSIs at each location in the fog in Figure 2, explains the seasonal differences in rooting pattern (Figure 3); in both July and October, best rooting occurred at the same WSI.

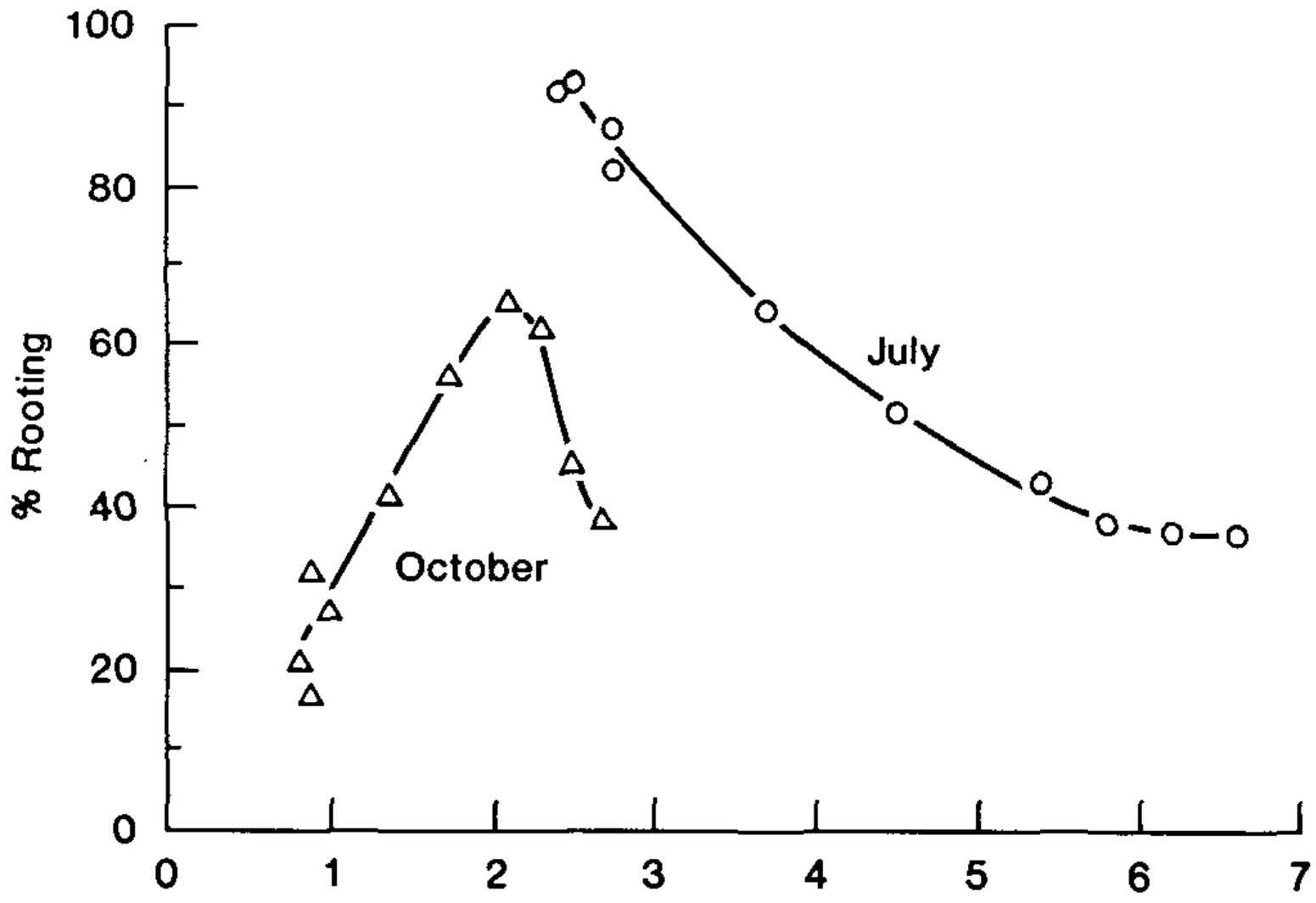

Figure 3. Percent rooting of fogged cuttings shown in Figure 2, in relation to the environmental water stress index (WSI), calculated for each location.

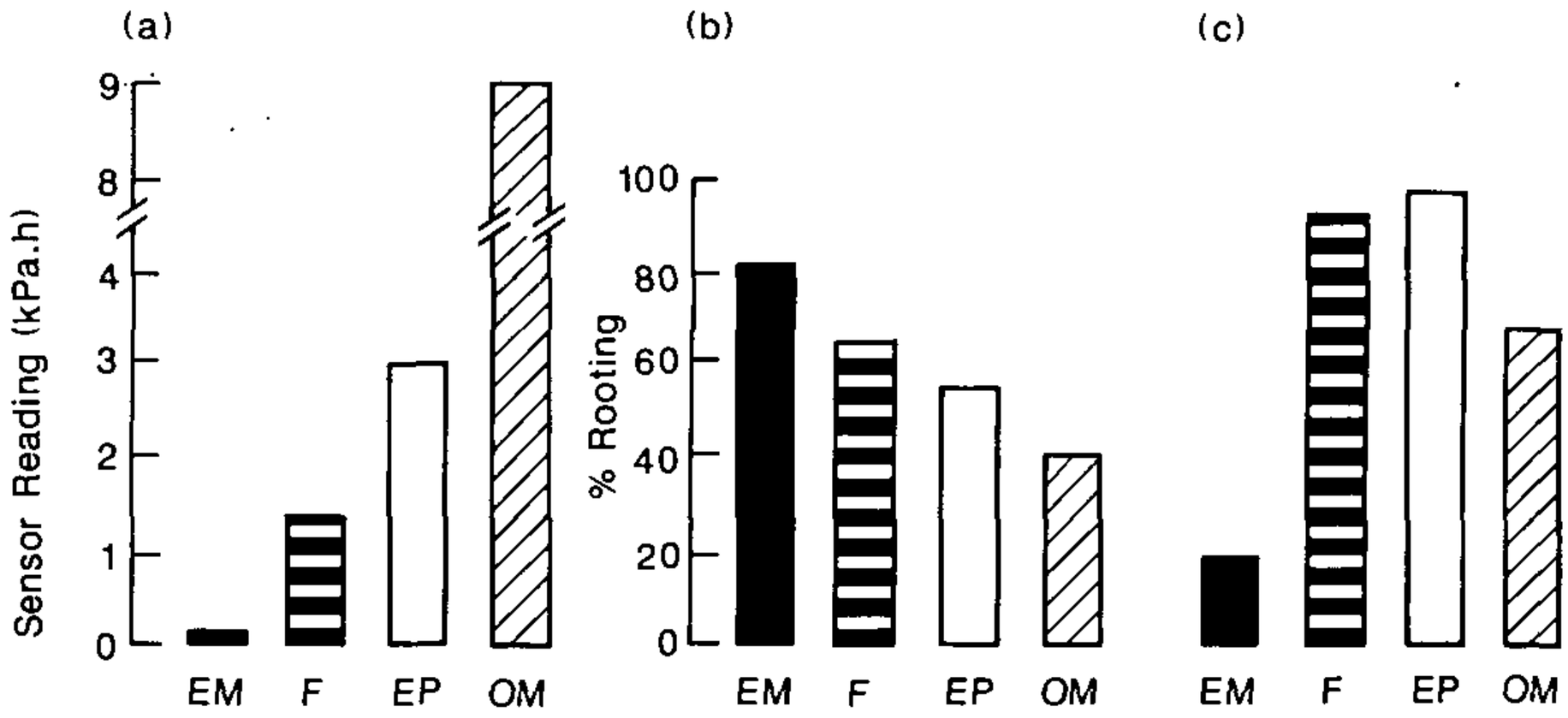

Figure 4. (a) Mean daily evapometric sensor readings in 4 propagation systems (EM, enclosed mist; F, fog; EP, non-misted polyethylene enclosure; OM, open mist), and % rooting of

(b) *Acer palmatum* 'Atropurpureum', *Photinia* × 'Red Robin' and *Viburnum* × *bodnantense* 'Dawn' (mean for the 3 species), and of

(c) *Cryptomeria japonica* 'Elegans'.

In collaboration with Dr. R. S. Harrison-Murray of East Malling, we have developed sensors which can provide continuous, quantitative monitoring of a propagation environment (details to be published). They can be used to compare different systems; for example in Figure 4a, open mist, enclosed-mist, a polyethylene tent, and fog were compared. In both the open and enclosed-mist the burst frequency was timer-controlled to give a 3

sec. burst every 20 min. from 04.30 to 20.30. The relative performance of each system could, of course, change if they were managed differently; one important use for the evapometric sensors is to compare, quantitatively, the effectiveness of alternative management procedures.

Preliminary rooting results showed that for May/June insertions of "soft" cuttings of broadleaf species, the percentage rooting achieved after three to five weeks improved with increasingly supportive environments (Figure 4b). However, the conifer, *Cryptomeria japonica* 'Elegans' rooted best in the "drier" polyethylene tent environment (Figure 4c), which suggests that different groups of species have different environmental optima.

CONCLUSIONS

Success in propagation is governed by many different factors but these studies show that the propagation environment plays a major role and that a narrow optimum range of conditions exists. Techniques for measuring the environment have been developed, fortunately at the same time as the methods for controlling that environment (through fog, computer control, automatic shading), have substantially improved. Combining these developments promises reduced failure rates both for weaning micropropagules and rooting conventional cuttings; this should provide the 'Best Available Systems' of the title, but in the 1990s rather than the 1980s. Experience gained from these technical improvements, should feed back into less sophisticated systems in the form of improved operational guidelines. The simpler systems will no doubt remain with us because they are often very cost-effective.

Acknowledgements: My thanks are due to Julie Reed and Peter Dolman for their assistance in the experiments reported.

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WEANING AND AFTERCARE OF MICROPROPAGATED NURSERY STOCK

MARGARET A. SCOTT

Agricultural Development and Advisory Service
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While there was initial enthusiasm from nurserymen to wean micropropagated propagules received directly from the laboratory, their success rate was variable. As a result most laboratories now have their own specialised weaning units to produce the rooted plantlet/liners for sale to growers, which can be handled in a similar manner to conventionally propagated material.

A specialist ADAS micropropagation unit at Brogdale Experimental Horticulture Station in Kent is, in collaboration with Efford EHS, investigating factors involved in successful weaning-off and growing-on of micropropagated material.

Work so far has concentrated on relatively high value crops, particularly those in the Ericaceae group, most of which are suited to growing under protection thus capitalising on the potential for growth from micropropagated material, e.g. *Rhododendron*, deciduous *Azalea, Pieris, Camellia, Kalmia,* and *Magnolia*.

This paper reviews the larger scale weaning and growing-on work in progress at Efford E.H.S.

Weaning has been defined as the acclimatization of the micropropagated material (propagules) from the precise laboratory medium and environment (*in vitro*) to typical horticultural growing environments and composts (*in vivo*). There are two distinct stages:

1. Transfer of propagules from culture media to compost and rooting under high humidity environments.

2. Hardening off and acclimatization of rooted material from high humidities to "normal" horticultural environments (under protection).

Laboratory treatments can have a marked influence on success

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Laboratory treatments can have a marked influence on success

of weaning and quality of plantlets produced. Treatments given during the weaning stages can also have a substantial effect on plant quality and growth in the industry.

Table 1. Grade-out of propagules from tissue culture (percentage).

Plant material	Propagule Grade (1= largest 4= smallest)			
	1	2	3	4
Rhododendron 'Wilbrit'	26%	17%	10%	40%
R. 'Blue Diamond'	9	27	16	23
R. 'Cilpinense'	4	43	13	40
Camellia 'Debbie'	25	42	33	—
Pieris 'Forest Flame'	14	35	51	—
P. 'Firecrest'	22	25	22	31

Table 2. Influence of propagule grade of rhododendrons on percentage and size of plantlets weaned.

	Propagule grade from tissue culture			
	1	2	3	4
Percent weaned	90	81	63	77
Percent first grade plantlets	52	17	8	10

INFLUENCE OF LABORATORY TREATMENT ON SUBSEQUENT WEANING

Trials have shown that the media recipes used *in vitro* can have a marked influence on the ability of the propagule to wean successfully *in vivo*, even though there appears to be little difference between them in the laboratory.

Work is showing that stage of rooting *in vitro* can have a significant effect on weaning. With certain species (*Magnolia*), propagules will root and establish when taken directly from the multiplication medium as mini-cuttings. Other species (*Pieris*) have failed to root or will root unevenly from this type of material and require transfer to a "root triggering" medium for the final laboratory sub-cultures.

Time spent on the root triggering medium can also be critical, most species benefiting from transfer to weaning prior to roots actually developing. Root-initiated material at this stage is much easier to handle. There is considerable variation among species and even cultivars within a species as to the correct treatment to obtain the best results.

There is still substantial variability in size of propagules received ex-laboratory which must be graded at weaning, not only to obtain even batches of plants, but also to enable differential treatment of grades, since the larger material roots and establishes faster. The smallest material is normally discarded as it roots poorly and is less vigorous. The influence of propagule grade follows through to establishment and potting. More evenly graded material

at the laboratory stage could lead to a reduction in costs since wastage could be reduced (See Tables 1 and 2).

INFLUENCE OF FACTORS APPLIED DURING WEANING

Weaning environment. The correct environment is crucial for successful weaning. Neither mist nor polythene covers were entirely satisfactory for the whole range of species, particularly the more delicate-leaved subjects. Closed propagators in a growing room are successful but are not a practical commercial proposition. Fog, on the other hand, appeared to offer a suitable compromise for a range of conditions and species. Fog must not be too wet; it must be evenly distributed and the droplets not too large. A pressurised air/water system ("dry fog") has given good results throughout the year.

Pest and disease. Sciarid fly has been a problem, but was successfully controlled using sticky yellow traps around the trays. Fungicide programmes based on those used for conventional cutting programmes have proved satisfactory for micropropagated material during weaning.

Supplementary Illumination. Use of supplementary illumination for weaning during the winter is being monitored and has produced excellent preliminary results with the test species, *Pieris*, improving speed of rooting, plantlet growth, uniformity, and quality. This is especially important for species that need potting early in the season to obtain the best results.

Compost/nutrition for weaning. Initial work used unfertilized media, but success with traditional cuttings from the inclusion of controlled release fertilizers (CRF) in the rooting medium prompted investigation of nutrition during weaning of micropropagated material. It was not possible to use the large granule CRF in the small-celled modules because of distribution problems but the Osmocote mini-granule (18:6:12) has been used successfully in these units. Feed requirement during rooting and weaning is species-dependent. Three groups can be identified:

A. *Fertilizer inclusion detrimental during weaning.* With *Kalmia*, fertilized media severely depressed rooting and establishment. However, once rooted and hardened off, a dilute feed programme prior to potting improved plantlet quality and establishment.

B. *Some fertilizers available during weaning of benefit in improving plantlet quality and early growth.* With *Rhododendron*, *Pieris*, and deciduous *Azalea*, non-fertilized material rooted and weaned satisfactorily but was smaller; with thinner caliper stems, compared to those from fertilized media. Liquid feed after stage 1 weaning improved plantlet quality but was still behind those where nutrients were available during stage 1 weaning.

C. *Incorporation of fertilizer during weaning an essential com-*

ponent. This was true for the production of quality plantlets to establish and grow away rapidly on potting, e.g. *Magnolia*.

Work on rates of mini-granules for incorporation in weaning media is still at an early stage, but 0.5 kg/m^2 in a peat-based mix has given good results (Table 3).

Table 3. *Camellia* 'Debbie'. Influence of nutrition during weaning on percentage of first grade liners produced.

	Nutrition during weaning		
	Nil	Mini-granule incorporated at Stage 1.	Liquid feeding during Stage 2.
Peat (sphagnum)	—	43%	25%
Peat:perlite (50:50)	3%	33	30
Peat:pine bark (50:50)	21	56	40
Mean	12.0	44.0	31.7

GROWING ON

A separate area of our work is looking at conditions/treatment/management influencing the growing-on of rooted plantlets, since this is the stage at which most nurserymen would be obtaining material. The work is still in its early stages and is considering:

Influence of time of year material is potted. Rooted plantlets ex modules are potted into 70 mm pots, ideally by early spring before the first flush of growth occurs. This encourages the root development that supports subsequent flushes of growth and produces quality liners by the end of the first season.

Grading. It is important to continue to grade at all stages and keep large and smaller grades separate. In a mixed batch, small grades become overwatered. This causes root problems and establishment of moss and liverworts. In addition, plants become crowded-out by the more vigorous grades.

Compost/nutrition. Most of the species involved in our trials come under the "salt-sensitive" category and over-nutrition can be a problem, especially at the young plantlet liner stage. Trials in progress are monitoring performance in response to type and formulation of CRF alone, and in combination with liquid feed programmes.

With micropropagated material it is important not to overwater, especially in the first few weeks after potting, in order to get roots established before the top begins growth. This can be encouraged by using a more open structured peat-based mix.

Stopping. Type and degree will vary with species. Early stopping of growth in *Rhododendron* is important to obtain good branching and to capitalise on the natural tendency of this material to break more freely than in conventional cuttings. Management of *Pieris* and *Camellia* is under review.

PERENNIALS, BULBS, AND SMALL SHRUBS FOR THE BEGINNER

TERRY C. HATCH

Joy Plants Nurseries
Pukekohe East

Many a young nursery worker dreams of setting up his (her) own nursery; most have very little capital to buy land, often ending up with a position that is not the best, to say the least! Our site is on the cold side of a steep hill; the largest flat area faces south and is windy. Also we do not have an overabundant supply of water, but the view is very pleasant.

Selecting plants that would be saleable in our general area has been a highly personal choice with the tendency towards perennials, bulbs, and smaller shrubs, with the prerequisite of drought and wind tolerance. Many of these plants have quite a long nursery life before they are ready for sale; also quite a number have been fairly difficult to propagate in any quantity, i.e. *Alstroemeria* 'Walter Fleming', but growing them is a challenge and is rewarding, even if not over remunerative. Data on these plants, many of which are now rare, is not over-abundant and then often suitable only for United Kingdom conditions. Some of these older cultivars are also unobtainable now and endangered to the point of extinction.

The climate here in New Zealand, being milder and damper than in the United Kingdom, makes for plant growth that is faster, softer, and prone to fungal attack, resulting in the need for frequent divison or repropagation in species that can stay *in situ* for a number of years in colder climates. Our long growing period of 9 to 10 months has the advantage, perhaps, of producing larger amounts of plant material, but lack of cold to break dormancy makes for sparse flowering in many species. Foliage has a longer display period and bulbs grow at a faster rate, e.g. hardy cyclamen takes 1 to 2 years to reach flowering size.

We can see then a need for perennials, bulbs, and shrubs to be selected that will perform well in our climate, with an eye, perhaps, for export as whole plants or as cut flowers.

Examples: *Helleborus orientalis* is a free-flowering plant in our climate with many colour forms. With a little help these could become a popular winter flowering garden subject by selecting plants with flowers having fuller petals and with cleaner colour or special markings and better cut flower qualities.

Nerine. This is a good flowering bulb for our climate, producing a range of cut flowers and garden material for pots. With the selection of newer, free-flowering types over the years since the 1930's much has been achieved. The potential for different forms is accelerating with some of the seedlings now showing double

flowers and the vase life extended by back breeding into the species. There are many points to consider, i.e. length of stem, number of flowers per stem, number of stems per bulb, etc.

The list of plants is endless, I am sure; most of the South African bulbs have hardly been touched by the hybridizer. South American bulbs and perennials, and Australian perennials all have a potential to be useful in our climate with selection and breeding, and a critical eye to the pitfalls on the way. In short, the field is vast for enthusiasts.

MICROPROPAGATION OF *XERONEMA CALLISTEMON*

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Abstract. A micropropagation method for *Xeronema callistemon,* a rare liliaceous plant endemic to New Zealand, is described. The explant material, consisting of the meristem sheathed in several leaves, was excised and sterilised. The trials were conducted with various media, supplemented with a range of cytokinins and auxins. The culture conditions were: light intensity, 2000 lux; photoperiod, 16 hr; and temperature, 25°C.

After preliminary stimulation on a medium containing full strength Murashige and Skoog minerals with 3 mg/l kinetin and 1 mg/l indoleacetic acid (IAA), shoot growth was best maintained on a medium containing 2 mg/l kinetin.

Shoot growth was dissected for further multiplication or transferred to a rooting medium containing half strength Murashige and Skoog minerals with 3 mg/l indolebutyric acid (IBA). The rooted plantlets were deflasked and gradually acclimatised to the greenhouse environment with a 98% success rate.

INTRODUCTION

Xeronema callistemon was discovered about 1920, on the Poor Knights Islands some 13 miles offshore from the North Island of New Zealand. The plants grow high on rocky windswept cliffs. Their closest and only relative is *X. moorei,* which grows in the mountains of New Caledonia.

X. callistemon looks very like a small flax plant with fan-like clumps of sword-shaped rigid leaves, each up to one metre long and 50 mm wide. In early spring (September) a stout flower stem appears, bearing a dense spike of bright red flowers up to 350 mm long, arranged in a brush-like cluster on the upper side. The flowers lack petals, but narrow red tepals hang below the pistil with the six stamens pointing upwards. From December the flowers mature into

flowers and the vase life extended by back breeding into the species. There are many points to consider, i.e. length of stem, number of flowers per stem, number of stems per bulb, etc.

The list of plants is endless, I am sure; most of the South African bulbs have hardly been touched by the hybridizer. South American bulbs and perennials, and Australian perennials all have a potential to be useful in our climate with selection and breeding, and a critical eye to the pitfalls on the way. In short, the field is vast for enthusiasts.

MICROPROPAGATION OF *XERONEMA CALLISTEMON*

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Abstract. A micropropagation method for *Xeronema callistemon,* a rare liliaceous plant endemic to New Zealand, is described. The explant material, consisting of the meristem sheathed in several leaves, was excised and sterilised. The trials were conducted with various media, supplemented with a range of cytokinins and auxins. The culture conditions were: light intensity, 2000 lux; photoperiod, 16 hr; and temperature, 25°C.

After preliminary stimulation on a medium containing full strength Murashige and Skoog minerals with 3 mg/l kinetin and 1 mg/l indoleacetic acid (IAA), shoot growth was best maintained on a medium containing 2 mg/l kinetin.

Shoot growth was dissected for further multiplication or transferred to a rooting medium containing half strength Murashige and Skoog minerals with 3 mg/l indolebutyric acid (IBA). The rooted plantlets were deflasked and gradually acclimatised to the greenhouse environment with a 98% success rate.

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dry brown capsular fruits with black spiny seeds. In cultivation, X. *callistemon* thrives best in a well-drained medium in rockerys or containers. It flowers after 10 to 15 years.

X. *callistemon* may be propagated from seed, although viability varies from year to year, or by division of the rhizomes. It is categorised as rare in the wild (1), although it is not uncommon in clutivation.

MATERIALS AND METHODS

X. *callistemon* plants were stripped of their outer leaves. The meristem, enclosed by several basal leaves measuring 10 to 15 mm, was excised. This explant material was disinfested with a wash in 0.6% sodium hypochlorite for 20 min., followed by three rinses in sterile distilled water, and a final dip in 0.2% sodium hypochlorite before plating.

The media trialed for shoot multiplication contained full and half strength Murashige and Skoog minerals (2) with Linsmaier and Skoog vitamins, 30 g/l sucrose, 7 g/l Davis agar, with the pH adjusted to 5.7. The strengths of hormones tested were 0 to 3 mg/l benzylaminopurine (BAP), 0 to 3 mg/l kinetin combined with 0 to 1 mg/l indoleacetic acid (IAA) (See Table 1).

The culture conditions were: temperature, 25°C; photoperiod, 16hrs; light intensity, 2000 lux. The plant material was subcultured each month.

The media trialled for root production were half strength Murashige and Skoog minerals with Linsmaier and Skoog vitamins, 30 g/l sucrose, 7 g/l Davis agar with the pH adjusted to 5.7 and supplemented with hormone levels of 0 to 10 mg/l IAA, 0 to 10 mg/l naphthaleneacetic acid (NAA), and 0 to 10 mg/l IBA.

Table 1. Media used in the micropropagation of X. *callistemon*.

Shoot proliferation:		
Full strength Murashige and Skoog minerals supplemented with:		
Myoinositol	100	mg/l
Thiamine HCL	0.4	mg/l
Sucrose	30	g/l
Davis agar	7	g/l
Kinetin	3	mg/l
IAA	1	mg/l
pH	5.7	
Shoot multiplication: full strength Murashige and Skoog minerals supplemented as above, plus kinetin, 2 mg/l		
Root elongation: half strength Murashige and Skoog minerals supplemented as above, plus IBA, 3 mg/l		

RESULTS

Within two months the explants showed a proliferation of bud growth on media with higher BAP, and with kinetin levels of 3 mg/l, in conjunction with IAA at 1 mg/l. Continued subculture on these media gave abnormal bud growth. Successful shoot production with a 3 to 4 fold multiplication rate each month was obtained using full strength Murashige and Skoog medium, with 2 mg/l kinetin.

Small clumps of shoots rooted most successfully on half strength Murashige and Skoog medium with 3 mg/l IBA, after 4 to 6 weeks. The rooted plantlets were deflasked and planted in seed trays containing a mixture of 50/50 peat/pumice-sand without fertilisers. The tray was enclosed in a plastic bag for 10 to 12 days then gradually hardened off to greenhouse conditions. It was important not to overwater. The survival rate was 98 to 100%.

DISCUSSION

The micropropagation of *X. callistemon* was devised in response to a demand for this rare plant. The seed is not always viable, and as the size of the "in vitro" plantlets at deflasking is the equivalent of two years old when produced from seed, micropropagation becomes a reliable and economical alternative.

Both juvenile and mature flowering plants have been initiated in culture, but as it is only three years since the first plants were deflasked it is still too early to determine whether micropropagation will shorten the time it takes to flower.

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2. Murashige, T. and F. Skoog. 1962. Revised media for rapid growth and bioassays with tobacco tissue culture. *Physiologia Plant.* 15:473–97.

IN VITRO CULTIVATION OF *TODEA BARBARA*—FROM SPORE TO SPOROPHYTE

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Abstract. The in vitro cultivation of *Todea barbara*, a fern endangered in New Zealand, is described. Spores were collected from the wild, disinfested, and grown in sterile water on half strength modified Murashige and Skoog medium with Linsmaier and Skoog vitamins without growth hormones. Culture conditions were: light intensity, 2000 lux; photoperiod, 16 hours; and temperature, 23°C. After six months sporophytes began to appear and were pricked out and replated on the above medium. Alternatively, this tissue was macerated, the dissected pieces of gametophyte tissue regenerating to increase the number of sporophytes available. When frond and root growth was sufficient the ferns were deflasked and hardened off under glasshouse conditions. After one year spore formation had occurred on the fronds of the ferns still held in culture. The cultivation of *T. barbara* from spore to sporophyte was repeated entirely under in vitro conditions. This process has been repeated annually over the last four years.

INTRODUCTION

T. barbara is found in South Africa, Australia, and New Zealand. A fern from the old world tropics, it is restricted to the milder climates of the North Island in New Zealand. It is a large attractive fern with fronds up to one metre long, dark green to yellowish green in colour, leathery, and smooth. Sporangia form at the base of the frond on the under surface, the remainder of the frond is barren. Versatile in habitat, *T. barbara* can grow in full sunlight or in shade, in rich humus, or in clay soil. Thus it is very suitable for the home garden. *T. barbara* is classified as an endangered species in New Zealand (1); that is, it may become extinct, as survival in the wild is unlikely.

The Black Hill Native Flora Centre in South Australia has named *T. barbara* amongst its rare and difficult to propagate plants. *T. barbara* can be propagated from spore, by normal methods, or by in vitro techniques, and consequently it will survive in the nursery trade.

MATERIALS AND METHODS

In autumn, spores of *T. barbara* were collected from the wild. Disinfestation was achieved by an agitated wash in 0.6% sodium hypochlorite followed by a rinse in sterile distilled water. Spores were grown in sterile distilled water on a half strength modified Murashige and Skoog medium supplemented with Linsmaier and Skoog vitamins, 20 g/l of sucrose, 7 g/l Davis agar, with the pH adjusted to 5.7. No growth hormones were used. Plant material was subcultured every two months, and held in culture conditions of

temperature: 23°C; photoperiod, 16 hours; and light intensity, 2000 lux.

The gametophyte tissue was macerated using a French "Mouli" parsley cutter that had been steam sterilised at 121°C for 20 min. The macerated tissue was resown on half strength Murashige and Skoog medium, as above.

An attempt was made to find a multiplication medium suitable for the proliferation of the sporophytes. Half strength Murashige and Skoog medium as above, was used with an addition of growth hormones, 0 to 1.5 mg/l benzylaminopurine (BAP), and 0 to 0.2 mg/l kinetin, with 0 to 2.0 mg/l NAA.

The sporophyte tissue formed spores while still in culture and these spores were sown on half strength Murashige and Skoog medium as above.

RESULTS

The disinfested spores of *T. barbara* gathered from the wild, germinated after ten days and grew slowly. After six months sporophyte fronds were showing amongst the gametophytes.

The sporophytes were pricked out, replated at two-month intervals, until after six months the root growth and fern size were adequate for deflasking. Ferns were planted in seed trays containing 50/50 peat/pumice-sand and covered with a plastic bag. After four weeks the plastic was slowly removed and the ferns gradually hardened off under glasshouse conditions.

The use of growth hormones to stimulate the proliferation of sporophytes of *T. barbara* was unsuccessful. The plants grew slowly and multiplication was limited.

The macerated gametophytes regenerated with a 4 to 6 fold increase in tissue substance, and within six months sporophytes were beginning to appear.

After one year in culture the spores that formed on the fronds of the ferns still held in culture were germinated and grown in a similar manner to the spores collected from the wild.

DISCUSSION

T. barbara may be continuously cultivated from spore to sporophyte under in vitro conditions. This method obviates the necessity to collect and resterilise fern spore from the wild.

The maceration of gametophytes was a method of increasing by 4 to 6 fold the available fern supply but the attempt at micropropagation of sporophytes using growth hormones was unsuccessful.

With the continuous supply of in vitro fern spore assured, and aided by the maceration technique, a feasible regime for the cultivation of *T. barbara* can be achieved.

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THE NECESSITY FOR NEW ZEALANDERS TO KEEP UP WITH THE LATEST PLANT SCIENCE TECHNOLOGY

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Auckland

As a plant breeder I find the late 1980s an exciting time. Right now we are on the threshold of a major technological breakthrough which will be comparable in impact to the development of air transport, television, and computers.

As this breakthrough is very much in our area of activity it is essential that everyone involved in horticulture appreciates what is happening and understands the implications it has for New Zealand. I am referring to what is commonly termed "Biotechnology" or "Genetic Engineering".

The development of "improved" plants and animals has traditionally been severely restricted by a whole range of biological barriers. Even in cases where it has been possible to bypass a barrier the methods have usually taken a long time. Dr Legro's development of the red delphinium is a good example. This has taken the whole of his working lifetime.

In essence, biotechnology embraces a number of related disciplines that have reached a stage of development, and have come together, so that things which plant breeders have long wanted to do are now starting to become possible. A whole range of techniques are covered by the term "biotechnology" and central to all of these is tissue culture, a process now familiar to most of you. Some techniques are now considered "Low Tech" like embryo rescue, endosperm culture, and anther culture. Others are considered to be "High Tech" and involve unravelling and understanding the genetic code itself.

One of the big attractions of the "High Tech" end is the process of "transformation". Here it is possible to identify individual genes and to move them from one organism to another. As the genetic code is essentially common to plants, animals, and micro-organisms it is possible to put animal genes into plants and *vice versa*. It will also be possible to manufacture genes.

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With traditional plant breeding, a great deal of time and effort have been required to achieve a favourable combination of genes. Such a combination can be thought of as a winning line in a lottery, but with far more numbers. When making a cross to introduce an additional desirable gene this sequence has inevitably been disrupted. Transformation offers the possibility of discretely introducing single genes or small rafts of genes without greatly disrupting the existing combination. Already people in many countries are working with genes which will confer resistance to specific pests, diseases, and herbicides, longevity to flowers, different flower and fruit colours, sweetness, and many other characteristics.

In a short article I cannot even attempt to expain the methods used. It must also be recognised that considerable background knowledge is required to be able to understand the details. However, this is no different than most of the other fields of technology we use each day. How many of us understand the electronics in our cars, televisions, or computers? The important thing is that as many horticulturists as possible understand the possibilities now opening up.

The New Zealand government, to its credit, has recognised the importance of this area by providing approximately $15 million for the development of biotechnology within DSIR over the next three years. Similar developments are being undertaken within the Ministry of Agriculture and Fisheries.

My greatest fear is lack of communication, or worse, inaccurate communication. I am not worried about communication between laboratory-based and field-based scientists. It is probably inevitable that the biotechnologist will be seen to be doing "difficult to understand" things and will, in consequence, be more highly regarded. It is also inevitable in the short term that fierce competition for funds will lead people to blur the line between what is currently possible and what they hope to achieve. However, I have no real fears that biotechnologists and plant breeders will not work together in harmony. I know that plant breeders look forward with considerable enthusiasm to the possibility of using new techniques. Equally, biotechnologists recognise that plant breeders and practical horticulturists will be necessary to ensure that their engineered plants are tested and survive in the real world.

I do fear lack of communication between the people developing the technology and the people involved in the various horticultural industries and the general public. Already garbled accounts are being published or broadcast which simply indicate lack of understanding. In addition some journalists have a penchant for portraying a "Frankenstein" image of genetic engineers.

Currently the level of communication with different sectors of the horticultural industry tends to reflect the degree of organisation

and the level of technical knowledge with these sectors. For example the kiwifruit and pipfruit industries are comparativley well organised and have established a track record in providing substantial funds for research and development. It is the ornamental industry, the one which most interests me personally, which gives me the greatest concern.

I have long felt that New Zealand had the potential to become the "Holland of the South Pacific". Overseas trips in recent years have only tended to confirm that we are letting this opportunity slip between our fingers. Short term exploitation of ornamentals developed over a long period by enthusiasts has taken place, but little or no investment in the development of new plants has been made by the ornamental sector. This is in marked contrast to countries like The Netherlands and Japan, where appreciable investment is made in developing new ornamentals. Currently our cut flower industry is dominated by plants imported from those countries. Similarly an increasing proportion of our bedding and pot plants come from Japan.

New Zealanders must face the fact that if we are to compete on the world market we must develop new products on an ongoing basis. With our geographical location, ethnic mix, and expectations of living standards, other countries are going to quickly obtain material developed here and produce it more cheaply. Unless we have something new to offer, interest in us as a supplier will quickly fade away. Ornamentals offer great scope as they are a fashion item and each product has a finite and predictable useful life.

Currently we have the scientists capable of generating a steady flow of new ornamentals and there is plenty of opportunity. For example we still await the true blue rose, blue dahlia, blue carnation, and yellow sweet pea, all of which could be developed to New Zealand's advantage. The current biotechnology plans are not surprisingly being targeted primarily at kiwifruit, apples, and agricultural plants such as clover.

It is important, if we are ever to do more than dabble with ornamentals in this country, that an appropriate infrastructure be developed. Research alone is not enough. Efficient production units with managers who have a good understanding of horticulture are essential. Quality products, produced to specification and delivered on time are as important as the new developments themselves. A knowledgeable retail sector that is prepared to promote and test locally developed material before it is offered overseas is desirable. Export sales people who understand ornamental plants, together with those who can devote sufficient time and knowledge to best exploit Plant Variety Rights and Patents in various countries are also an important ingredient.

In general the horticultural industry shows little interest in promoting horticulture as a desirable career at school level. Enroll-

ments in horticulture courses, as at other places in the world, are dropping at Lincoln and Massey Universities. Remuneration for experienced plantspeople compares unfavourably with other areas of activity. Retailers demand very high mark-ups, yet only employ staff with minimal horticultural knowledge. Producers show little understanding of what is involved in developing new plants and are often unwilling to build in a modest royalty to enable the plant breeder to do his work. None of this bodes well for the establishment of New Zealand as a centre of excellence for the development and supply of new ornamental plants.

The technology is advancing very quickly. If we do not seize the opportunity now it may be too late. Many other countries are involved in this area of study. Countries which a few years ago seemed unlikely competitors are taking positive steps to develop and exploit new technology. It is important that the ornamental industry acts as a coherent unit and that new technologies are not put into the "too difficult to understand" category. It is up to all of us to ensure that New Zealand is not left behind.

EXPORTING PLANTS FROM NEW ZEALAND

MIKE SHEERIN

Duncan and Davies Nurseries, Ltd.

Waitara Road, New Plymouth

I have had some direct experience over the last 5 or 6 years in both the preparation of material for export and the marketing of that product. I would like to relate some of those experiences to you now, tell you some of what is involved, and give you some opinions of the export scene as I see it.

My first comment relates to New Zealand's woody nursery production in relation to the rest of the world. I work for a large company and we grow a diverse range of woody plant material. Our domestic market is very small and our climatic advantages considerable. The countries into which we sell, mainly North America and Europe, conversly have large markets, producers grow a narrower range of material, and there are many different climatic zones within those areas. Many are efficient producers of large volumes. Growing a limited range they do not need large overheads to keep their production on the rails. My company is perhaps the largest of its type in the Southern Hemisphere, yet I have been on many nurseries in the United States far larger in area than ourselves, although not as intensive. I believe we are niche marketers in the export sector. We must be careful what we grow to export because, if it does not sell, there certainly is no market for that

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production here. Many of the orders we ship contain greater volumes of some cultivars than the entire New Zealand market would absorb in a year. Others many times over. Some we grow solely for export.

We sit here in New Zealand looking wide-eyed at firms such as Monrovia and Weyerhauser and Schmidt in the U.S.A. Why are we not selling volumes to them? We are involved in a very conservative industry. Change does not come about fast. We have been exporting now seriously for 20 years. It is just 6 years ago that our North American agent started using printed order forms. Prior to that he was using pilfered hotel stationery to book orders. Our image as and international company was not helped either by our catalogue and price list being several sheets of photocopied typing stapled together. Now we have what I believe to be one of the best and most attractive catalogues about, sought after as a reference if nothing else. We now have the same faces calling on clients each year, and as a result we are gaining many new accounts. These are mainly mid-sized nurseries growing a wider range of stock whose future lies in having something different. People must be confident that you are going to be able to perform and if they buy are going to be back next year.

Growing the plants, for us, is probably the easiest part. Meeting the customer's requirements and expectations is something else. Overseas, nurseries are situated in good growing areas. Their market may, however, be in a very severe climatic zone. That producer's interest will be in hardy stock only, despite the fact he may be in southern California or the south of France. Another producer may be growing specimen trees, which on sale, will command a premium price. He is likely to be more worried about quality rather than purchase price. We do very well on the west coast of North America with our *Cornus* spp. We visited a grower in Tennessee recently who budded 75,000. Two days later we called on another, not 40 miles away, budding 300,000 out of 1,000,000 seedlings. In that area there are well over 50 large nurseries and, goodness knows, how many dogwoods!

Some of these areas are not well serviced by transport, or are many miles from a large airport. To get the plants safely and quickly to the customer is critical. Hence we ship to each market on set days of the week. We have people at each national point of entry to guide the consignments through the Dept. of Agriculture and through Customs and then get them on the correct transport to their final destination. We have to be very careful of the routes the airlines take. There are some areas through which plant material must not pass. The paperwork must be as required and accurate. The plant material must be prepared to meet the entry requirements of the importing country. The Irish Republic, for example, will only accept material bareroot, washed clean, and wrapped in news-

paper. We have other customers with similar requirements. Sphagnum moss is not acceptable—the plants must be wrapped in peat moss. We have great difficulty in some countries finding out just what their requirements are. We have, in fact, had to send in trial shipments to find out if certain growing media are acceptable. Another problem is that the Inspecting Officer in the importing country has final control and judgement over what is acceptable, despite written regulations. Unfortunately, people and criteria change. Japan, into which we have shipped successfully for many years, is an example of that. Given the current situation it is becoming uneconomic to ship to that market.

The client may need an import permit or a post-entry quarantine permit. All these facets must be covered to enable us to perform. We must make sure the cargo travels under controlled conditions. We must ensure the plants do not arrive at their destinations on a Friday or sit somewhere over a weekend out of our control. We have to advise the client which airline and flight the plants will be on and when to expect them. We then have to check later that he has got them. Only by giving this level of service does business and reputation grow. There is plenty to go wrong after the plants leave New Plymouth and you must have a system in place to ensure that does not happen.

Each market has different requirements. The Dutch must have their material before the 15th May because that is the day they finish planting. If you confirm an order to a German client you must deliver that exact grade and quantity, come what may. We once sent a shipment to a client in two grades, as quoted and larger. Advice went with the order telling of the two grades, apologising and stating that the price would be the same for both. A reply quickly came back accusing us of being liars. We had confirmed and stated we would send a certain grade and quantity and that was what he ordered—not bigger ones—a most dishonest practice. Many European clients expect to receive liner material with an entire root ball undisturbed. We knock plants out, depending on what they will tolerate, to get so many per kilo, and that is built into the price. The freight component of the landed price of the plant is horrendously high and few would be prepared to pay the freight on material sent undisturbed.

Everybody wants their deciduous material as soon as they can get it, like before it has dropped any leaf. We have superb nursery conditions for growing deciduous plants. Getting them into a condition to ship is something else. Some plants, for instance *Acer* spp., are quite easy. Others, such as *Cotinus* and *Cornus* cultivars, are not. The problem with deciduous stock arriving in the northern hemisphere after the longest day of the year is that it can grow on into the winter with immature growth and inadequate root establishment. Winter hardiness then becomes a problem. Deciduous

material must also flush into growth quickly on arrival. To do this it must have had an adequate chill prior to being introduced to warmer temperatures. To do this we endeavour to cool store all material for a period before shipment and this is essential. We are also looking at materials such as Alar, nutrient levels, and even copper sprays to harden growth. On some plants we are able to remove leaves mechanically with a crude machine designed to remove feathers from chickens.

Many areas have extremely hot and dry summers. Evergreen material ideally should be delivered into these areas by early spring or problems may occur. In many cases we split a client's shipment to get as much of the order to him as early as possible. As with the deciduous plants, many evergreens are not suitably hardened or rooted to send as early as the customer would like.

What you have heard may be enough to put people off importing plants from New Zealand. We are now in our 15th year of shipping stock into North America and that market is growing at over 20% per annum. To meet the requirements of our clients and to maximise growth and re-acclimatisation of the plant material we aim to have all stock delivered before the longest day. To enable us to do this we have installed mechanical root washing and are continually modifying methods to move an increasing quantity of stock through the same facility in a very rigid time frame. Delivering on time is absolutely critical.

In an endeavour to help customers with the re-establishment of plants we put suggestions on handling in with each packing slip. Many clients line deciduous material straight out on arrival. If this is done irrigation is essential and roots will benefit from mulching in the autumn to help protect from excessive cold. Fertilising has to be watched carefully. Good root growth is what is required, not soft, sappy top growth. Likewise if growing in containers, keep stock cool initially, as it has come from the depths of a New Zealand winter. Keep fertiliser levels down and watch the watering. It can help to stand the roots overnight in water prior to potting or planting. Light shading will also help. If not ready to handle on arrival, keep in a cool place. Check first to make certain the stock is not drying out. Watch watering in the carton. The plants near the bottom, especially something like a *Magnolia* with soft roots, can deteriorate quickly if lying overwet in the bottom of a waxed carton.

Evergreen material requires different handling. I feel many people would do better to avoid potting evergreen material on arrival especially if it has been washed out bare-root. I have seen very good results achieved when the plants have been encouraged to root up with the minimum disturbance before potting up. This does not mean that material can not be potted immediately and many people do that very successfully. Like us, plants can suffer from jet

lag and need a day or two to sort out which way up they should grow. Always check that the roots are not too wet or too dry immediately on arrival. Take the appropriate action as required. Most of our stock goes out in nisular rolls tied up with a rubber band. Roots can be checked with very little disturbance. Try leaving the plants in the roll, spaced out for a day or two in a cool propagation structure, with bottom heat if possible, misting the tops as required. Pot up when you see root activity. Again, watch fertiliser and watering. Ween to normal growing conditions as you would a rooted cutting of that species.

If you don't have such sophisticated facilities, heel the plants into a flat in a reasonable depth of material which must be open, warm, and free draining. Use something like an open potting medium with no fertiliser; non-toxic sawdust and bark are good, as is peat, but watch the watering. Keep in a cool shade house, mist the tops and pot when the roots are active.

These suggestions have come from people who have had very good results even with notoriously difficult plants. Another person kept his deciduous plants after canning in complete darkness and cool conditions until top growth was evident and the material came into growth vigorously. Included were a number of *Cornus* cultivars which normally are very tardy to leaf out on arrival. They do, however, grow brilliantly the following spring. We sell thousands of these and they never leaf out properly on arrival. Etiolation may be well worth trying.

To simplify re-establishment we are starting to work with clients growing under varying conditions to look at various treatments to aid early shipment and the handling of the difficult cultivars. This interchange is very important. If some can succeed with plants such as *Metrosideros carmineus* 'Carousel', others should be able to do the same but not if they are put straight out in a full fertiliser potting medium in a gallon can.

We also ship a lot of material by sea containers. Our company has a nursery in the United Kingdom and we send them up to 60 containers of stock a year, mainly *Camellia* cultivars. The voyage takes at least 4 weeks and most plants are in the container for 6 to 8 weeks. After 10 weeks I start to worry on the out-turn. Pre-chilling immediately on packing is essential. We get the odd hiccup with machinery and are still learning what will and will not ship. This is done by putting trial plants in with shipments. We have made a lot of progress in streamlining methods used to handle the plants. Dehydration is a major problem and we have overcome this in various ways such as wrapping the root ball in a polythene bag or packing an entire container in a polythene wrap. A variable, yet to be overcome, is being able to efficiently quick-chill the plants down after packing [they travel in large crates].

Finally, we have considerable problems sometimes in getting

clients interested in trying something new to their area. In our catalogue we give fairly conservative hardiness ratings for some cultivars we are not sure of. We have taken an approach of adding material to orders we feel would be suitable to try in a client's area. In this way we hope to gain feed back on both hardiness and how the plants have performed in their new environment and also, of course, to increase our sales.

Growing plants for a living is a very fulfilling occupation. All involved have a common interest. The people in our industry are some of the nicest and most genuine you could meet. There is a lot to gain from a pooling of knowledge and we are always interested in listening to people's ideas on how to overcome problems associated with re-establishing our material in other countries. I am particularly interested in broadening my knowledge in the techniques of long-term cool storage of deciduous material and sea shipment in general. We have modified our cool store, how successfully we are yet to find out. This will enable us to ship material into the northern spring helping to overcome some of the May/June mayhem.

In summary, there is a great potential for the export of plant material from New Zealand. You must know your customers' expectations and market—remember not to try and sell dogwoods in Tennessee! You must tell people which plants will prove difficult and which will not. You must seek ideas and improvements in handling techniques. You must deliver on time and above all you must be prepared to provide a level of service I am afraid us Kiwis are not used to providing. To be successful the plant material must be of first quality and all activities must be planned and executed efficiently to get a very perishable product to the customer on time. There are no short cuts to success, just 4 months of autumn and winter madness a year!

THE CAPILLARY BED METHOD OF IRRIGATING NURSERY STOCK

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Capillary watering of plants was first developed as a research tool to eliminate uneven watering as a factor in experimental work. The National Institute of Agricultural Engineering (1) in England published in 1964, a paper on the results of that work showing how a bench system could be used for the watering of house plants. In Ireland in 1975 Lamb, Kelly and Bowbrick (2) described how capillary beds could be used for the production of outdoor nursery stocks. Margaret Scott at Efford in England was making similar modifications for outdoor use. This paper describes the further modifications and adaptations of the system in a commercial nursery.

The principle of the system is that water flows upwards from the water level into small soil spaces or pores by capillary attraction. The rise in water obtained increases as the size of pore decreases. There are a range of pore sizes in compost. The capillary rise will vary with these. The smaller spaces will be filled with water while air will remain in the larger ones. Hence the water/air ratio and the moisture content can be controlled by the composition of the compost and by the level of the water below the surface. Within the compost it varies at different levels within the pot. The compost at the top being drier than that at the bottom.

Once capillary action has been established the water loss by transpiration and evaporation from the pot is replaced by water taken up by capillary action by the compost from the substrate below.

In theory it is the ideal watering system and under experimental conditions it consistently proves to be the best method of producing uniform crops. However, it has not been widely adopted in the nursery trade for a number of reasons;

1. Lack of understanding of the simplicity of the system.
2. Capital costs.
3. Difficult to build on sloping sites.

The capillary bed is a *sealed* system laid on *level ground* and supplied with water (controlled by ball-cock) via a header tank. The water in the bed can be replenished as it is used throughout the 24 hours via the ball-cock. Therefore there is no peak demand. We pump water directly from the borehole, which has a capacity of 2,400 gal./hr (12,000L/hr). This is sufficient for our 5 acres of capillary beds.

There is no need for reservoirs, electronic controls, or powerful pumps with this system.

The savings on the water distribution network however, are lost in the construction costs. The ground must be levelled with a zero fall in all directions. We do this by machine. Our bed sizes are determined by the polythene sheets available, our largest is 250 ft. × 42 ft. wide (80m × 13m). Next we kerb with concrete garden edges, 1000 × 20 × 50mm. These form the sides and are laid absolutely level with a spirit level. Next we dig shallow trenches 50mm deep to accommodate the water supply and drainage pipes. If the ground has to be levelled to sub-soil we spread finer sand over the ground before laying the polythene to protect it from sharp edges or stones. Then we roll out the sheets of polythene and align it with the kerbs. Having done that we re-roll the polythene to one end. We bring in the grit and sand using a bobcat loader.

Originally we made the bed with 100mm of sand but as the bottom 50mm is permanently under water during the growing season we have now changed the specification to a bottom layer of 50mm of grit and a layer of capillary sand 50mm on top of this. The grit more or less coincides with the water level and the sand gives us good capillary action. In winter time and during periods of heavy rain the grit gives us excellent winter drainage.

Once the sand is in, the bed is flooded and allowed to settle for a few days. Then using the water as a level the sand is moved around until a perfect level is obtained. This normally takes about 2 days work for 2 people on a large bed. The water supply, header tank and ball-cock are fitted as well as the drainage overflow. This work takes about 1 day.

The construction cost for a capillary bed on this scale is approximately £2.50 per sq. metre. Starting with level ground 2 men can make a bed of this size in 1 week approximately. Levelling ground is a major cost. The most economical way is to level the total proposed capillary bed area with heavy machinery initially and then to obtain a finer level with smaller machines as areas are required for construction.

The capillary bed system gives the following advantages;

a) There is no labour requirement whatsoever with the system.

b) It is completely automatic.

c) There is no week-end or holiday work.

d) Should a breakdown occur each bed contains a buffer capacity of 3 to 4 days water before plants show signs of water stress.

There is no wastage, it is a sealed system and all the water is used by the plants. It is an efficient system using approximately half the water of overhead irrigating systems. It provides better working

conditions and better controls. Neither the surface of the compost nor the foliage is ever wet. Surfaces are never waterlogged, so it provides nicer working conditions.

There is no leaching of nutrients as with overhead irrigation. So ferilizer rates can be reduced by one third. The top of the pot is driest so there is less weed seed germination.

Plants on capillary beds are remarkably stable. There is a capillary bonding between the bottom of the pot and the sand. Secondly, the compost in the bottom of the pot is heaviest and at the surface is lightest, this gives extra stability. Conventional stabilizers stuck into the ground can not be used because they would break the polythene sheet.

Capillary bed systems have their greatest influence on the root systems of plants. The compost is always at field capacity, therefore the plant does not have to produce excessive roots to search for water and the roots stay in a nice juvenile condition.

There is a very fine spread of roots throughout the compost. Root curl, common in overhead systems for taproot plants, is not as pronounced. Plants such as *Quercus* and *Eucalyptus* develop excellent fibrous roots that do not wind-blow when planted out. The roots do not go into the substrate. Since the water level is constant, they do not have to search for water.

In winter the substrate is critical in determining the drainage of the compost. A pot standing on gravel has no downward pull. It develops a capillary fringe in the bottom of the compost where the water stagnates and root death results. However, capillary beds, on the other hand, suck the water from the bottom of the pot and the capillary fringe is transferred to the sand. Therefore, with a good drainage system winter root deaths can be eliminated.

DISEASES

The foliage is never wetted except by rain, therefore, there is no washing off of fungicides and so the foliage is protected longer. It is quite noticeable that the occurrences of leaf diseases lessen under these conditions (3).

Water is necessary for spore germination in *Phytophthora* species. Water is even of greater importance since it is essential for the production and motility of the zoospores which swim or are carried around in water in contact with the host roots where they germinate and infect. To control this disease surplus water must be immediately removed and surface flow must be avoided. The effect of surplus water on the spread of *Phytophthora* root rot has been confirmed in experimental work by Smith (3). Sub-irrigated capillary beds gave the best control of this disease. This was only achieved, however, where the roots were not allowed to root into the bed material. American researchers have shown that the water

regime affects not only the pathogen but also the host. Under drought conditions they reported that cracking of the roots can occur and these become loci for infection.

Species of *Pestalotiopsis* and *Monochaetia* cause leaf petiole diseases. *Pestalotiopsis* thrive under wet conditions and is spread in water droplets. In experimental work by Dr. Smith she proved that very little infection occurred on capillary beds as against the same crop irrigated by overhead sprays.

Peculiarly, there is also evidence to suggest that *Phytophthora* does not spread from pot to pot. That the upward action of the capillary prevents the downward movement of zoospores. The final advantage of capillary beds where disease does occur is that as the bed is a sealed system and with the network of drainage pipes they can be effectively sterilized.

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3. Smith, P. 1981. When water can be deadly. *Nursery Man. and Garden Centre.*

MONROVIA NURSERY COMPANY: PROUD OF OUR PAST— BUT LOOKING TO THE FUTURE

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SUMMARY

Monrovia Nursery Company was founded in 1926 by Henry E. Rosedale on a ten acre site in Monrovia, California. In 1952 the nursery moved to Azusa to allow for expansion.

Today Monrovia Nursery produces 55 to 60 million plants annually on two 500 acre nurseries in Azusa, California and Dayton, Oregon. Both nursery sites have been selected because of their microclimate and the readily available source of high quality water. At each nursery fertiliser is put into the growing medium and this is supplemented by nutrients in the irrigation water, which is recycled. The water treatment plant adds fertilisers and herbicide to the water before it is reused. The health of plants is regularly monitored by the Research and Development Department.

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The two different growing locations enables the Company to produce over 1200 plant cultivars and introduce over 150 new plant cultivars.

The majority of the production is outdoors but some five acres of greenhouses are used for tender plants such as *Hibiscus* and *Gardenia*. Over 70 acres of shade houses are used for *Camellia*, *Azalea*, ferns, and liner production.

Approximately 1000 people are employed in both nurseries with up to 400 working in the 70 acres of propagation area. Cuttings account for 80 to 90% of production. Between 35 to 150 people produce 50 million cuttings per annum. The majority are inserted into trays after disinfestation and hormone treatment, followed by setting under outdoor mist.

Propagation by seed accounts for 8 to 15% of production. All seed is sown by 2 or 3 people that is either collected on the nursery or purchased from around the world.

Between 3 and 6% of production comes from fern propagation, budding, grafting and tissue culture. Grafting is mainly used for fruit plants and southern magnolias. Upright junipers were grafted but are now produced from cuttings. The tissue culture laboratory produces about one million plants that are either difficult to propagate or in short supply such as *Syringa*, *Actinidia*, *Bergenia*, and *Magnolia*, per annum.

Potting or canning of liners and larger grades is done by crews out in the nursery using a soil-based growing medium. Up to 15 crews of 12 workers can each plant 24,000 #1 or 7,500 #5 containers per day.

During spring, the busiest time for shipping, 35 semi-trucks are loaded per day. Weekly deliveries of plants with the label "Distinctively Better" are made throughout the United States and Canada; 85% of all stock is sent out between March and June. About 65% of our business is sent out of state in refrigerated trucks.

COSTING PLANT PRODUCTION BY THE USE OF REASONABLE EXPECTANCY (RE)

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Costing plant propagation by the use of reasonable expectancy (R/E), is an area of consideration of plant propagators world-wide. The Index of our Society lists 17 papers under the title of "Cost Accounting" and 30 papers under the title of "Costs" from 1950 through 1980. I vividly recall a paper presented in 1966 by James S. Wells (1) which created much discussion.

Jim used a formula as follows: If labor costs of the total personnel payroll are 50% of operating costs, the true cost of the operation is the sum spent in direct labor multiplied by four. As discussed at that meeting, and again in 1967, the formula rests on the premise of 50% labor costs in operating costs.

Zelenka Nursery Inc., located in Grand Haven, Michigan, USA uses a costing system based on man-hours. This system allows a production control process which enables them to record labor distribution by activity and simultaneously monitors efficiency. Flow charts to show costing at two departments, the greenhouse, and the liner farm, as well as a chart showing how loaded labor rates are determined, are shown in Figures 1, 2, and 3.

The genus used in this paper is *Taxus,* showing the costing in the nursery greenhouse and liner farm departments. We produce more *Taxus* plants than any nursery in the world, to my knowledge, so we have large numbers to work with. Work activities at the greenhouse relative to this crop would include the following: bench preparation, taking cuttings, preparation of cuttings, hormone application, sticking cuttings, culture, pulling cuttings, and grading. We have established an R/E amount/manhour for each of these activities.

For example, Code 1110 (taking *Taxus* cuttings) and Code 1210 (preparation of *Taxus* cuttings) have an R/E of 1,500 cuttings per manhour. Code 2311 (sticking *Taxus* cuttings) has an R/E of 2,000 cuttings per manhour. The production control R/E forms are filled out daily by the various division leaders and are turned into the Accounting Department. This data is then fed into the computer for an immediate printout to management. This R/E form shows non-productive hours such as travel between farms, coffee breaks, supervision, etc. The two right hand columns show the R/E and the percent of R/E for the crew and the crop. Simply, the R/E is established by timing how much a crew can accomplish at a given activity in one hour and then dividing by the number of workers in that crew.

This number is units/manhour and we make that 85% of the desired rate.

Example: Crew of five taking 6,375 *Taxus* cuttings in one hour.

$$6{,}375 \div 5 \text{ people} = 1{,}275 \text{ cuttings/manhour}$$
$$1{,}275 \div 85\% = 1{,}500$$

Minimum acceptable performance is 85% of the R/E and in many cases, we have employees who exceed 100% of R/E.

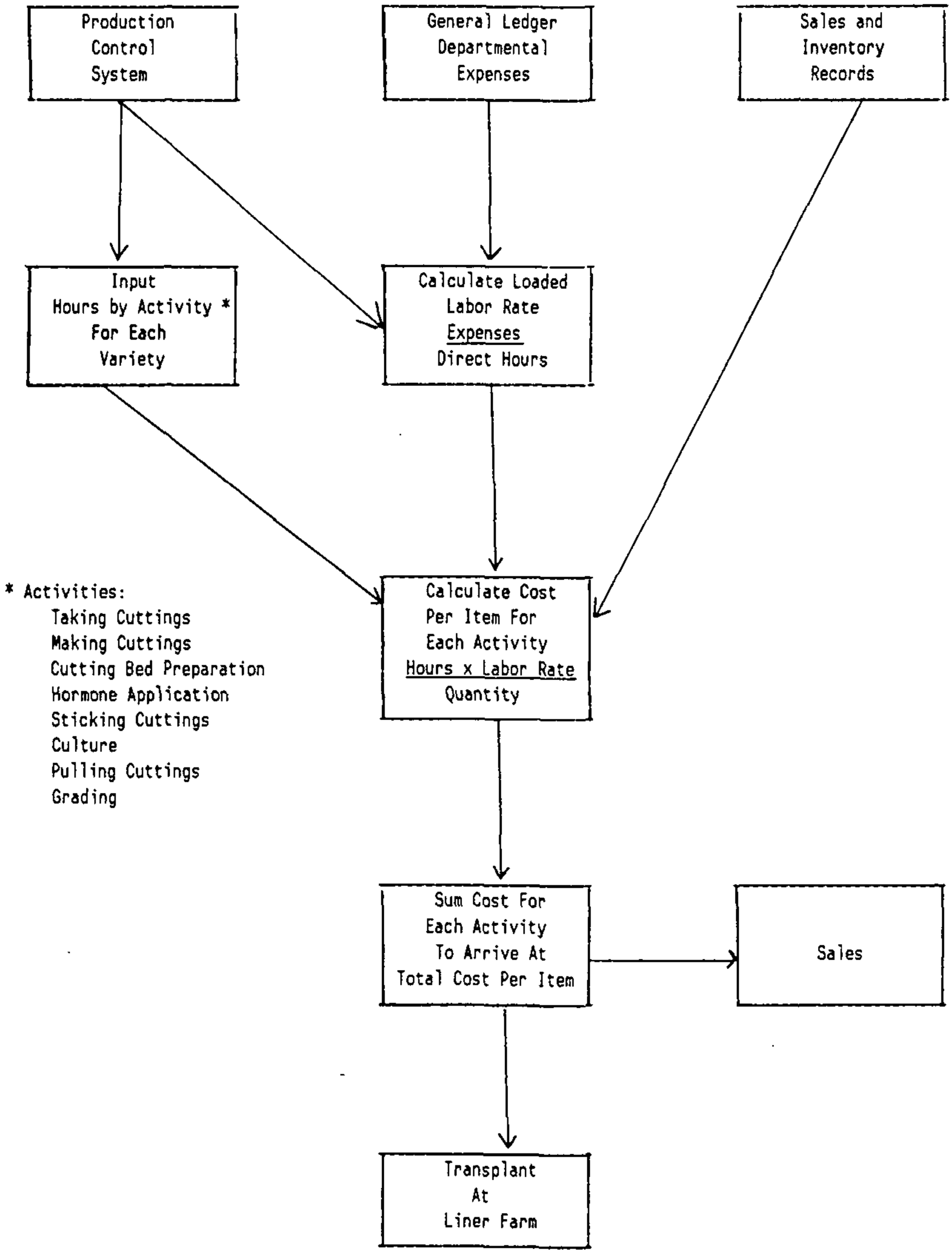

Figure 1. Greenhouse costing.

At this point, I would hasten to add that several United States nurseries have used this R/E system and it did not work for them. Without knowing all the details, I would suspect they had R/E rates set far too high. The R/E for each activity must be attainable! The "Thrill of Victory" is to equal, or exceed, an R/E: "The Agony of Defeat" is to work as hard as humanly possible and never achieve an R/E. If the R/E goals are unrealistic, this program will not work!

Two most commonly asked questions about this R/E concept are "piece work" and "rewards for exceeding R/E's." At our nursery we have no departments on a piece work program. We are fully aware that many nurseries do have such a program, but we feel that with our R/E program, piece work is not applicable to our program. The reward for exceeding R/E is a beautiful inner feeling of success.

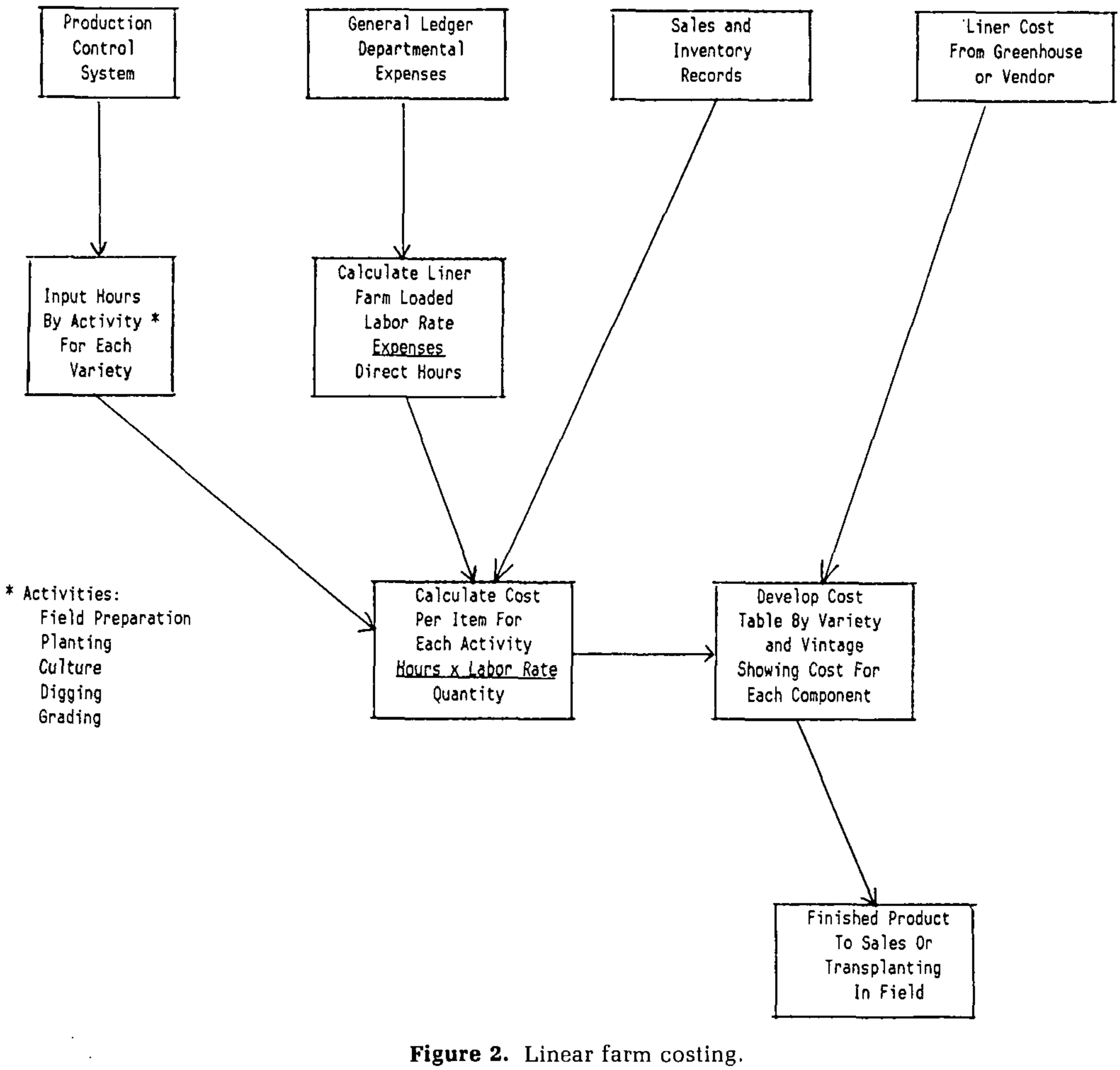

Figure 2. Linear farm costing.

There is no monetary reward, but there is a definite personal satisfaction reward. Normally, in the nursery community, people are hired and truly do not know what is expected of them, other than to "work as hard as you can"! The R/E system clearly tells them what is expected of them for the activity they are performing.

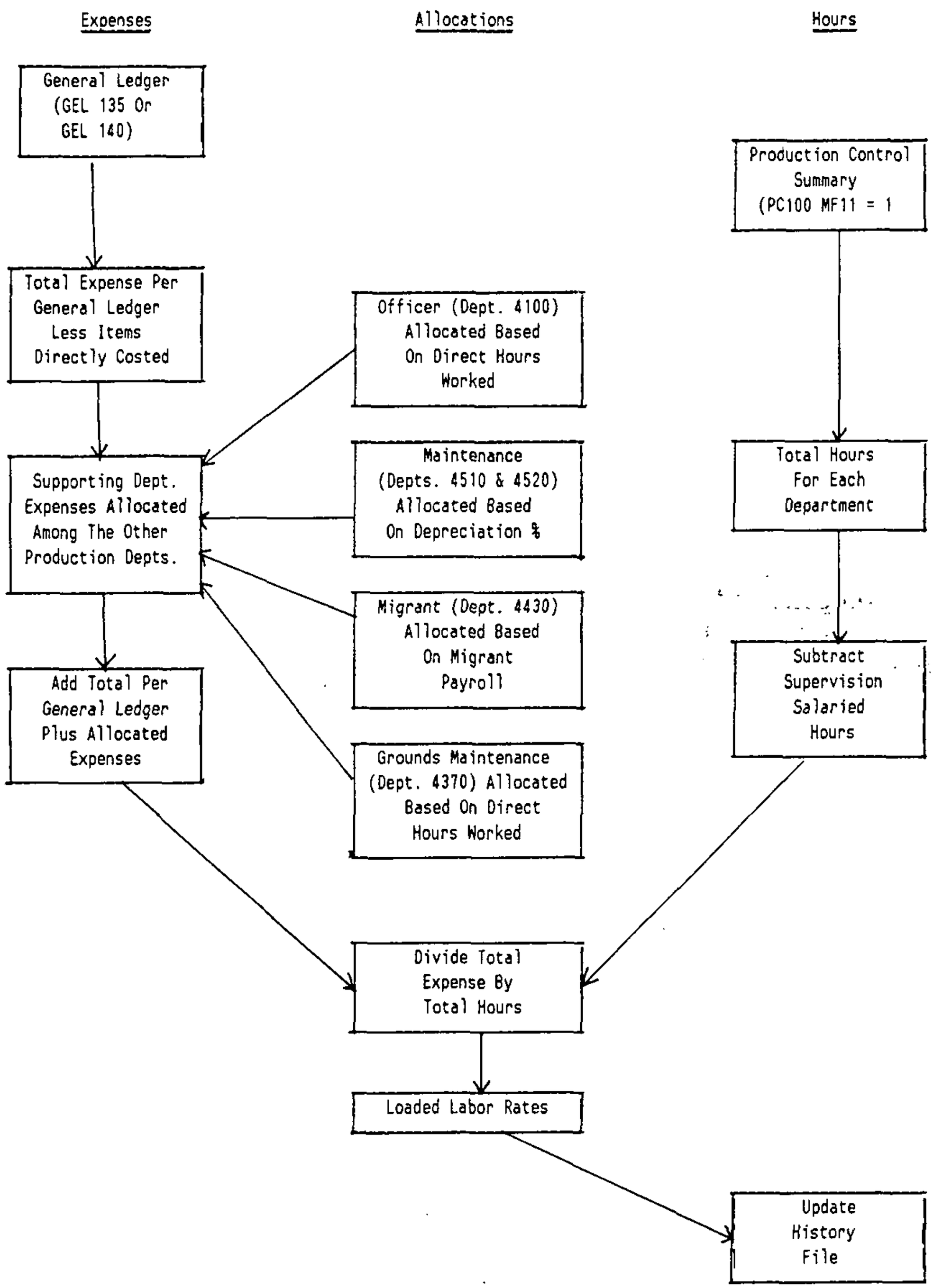

Figure 3. Loaded labor rates flow chart.

To further illustrate this point, after the *Taxus* cuttings are rooted, the plants go to our liner farm in transplant beds for three years. Activities which would have specific R/E's in that department include: field preparation, planting, culture, harvest, and grading. Again, repeating, it is mandatory that the production control R/E forms are turned in daily.

The philosophy behind this program is to determine the exact cost of each crop for intelligent and profitable pricing. I know that it never happens in New Zealand, but in the United States—I am sad to say—we have production nurseries that set their prices from a fellow nurseryman's catalog! Often, I have pondered how the neighbor arrived at his prices! This practice could and has created a domino effect. To show you how our nursery tracks this data, Figure 1 shows the greenhouse costing flow chart and Figure 2 depicts the flow chart for liner farm costing. Also, since there is some confusion as to how loaded labor rates are determined, I am attaching Figure 3. The hourly loaded labor rate is different in each department at our nursery.

I can sympathize with the words, "What in the world does this have to do with plant propagation?" I had the exact same thoughts in 1966 listening to a paper on the same topic. We must, in order to have a profit in our nursery, fully understand our true costs. If we cannot root a *Taxus* cutting profitably, in accordance with our company management direction, then there will be an effort to go outside the company and purchase from a vendor. Pure and simple, the nursery community is in business to make a profit! It is mandatory that data be recorded to assist us in tracking these costs. Nurseries hire propagators to put roots on cuttings, to germinate seeds, and to knit scions on understocks—economically!

To conclude these remarks, we all must be totally and fully committed to record keeping and true costing information. We all must "Seek and Share" all facets of plant propagation in accordance with the motto of our prestigious Society.

Acknowledgments. Considerable data in this paper were prepared by Mark Richey, head propagator, Zelenka Nursery, Inc. The figures were prepared by Richey and presented at the 1987 IPPS Eastern Region meeting as part of the exhibit portion of that Conference. I extend my deep appreaciation to my co-worker and fellow propagator.

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AN EFFICIENT METHOD OF PROPAGATING WITH GROUND BEDS AND INTERMITTENT MIST

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We propagate in ground beds, 4 by 48 ft, bordered by crossties or treated 6 in. wooden poles. The rooting medium is a fine sandy loam soil which has been amended over the years with sand and organic matter. The clay colloidal material improves the cation exchange capacity and contains nutrients not available in artificial soils. We fumigate with methyl bromide at a rate of 1 to 1½ lbs. per 100 sq. ft.

We use 6 guage, 6 in. concrete reinforcing wire, 6 ft wide, which is nailed to the wooden poles or crossties, to cover the beds and support the polyethylene. We use either a 2 ml clear polyethylene, which we cover with a 48% shade cloth, or a 2 ml white polyethylene, which has been manufactured to our specification so as to transmit approximately 50% light. We have constant water pressure to a solenoid valve, which is connected to a wiring system controlled by time clocks. We use ¾ in. 100 psi black poly-pipe with spaghetti tubes leading to nozzles. These lines are easy to work and afford flexibility in nozzle placement. We use a Spraying Systems nozzle with a D-1 oriface, which we have modified with a ⅛ in. stainless steel welding rod to deflect the spray.

We take our cuttings from our stock blocks. We consider the care of stock blocks to be of utmost importance. We take the cuttings in the mornings, when moisture stress is not a problem. We take our cuttings to length and strip and bundle them in the field. We keep the cuttings turgid by keeping them moist and cool at all times until they are stuck in the beds. We take 24-quart ice chests to the field and pack the bundled cuttings in ice. Once every couple of hours the foreman takes the prepared cuttings to our moisture chamber, which is a small cold storage room with a fogging system. We leave three or four leaves on each cutting and do not cut the leaves except on very large-leaved species. We bundle in the field in groups of 25 so we can count production for our piece-rate system.

We finish taking cuttings by lunch time and stick each morning's production in the afternoon of the same day. We dip the cuttings in a solution of 3,000 to 10,000 p.p.m. IBA or IBA plus NAA, depending on the species. We use a portable shade structure to keep the plants from wilting until we get the frames in place and the bed covered with polyethylene. At this stage the plants are misted as needed to provide as close to 100% humidity as possible on

the leaf surface while maintaining a well-drained soil condition.

As rooting commences, the misting schedule is reduced gradually and more ventilation is cut in the polyethylene until the plants are hardened off. At this point all the polyethylene is removed and we shade the plants for a few days, weaning them from the intermittent mist and watering less frequently. The entire process from an unrooted cutting takes from four to ten weeks, depending on the species and the time of year.

We test our soil and from the results choose our fertilizer, paying particular attention to imbalances that may cause problems. During the growing season we monitor the soluble salt level closely, and fertilize so as to keep the soluble salt level high yet below toxic levels.

The plants are completely exposed to the elements of weather until after normal leaf drop. This indicates that the plants have built up their carbohydrate reserves in the root system naturally and are becoming dormant for the winter. We then cover the beds with microfoam over the wire frames and cover the microfoam with polyethylene. We nail the polythylene with wooden strips to the crossties and seal with soil. Prior to covering for winter we water the plants well and spray with a fungicide. The purpose of winter protection is not to keep the plants warm, but to protect them from rapid temperature fluctuations.

We dig the plants before they break dormancy but as late as we think is safe, so as to keep the plants as fresh as possible. We pack in polyethylene-lined and wax-lined boxes, with the roots wrapped in sphagnum moss and the tops separated with excelsior. We hold the plants in cold storage in these boxes at 34°F until the customer is ready for them.

THE NURSERY BUSINESS IN NORTHERN ILLINOIS

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SUMMARY

A number of nurseries in 1940 formed a group called the Ornamental Growers of Northern Illinois. The main market for these producers is landscape contractors, landscape architects, and other nurseries. This group has a high profile at public meetings and Trade Shows. The group is promoted through a newsletter and "The Plant Locator"—a list of plants and grades with nurseries able to supply.

There are 20 member nurseries growing trees, shrubs, and perennials on more than 4100 acres. Many of the nurseries in the group have been in the business for more than one generation but each nursery retains its own identity. Some members have introduced their own plants, while the group is working together with the Morton Arboretum and the Chicago Botanic Garden on a Plant Introduction Scheme modeled on the British Columbian Plant Introduction Scheme.

SUPERIOR MALE KIWIFRUIT—EVALUATION, IDENTIFICATION, AND PROPAGATION

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INTRODUCTION

Pollination is a vital factor in the successful production of kiwifruit (*Actinidia deliciosa* (A. Chev.)) C. F. Liang *et* A. R. Ferguson var. *deliciosa*. Pollen must be transferred from the anthers of the male flowers to the stigmas of the female flowers. This event is of particular importance to kiwifruit production because:

1. The plant is dioecious, i.e., male and female flowers occur on separate vines.
2. Fruit weight at harvest depends largely upon the number of seeds set (4), and seed number is influenced by the amount of pollen transferred.

At the Ruakura Agricultural Centre we have developed a method of optimising pollen transfer using spray pollination (6). As

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SUMMARY

A number of nurseries in 1940 formed a group called the Ornamental Growers of Northern Illinois. The main market for these producers is landscape contractors, landscape architects, and other nurseries. This group has a high profile at public meetings and Trade Shows. The group is promoted through a newsletter and "The Plant Locator"—a list of plants and grades with nurseries able to supply.

There are 20 member nurseries growing trees, shrubs, and perennials on more than 4100 acres. Many of the nurseries in the group have been in the business for more than one generation but each nursery retains its own identity. Some members have introduced their own plants, while the group is working together with the Morton Arboretum and the Chicago Botanic Garden on a Plant Introduction Scheme modeled on the British Columbian Plant Introduction Scheme.

SUPERIOR MALE KIWIFRUIT—EVALUATION, IDENTIFICATION, AND PROPAGATION

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INTRODUCTION

Pollination is a vital factor in the successful production of kiwifruit (*Actinidia deliciosa* (A. Chev.)) C. F. Liang *et* A. R. Ferguson var. *deliciosa*. Pollen must be transferred from the anthers of the male flowers to the stigmas of the female flowers. This event is of particular importance to kiwifruit production because:

1. The plant is dioecious, i.e., male and female flowers occur on separate vines.
2. Fruit weight at harvest depends largely upon the number of seeds set (4), and seed number is influenced by the amount of pollen transferred.

At the Ruakura Agricultural Centre we have developed a method of optimising pollen transfer using spray pollination (6). As

part of that project we have also identified certain male selections which have improved seed setting ability (7).

In this paper we follow the course of these males from initial selection through to commercialisation. We also look at the identification and propagation of these nominated selections.

EVALUATION

In the 1950s male vines growing in commercial orchards in the Bay of Plenty were surveyed for flowering characteristics. Some information was also collected on pollen viability. Subsequently W. A. Fletcher assigned names to two of these males, Matua and Tomuri, which were particularly suitable as pollinators of Hayward (2). This work was continued by R. M. Davison (DSIR) who collected together 32 different male plants from commercial orchards, including Matua and Tomuri. These were evaluated in the late 1970s at the Te Puke Research Orchard for vine growth and flowering, pollen production per flower, and pollen viability (5). The best eight of these were coded as M51 to M58.

In our work on spray pollination we have used males propagated from the original M-series vines, and also Matua. We found that some of these performed poorly in field trials even though pollen viability was high. After two seasons of controlled pollination studies to further test this observation, we found that M51, M52, M54 and M56 set twice as many seeds as Matua or M55 under the same conditions. These superior males were therefore recommended for wider use in commercial orchards (7).

Recognising the need to provide true-to-type material to the industry, an agreement was entered into between the Ministry of Agriculture and Fisheries (MAF), Department of Scientific and Industrial Research (DSIR), and the New Zealand Kiwifruit Authority to supply softwood cuttings of known origin to nominated nurseries for propagation (9). These nurseries would then be able to provide to the industry, plants bearing labels ensuring that they were true-to-type.

IDENTIFICATION

Prior to this commercial release, propagation material from M-series males had already been distributed quite widely on an informal basis. With the interest in the performance of particular males, many growers wished to be able to identify those they had in their orchards. In 1986 we photographed and took leaf and flower samples from all the M-series males growing at the Rukuhia Horticultural Research Orchard at Hamilton. These were examined closely to try and determine any identifying characteristics (10). Leaves showed a high level of variability within the one vine and among vines of the same selection. Differences between floral

characteristics were more consistent but even then, some of these differences were very subtle.

Table 1 shows those features that may be able to be used to identify the recommended selections of M51, M52, M54, and M56. Selections M51 and M52 can be separated on the basis of flower shape and anther colour. There is no similar clear separation between M54 and M56.

This table is intended for use as a guide only as we found considerable variation within selections at the same site, so other locations may be different again.

Table 1. Identifying characteristics of M series kiwifruit males.

	Selections			
	M51	M52	M54	M56
Flower size	small	medium	medium	small/medium
Flower shape	flat	cupped	cupped	cupped
Anther colour	pale yellow	yellow/orange	yellow/brown	yellow/brown
Anther size	small	large	medium	small
Pollen shed	yes	no	no	yes
Flower abscission	no	no	yes	yes
Blooming coincidence with Hayward cultivar	mid	mid/late	early	mid

PROPAGATION

Propagation of both male and female kiwifruit vines has traditionally been by grafting on to seedling rootstocks, usually of the Bruno cultivar. However the use of stem cuttings has become increasingly popular. While some researchers have found hardwood cuttings very successful (3, 12), others have reported some diffficulty with their propagation (1, 11).

In our research work we propagate nominated vines by softwood cuttings. No differences have been noted between rooting percentages of male and female cultivars (11), therefore we treat both the same. The method used is based on that of Bosman and Uys (1), with modifications.

With males the cuttings are taken from the orchard at pruning time, which is immediately after flowering finishes in early summer (December), whereas for females mid-to-late summer (January to February) is the usual time. Male cuttings are made from flowered laterals or from surplus replacement canes which are thinned out. The latter provides preferred material, but it is less abundant. However the same effect would be achieved by having managed stock plants. Single bud cuttings are prepared from firm wood which is preferably about as thick as a pencil. The leaves are reduced in size by about one-half. The base of the cutting is dipped

for five sec. in 5000 ppm IBA in 50% ethanol. No wounding is done, and we have not found it necessary to apply a wound protectant, as used by Bosman and Uys. The cuttings are planted in a pumice-filled bed with bottom heat at 27°C. Mist is set for 10 sec. every 10 min. The bed is covered with 60% shade cloth. Roots normally appear within two weeks, and the cuttings are ready for potting a further two weeks later. Rooting percentages vary between 60 and 80%.

At the time the cutting is potted, a shoot may or may not have emerged from the bud. If the bud does burst early the plant could be expected to make up to 50 to 60 cm growth in the first season. A proportion of cuttings may not break bud in the first season. Once these cuttings have been identified after potting it may be beneficial to remove the bud cover with a sharp knife as there is evidence to suggest this tissue contains an inhibitor (8). If left, these cuttings would still be expected to make strong growth the following spring.

Our practice has been to line out all rooted cuttings in nursery rows in the spring (September/October) for a further year's growth before transplanting to their final orchard position.

SUMMARY

The male selections evaluated in this study were taken from a survey limited in size and carried out some years ago. Since that time other males have been found which have seed-setting ability equal to or better than the M-series selections, and further improvements in male performance may still lie ahead.

We have found differentiation among male selections by means of botanical features to be very difficult given the degree of variability encountered. It is likely that positive identification can only be made by means of some biochemical analysis.

Propagation of the vines by softwood cuttings presents few problems, although our system could undoubtedly be improved. The provision of softwood cuttings to nominated nurseries proved to be a successful means of quickly introducing relatively large amounts of true-to-type plant material to growers for the betterment of the kiwifruit industry.

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CHEMICAL USE IN NEW ZEALAND—THE UNDOCUMENTED SIDE EFFECTS

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Standards governing the use and sale of chemical pesticides in New Zealand are based on international guidelines. A Pesticides board administers Government regulations intended to safeguard end users, the public, and the environment. Representatives from grower groups, manufacturers and resellers, and Government departments make up a Board of twelve. Its their task, with guidance from independent counsultants and referees, to make judgements and set parameters by which pesticides may be pruchased and applied. These decisions are invariably made on "hard facts" presented as documented evidence by the intending marketer of the product.

History has demonstrated that while this process of regulating pesticide availability to the market place has mostly met the aims of the legislators, exceptions have and will likely always occur. Knowledge is not finite and documented evidence will not necessarily always present all of the hard facts on which such judgements can be made. It is the prupose of this paper to trace some of the recent documented and undocumented history of pesticide use in New Zealand which has resulted in some of the causes of general

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concern and anxieties expressed by many end users including plant propagators and the general public.

Over the past twenty years or so since the time of Rachel Carson's "Silent Spring" and the resulting demise of the chlorinated hydrocarbon chemical compounds, DDT and the like, public awareness and mistrust of manufacturers and chemicals in general has grown.

In those days New Zealand was a big user of these DDT type chemicals. We imported technical DDT's by the shipload and processed it into a variety of agricultural and horticultural pesticides. Since its introduction in the late 1940's, it was enthusiastically aerial top-dressed onto farmlands regularly for a period of twenty years or more. "Silent Spring" put a stop to all that. Eventually by the late 1960s there was monumental documented and undocumented evidence available from around the world which convinced our then Agricultural Chemicals Board and the forerunner to the Pesticides Board to put a blanket ban on all DDT type products for agricultural use and a restricted use for horticulture. This was because nobody wanted to buy New Zealand foodstuffs contaminated with a potentially health harmful pesticide residue.

At that time also NZ Health Department studies in certain rural communities had detected levels of DDT contamination in human mothers' milk as high as 100 ppm when tolerances in export foodstuffs was less than 2 ppm.

Then we had our long running 2,4,5-T controversy with manufacturers, farmer interests, and the Agricultural Chemicals Board on the one hand, and concerned environmentalists and a suspicious public on the other. The build up in this debate coincided with the demise of DDT and related products. Open debate was encouraged and fueled by the news media.

With the chemical under close scrutiny from the early 1970s until the mid 1980s various professional studies and surveys were made into its contibution to spina bifida which environmentalists were claiming. The case was never proven to the general satisfaction of the scientific community; however the point was made and accepted that the dioxin impurity associated with 2,4,5-T manufacture was extremely hazardous.

To the bitter end, throughout this period of claims and counter claims the compound was defended stoutly by the Pesticides Board as it had no hard factual documented evidence to support the claims for its deregistration which was the position the anti-lobbyists were endeavouring to establish. Eventually various factors contributed to the exit of 2,4,5-T, including poor public image and PR for the manufacturer, Agent Orange, and eventually the development of alternative products.

We have been one of the last countries to cease manufacture.

The chemical has been widely used for a period of over 40 years in this country and one would have to conjecture what undocumented evidence went undetected in the earlier years of use when formulations then were relatively crude and use and application was haphazard compared to the restrictions placed on it in more recent times.

At the present time the general public and commercial end users of pesticide chemicals have a growing sensitivity and aversion to the use of chemicals. Currently glyphosate has captured public attention. Two local bodies here in Auckland have banned its use along with other herbicides until further notice. These are the Devonport and Waiheke island councils.

Councilers have voted to ban the use of chemicals in favour of alternative controls, mainly mechanical. These decisions are based on undocumented assumptions that most pesticide chemical sprays are best regarded as health hazardous and the public should be protected from them. Dr. Matt Tizard, Auckland, has specialised in the treatment and cure of people with pesticide and chemical spray poisoning.

Similar beliefs are shared by many end users, including plant propagators. Undocumented and documented data has led many to the view that pesticide chemicals are unclean, health hazardous, and environmentally polluting. They can lead to, or be the cause of, biological imbalances, resulting in aggravating rather than solving pesticide problems.

We have plant propagators philosophically opposed to the use of chemicals. Grahame Platt of Platts Nurseries, Albany, states "That if a NZ native plant is going to be affected by pests or diseases then the sooner it dies the happier he will be. He only wants to grow survivors and if an ornamental species requires an artificial life support system then he doesn't want to know about it."

Others like Richard Ware of Plant Propagator's, Napier, is an avid user of a fish emulsion to prevent pest damage. His experience has demonstrated the product provides an oily film and odor on treated plant surfaces which appears to deter insect attacks.

Because of the documented and undocumented case against the use of chemicals there is an increasing interest towards the sophisticated use of organics. Recent research has demonstrated the efficacy of host specific pathogens. These include virus, bacteria, and fungi which may demonstrate antagonism towards specific diseases or pests to give effective commercial control.

Genetic engineering is believed to offer limitless potential as an alternative to chemical protection. Parasite and predators against pest damage have gained respect and acceptance in commercial horticulture. In particular predator mites now have an established track record as positive deterrents to spider mite invasions.

It takes a brave knowledgeable grower who can step out against

the status quo of chemical application and supplement undocumented alternatives as crop protectants. The bottom line in all commercial production is profit; without it we fail. At the commencement I made mention that knowledge is not finite. Do any of us know all the answers on crop protection? Can we afford not to use chemicals which will maximise quality and quantity? If we do, how certain can we be that they are safe to ourselves, our environment and our customers? Recent history has many examples of judgements and knowledge which in hindsight has proven to be false.

The evidence would seem to suggest, take note and accept documented hard evidence as a starting point in any management decision when chemical pesticide applications are contemplated. But beware also that the biology and environment in which we grow our plants is full of complexities and endless inter-reactions. Chemicals are only a useful convenient management tool. They have a place for immediate short-term use, yet always have the potential to generate biological imbalances.

In the end it is us who must live by the results of our decisions. We have a choice. Take note of experiences and observations. For these will be your undocumented evidence as to whether the side effects from the chemicals used are positive or negative for plant propagation.

Documented evidence gives us part of the picture dependent upon the views and aims of the presenter. The chemical manufacturer has profit as an aim. The research scientist has status cudos to achieve. The end user, the plant propagator, has a viable business venture to successfully manage. Somewhere between documented knowledge, undocumented experiences, and observations, judgements and opinions must be formed. Both have a place. Documented knowledge is a useful starting point but as history has shown us, decisions based on documented knowledge alone can sometimes be misleading.

WHAT'S NEW IN PLANT PROPAGATION?

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In the revision of the textbook by Hartmann and Kester, *Plant Propagation: Principles and Practices,* for the 5th edition, we have been searching the horticulture literature for new significant developments in plant propagation that justify being covered in a plant propagation book. We have considered a number of important emerging situations that will be discussed in this paper.

In the first place, we have added a new co-author to our book, Dr. Fred T. Davies, Jr. of Texas A & M University. Dr. Davies was president of the IPPS Southern Region in 1986.

PROPAGATION FACILITIES AND EQUIPMENT

Greenhouse coverings. In the past the principal coverings have been glass, polyethylene, and fiberglass. Two promising new materials are acrylic (Plexiglas, Lucite, Exolite) and polycarbonate (Polygal, Lexan, Cyroflex, Dynaglas). They are available in rigid, double-wall construction that gives good insulating properties. Some have inside coating that prevents condensation, droplet formation, and dripping. These materials are unlikely to replace the great popularity of the less expensive polyethylene, single and double, coverings, but they do give another alternative, particularly as a glass substitute.

Computerized greenhouse environmental controls. Computer equipment is available now to control all aspects of the greenhouse environment—heating, cooling, ventilation, humidity, shade and energy curtains, irrigation, fertilization, lighting, and CO_2 enrichment. The continuous recording of the information permits reviewing the complete operation and changing the patterns if necessary.

Nurseries in The Netherlands and Belgium are the leaders in computerized greenhouse controls but there are a number of such installations in the U.S. There are several companies that offer these installations, for example, Priva, Ontario, Canada; Oglevees, Connellsville, Pennsylvania, and Wadsworth Control Systems, Arvada, Colorado. Computer greenhouse controls are quite costly for the initial installation.

Premixed propagation and growing mixes. These are soil-free mixes prepared by many companies in bagged and bulk forms and are available in many combinations of materials. Of a survey[1] of 120 commercial mixes, almost all contained peat moss, most con-

[1] Premixed media, *Greenhouse Manager,* September, 1988, pp. 120–131.

tained vermiculite, and a few had perlite; almost all had, as additives, limestone and a wetting agent; many had a starter fertilizer and trace elements. Very few had bark, sawdust, or rockwool; two contained some soil; a few had gypsum, bentonite clay, or a pH buffer.

Some companies will deliver mixes to large nurseries already loaded into cell packs, seed trays, or pots.

Fog installations. These are being used more and more despite their high cost. Fog has the advantage of producing very fine water droplets, from 20 to 30 microns, that stay suspended in the air, increasing the RH to nearly 100%. It does not leach nutrients from the plant leaves or waterlog the media. Mist, on the other hand, has water particles 50 to 100 microns in size which settle out rapidly. Three types of fog generators are currently available: (1) The Agritech and Humidifan systems, that forces air through water being ejected from a spinning nozzle with the atomized water being forced into an air stream by a fan attached to the rear of the unit. (2) The Mee system, where water is forced under high pressure, 500 to 1000 psi through mist nozzles with very fine orfices. The water then hits an impact pin which atomizes the droplets to less than 20 microns in size, producing a dense fog. (3) Sonicor Ultrasonic humidifiers (made in England) use compressed air and water. Water is disrupted by passage through a field of high frequency sound waves, generated by the compressed air, to create a dense fog.

With fog, good controllers are necessary; they should operate to maintain a fixed RH. Time clocks do not work satisfactorily.

Good sources of information on greenhouse facilities and materials are the trade magazines, *Grower Talks*, published by Geo. Ball & Co., West Chicago, Illinois, and the *Greenhouse Manager*, published by Branch-Smith Publishing, Fort Worth, Texas.

SEED PROPAGATION

Seed physiologists are continually conducting research on the mechanisms of seed development, dormancy, and germination but much of this work has no direct application for the practical plant propagator. Nevertheless, seed propagation is a fertile field for studying dormancy (6), hormone physiology, enzyme physiology, genetic and environmental relationships.

Somatic or "artificial" seeds Somatic embryogenesis is a promising new development—a vegetative form of propagation, using cell culture methods (16). Somatic (vegetative) seeds are produced from embryos grown from callus, cells or protoplasts; the embryos are then encased in an artificial protective seed coat. Thousands of encapsulated somatic embryos can be clonally produced from a single plant. Somatic or "synthetic" seeds have been produced from grains, vegetables, oil and date palms, coffee, and conifers. This, then, is a potential for clonally producing new plants

of difficult-to-root species by avoiding convential propagation methods, but using clonally produced "artificial" seeds.

Bedding plants and plug production There has been tremendous growth of the bedding plant industry and the ever-increasing use of mechanized plug production for seed propagation of annual and perennial herbaceous ornamentals and vegetable crops. This is a great story in itself (11, 14). Bedding plant production in the U.S. in 1976 was 64 million dollars, in 1986 it was 232 million dollars. There are over 1.5 billion plugs a year produced in the U.S.—and climbing (3).

Seedling plants for plug growing are best started in fog (40 to 60 micron water particles) with root-zone heating. One should start feeding plug sheets about 2 days after sowing. Supplementary light should be used, especially in winter and in areas furtherest from the equator. High pressure sodium vapor lamps are good to use—250 to 1000 ft. candles. Best to use movable boom irrigation. Almost everything about plug production is or can be mechanized—seeding, growing, and transplanting.

CUTTING PROPAGATION

To date, adventitious root formation remains one of the least understood of plant functions. Despite years of active research the primary chemical stimulus for adventitious root formation remains unknown. And no chemical has come forward in the past 5 years to replace IBA or NAA as a stimulator for adventitious root initiation, although the K salts of both these chemicals are being used more widely, due to their water solubility.

Etiolation Etiolation of the stem tissue from which adventitious roots are to form has long been known to stimulate root initiation (2). The recent renewed interest from the studies of Maynard and Bassuk (1, 7, 8) at Cornell and the earlier work by Howard (5) at East Malling have elucidated some of the mechanisms involved. They have also shown how practical use can be made of etiolation to improve rooting of difficult subjects. Maynard and Bassuk's use of Velco strips—dipped in IBA/ talc powder, then used for banding around the etiolated stem bases is a most imaginative treatment for injecting IBA into stem tissue during the etiolation process. Etiolation seems to make plant tissue much more sensitive to auxin.

Stock plant irradiance This is proving to be much more significant than previously believed. In a study (4) with 24 species tested, *increasing* light intensity *decreased* rooting with 14 species, *increased* rooting with only 6 species, whereas little or no effect was noted with 5 species. A generalization is difficult, but is seems that with most species using moderate light conditions for the stock plants is likely to promote rooting, as compared to high light conditions.

Direct sticking of cuttings This is best used for easily-rooted,

quick-growing species. It is best to take cuttings in mid-summer, using new growth with cuttings set 3 to 4-liter pot. A peat-based rooting medium having a slow-release fertilizer added works well (12). They can be rooted in a poly-covered quonset house under mist or fog, with saleable plants ready about 12 months later. A disadvantage of direct-sticking is the increased space requirement.

Bacterial root induction Root induction by inoculation with *Agrobacterium rhizogenes*, a naturally-occuring bacterium, has induced roots to form on stem tissue of difficult-to-root species (14). This is also known to incite hairy-root disease, which is characterized by adventitious root production at the point of infection. This practice has the potential to induce roots in difficult species (9).

GRAFTING AND BUDDING

Chip-budding One of the most significant developments in this category is the increasing use of chip-budding in the propagation of fruit and ornamental trees. Many large nurseries are finding chip-budding to be completely satisfactory. It has the advantage of not requiring the bark to be slipping, thus extending the budding season. Studies by Howard and co-workers (13) in England have found a better healing and vascular connection with chip budding than with T-budding. Chip-budding seems to be most successful in areas with cool growing seasons, while T-budding is quite satisfactory in areas with warm to hot growing seasons.

Simultaneous grafting and rooting There seems to be more interest in this type of propagation in recent years, although it has long been used in the propagation of citrus. An interesting recent example is in the propagation of roses in The Netherlands where it is given the name "stenting" ("stekkenn", to strike a cutting, plus "enten", to graft). A leafless rose rootstock cutting of an easily rooted material is prepared onto which the leafy scion cultivar is grafted—by some type of machine grafting—then the combination is placed under mist so that graft heals while the rootstock cutting roots (17).

Predicting incompatible graft combinations In the past, trial and error was the only way to know for sure whether or not a graft combination was going to be successful—and the results might not be known for years. Santamour (10) at the U.S. National Arboretum in Washington, D.C. has devised a unique test that predicts the success or failure of a proposed graft combination. He has been testing his method on a wide range of woody plants. An electrophoresis test is used, examining cambial peroxidase banding patterns of the proposed scion and stock. If the patterns match, then the combination may be said to be compatible; if they do not then incompatibility may be predicted. A simple electrophoretic diagnostic system is being developed to allow propagators to perform the procedures themselves.

TISSUE CULTURE

A great many new species and cultivars are continually being described in the horticultural literature that have been propagated by micropropagation techniques. The techniques of tissue culture are also being continually refined and improved to increase the success rate. Formerly success was obtained only with herbaceous material. Now all types of woody perennials are also giving good success. Testing is underway to determine if plants propagated by tissue culture perform as well as those propagated by conventional methods, which has generally been the case.

Micropropagation by tissue culture is in the process of finding itself—where and with what plants it is feasible to use economically. In some instances the market has been flooded with certain tissue-cultured plants and some large outfits have been pulling back from such extensive propagation. The problem of avoiding variability in the product is something that must also be faced in micropropagation.

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AN OVERVIEW OF PROPAGATION AT SKAGIT GARDENS

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SUMMARY

Skagit Gardens is a supplier of finished annuals and herbaceous perennials to retailers and smaller grades to other growers to grow and market. To offset the peak spring seasonal labour requirements other crops such as poinsettias and other propagated material are grown during the quieter times for sale in winter. This creates year round cash flow and reduces staff turnover. Producing quality plants and the ability to deliver when required are seen as important business objectives. Sales are achieved through buyers calling at the nursery and through brokers.

Mechaanisation is occurring in all aspects of the nursery as it becomes affordable and justified. Production scheduling is now done by computer using specially designed software; bedding plant seeds are sown mechanically and germinated in growing rooms, which saves 3 to 4 weeks production time. Different environments are used for germination, growing, and holding plants before shipping. By only offering propagated material to other growers that Skagit Gardens uses in its finished program, we have increased flexibility in how the product is used; the interconnection between propagated material and the finished product is the key to success.

ESTABLISHING A NEW ZEALAND GREEN TEA INDUSTRY

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INTRODUCTION

Several attempts have been made at establishing a tea industry in New Zealand, the most definite of these having been in the north of the South Island. As far back as the 1920s Motueka farmers, in a bid to find new crops for the area, investigated tobacco and tea production. The last remaining tea bushes I believe were at Marahau on the coastal strip in the 1950s, while during that period tobacco production was approaching its peak of around 2000 hectares.

During the 1960s another attempt was made to establish tea production, this time on the west coast of the South Island, and trials were carried out on several sites. This attempt was based on seedling production and the remnants of that indicate the excessive variability of types that resulted. Failure was, I believe, as much due to apathy of the local farmers as anything else. There was support and encouragement from the local Public Relations Officer and help from some existing farmers who were mainly involved in dairying, but when dollars and committment were needed to plant commercial areas, enthusiasm was wanting. Failure was blamed on a number of things, including devastation by opossums, but the people of the area were not ready to diversify into horticulture. It might be different now. In 1979 the first winds of change blew through the tobacco industry with the Government announcement to begin restructuring and removing protective legislation. At the same time a tobacco farmer returned from visiting the Nerada plantation in Queensland and discussed with DSIR the possibility of tea production in the Motueka region. Seed was imported from several sources and plots established with the variability one would expect from open pollinated seed. A feasibility study established that production would not be economic with the New Zealand cost structure and the nearest world market so far away and the project would have died at that point had it not been for an approach from the Japanese to consider green tea production for export to a Japanese company. With an assured market the situation changed somewhat.

ESTABLISHMENT OF A NEW ZEALAND GREEN TEA INDUSTRY

In its most simplistic terms the initial growers met, formed a group, and decided to levy themselves to get the project underway.

In 1981 two members visited Japan and purchased the first cut-

ting material of *Camellia sinensis* cv. Yabukita and returned with this and it was propagated and placed in quarantine.

In May 1983, 800 rooted plants were released onto the Riwaka Research Station to begin trials on propagation and culture of green tea. The project was born from 800 rooted plants and a desire from Sagara Bussan of Japan to purchase the production from 100 hectares.

Two further lots of cuttings were purchased but one did not establish well and the other was destroyed after the identification of a mite not found in New Zealand on the foliage.

THE PROPAGATION RESEARCH

In the early part of 1980 it was clear that a seedling population was going to produce variable rather than quality teas and so some work began to investigate clonal propagation. At Riwaka we had been successful developing a low cost system for hop plant production and the same system was adopted for the *Camellia*.

Success was not immediate as timing of cutting production appeared to be most successful from mid-February to mid-March. Earlier than this, cuttings decayed—later they sat all winter and finally rooted in the spring. The system involved a low wooden frame of 100 × 25mm timber with wire hoops to hold the polythene covering off the cuttings. The frame was set on a shingle base covered with a sheet of black polythene and then filled with 75mm deep propagating compost—a mixture of 50/50, peat/coarse sand.

After setting and watering, the cuttings were sealed into the frame. All of this took place under a shade house to cut out the extreme heat buildup of such a structure in direct sunlight.

In the February–March period, 90 to 95% rooting was achieved within 2 months and the unrooted cuttings were generally of some selections that were obviously difficult to root.

Cuttings were generally tip growth, semi-hardwood, 8 to 10cm long with bottom leaves removed along with a 2cm long sliver of bark, then dipped into Seradix #2 rooting hormone powder (0.3% B-indolylbutyric acid). Though extremely successful, it soon became clear that to produce the required 2,000,000 cuttings by this technique it was going to require a major investment in peat and timber framing.

Early in 1982, Dr. Cohen of Plant Physiology Division, DSIR, and Mr Bruce McKay of the Nursery Research Centre, obtained material and began looking at tissue culture and mist propagation techniques. Both of these were ultimately dropped because of cost factors, though mist and bottom heat were used at Riwaka to bulk up the initial number of plants available for stock. This allowed use of much softer wood.

It was time to modify the closed box system and try some form

of field propagation. In late 1983, cutings of hardened spring growth of the plants released from quarantine were set directly into a field situation. The peat and framing were eliminated and cuttings were set directly into a sandy loam, with wire hoops over the top, covered with plastic dug into the soil on each side to maintain humidity, and covered with a double layer of windbreak cloth. A trial to try soil fumigation prior to setting, and setting through black polythene mulch also under the tunnels, showed us all we wanted to know to begin on a much larger scale. We gained very little from fumigation except a clover problem; the weeds were uncontrollable without the black polythene; the polythene, though successful, created problems for feeding once rooting was underway.

THE COMMERCIAL PROPAGATION

Galvanised hoops with a wire spring clip to tension and hold polythene in place are available commercially in New Zealand and so form field cloches for outdoor vegetable and strawberry production. These formed the basis for the commercial propagation of tea. Using wide polythene for the cover enabled sufficient sealing along the soil to adequately stop excessive moisture loss. Along the centre of each tunnel an alkathene tube with micro-sprinklers attached formed an irrigation system. This was manually operated but could easily have been automated. Irrigating during the summer was done 3 or 4 times per week initially but as rooting began this was reduced to 1 or 2 times per week.

A layer of windbreak cloth, to provide shading, was laid on top of the polythene initially, but later light wooden frames were added with a double layer to give protection from sunburn.

Because of the requirement for very large amounts of propagating wood and so as to conserve material a decision was made to change to leaf-bud cuttings. This was adopted for all propagation from 1985 onwards. A sliver of bark was removed from each cutting prior to dipping in Seradix #2 and sticking. Holes were not made in the polythene mulch but the cut end of the cutting was simply stuck through the polythene.

Cuttings were set approximately 2.5cm apart each way and wet down frequently as sticking progressed. Wood was firm enough to begin cuttings in midsummer (mid-December) and continued each season until May. Early cuttings rooted before winter while later cuttings rooted the following spring.

Losses were mainly from *Glomerella cingulata* attack. Aeration to reduce humidity and frequent spraying with captafol (difolatan) or prochloraz (octave) were practised to control *Clomerella*. During 1987/88 narrower polythene was used allowing a 5 to 10cm gap along the bottom of each side of each tunnel and, although spraying continued, the decreased humidity resulted in no *Glomerella* attack. In late October the polythene covers were

removed and, after 4 weeks, the shade cloth also.

In spring of 1987 a serious nutrition deficiency developed as cuttings began to put on new growth. Because of the polythene mulch no solid fertiliser could be applied and weekly applications of liquid feed (7:2:4:2+TE) were begun. It took until January, 1988, before cuttings began to respond, but this was totally overcome by late autumn and plant growth was 20 to 30cm high.

Liquid feed was applied with all fungicide sprays during 1988 to try and overcome the nutrition problem. A trial was laid down using 8–9 month Osmocote 18:2.6:10 at 25 gms/m^2 worked into the soil prior to setting. By October, 1988, growth of shoots with this treatment appeared superior to untreated shoots but no measurements have been made. Cuttings have been allowed to grow *in situ* during the summer following setting and in autumn they have been trimmed down to a standard height of 20cm in preparation for planting in spring. Wrenching has also been done twice, once in late February and again in May, by passing an hydraulically-mounted steel wrenching bar beneath the cuttings.

COMMERCIAL PLANTING

In spring, 1987, and early spring, 1988, planting began in the field using Powell tobacco planting equipment or, for the large plants available in 1987, a modified orchard tree planter. This has worked extremely well with in excess of 99% field take.

Planting has been on clay, sandy loam, and stony sites, on ridges and on the flat. Nutrition is either by fertigation or solid fertiliser, inline dripper irrigation, or sprayline overhead and, so far, all variations have been successful.

Weed control is a major consideration with any new large scale field crop. The desiccant herbicides, paraquat, Diquat, and Preglone have been used up to the plant using shields while oryzalin (Surflan) (4–6 kg a.i./ha.) has given excellent weed control sprayed over the rows 3 to 4 weeks afer planting and followed by irrigation or rain. On second year plantings oryzalin has been used over the immediate row with simazine between the rows. Trials on 4 year old plants have shown that simazine can be safely used right up to the stems of plants so, in the future, this will become the main herbicide.

As stock plants became big enough to begin taking larger amounts of cuttings the Grower Cooperative took over the propagation and, since 1985, two million cuttings have been set and approximately 60 hectares planted.

This whole project was initiated by the private sector, carried through by public and private sector cooperation and then, by a group of dedicated farmers banding together, levying themselves and totally funding the costs involved in establishing a new industry.

It has involved probably the largest propagation of a single cultivar of a plant by cutting propagation at one time in New Zealand and the total plants required to set up the industry have all been grown in the space of just 5 years from the original plants leaving quarantine. Over all, costs have been 12 cents per plant.

SLOW-RELEASE HERBICIDES: AN UPDATE

ELTON M. SMITH

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The need for effective chemical weed control in container-grown nursery stock is obvious. Equally, or perhaps more important, is the need for pesticides that are as safe as possible to society with minimum chance to contaminate the air, soil, or ground water.

Weed competition has been estimated to cause an annual loss of over 3.5 billion dollars in yield and quantity of crops in the U.S. alone (1). In nursery research studies it has been reported that 624 man-hours are required to remove weeds from an acre of one gal. (3.78 liter) containers (approximately 30,000/A) (4). At a labor rate of 5.00/hr the cost to weed an acre could exceed $3,000.

Hebicides, indeed, can reduce these costs significantly. The herbicides, however, must be effective, non-phytotoxic, and environmentally safe.

To assist in this effort slow-release herbicides have been the focus of research at Ohio State University. Original research by Varma and Smith in Georgia (9) and subsequently Ohio (1,3,5,6,7,8) have indicated the feasibility of utilizing particular pre-emergence herbicides in a slow-release form.

In 1980, Koncal (3) incorporated separately, metolachlor (Dual), alachlor (Lasso), oxadiazon (Ronstar) and oryzalin (Surflan) into tablets made of plaster-of-paris in a template. Only highly soluble herbicides leach out of the tablets and result in acceptable weed control. Solubility of metolachlor is 330 ppm, alachlor 242 ppm, ozyzalin 2.5 ppm and oxadiazon 0.7 ppm. Metolachlor and alachlor were most effective in controlling weeds, but neither oryzalin or oxadiazon were effective at all. Very good weed control was achieved for 120 days with metolachlor impregnated tablets.

In 1982, Ruizzo (5) used dicalcium phosphate with magnesium stearate to prepare tablets by dry compression in a Stokes single punch tablet machine. Metolachlor, alachlor, propachlor,

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chloramben and naptalam effectively controlled weeds for 112 days with no significant injury to *Euonymus, Ligustrum, Forsythia,* and *Cotoneaster* species. One tablet (1.5 gram, 12 mm diameter) was used per 1 gal. container. Metolachlor was the most effective herbicide.

In 1986, Smith, Gorski and Moore (6) pointed out that the soluble herbicides that were effective in controlling weeds were most effective against grasses but weak with broad-leaved weed species. Metribuzin (Sencor and Lexone) was more effective in controlling a wider spectrum of weeds but was found to be more phytotoxic to woody landscape plants. Metribuzin is not a registered compound for the nursery industry in the U.S. but has the necessary solubility.

In an attempt to increase broadleaf weed control Smith and Treaster in 1987 (7) evaluated cyanazine (Blaydex) and Terbacil (Sinbar) incorporated into dicalcium phosphate tablets. Both materials controlled broadleaved weeds and grasses for 10 weeks. Cyanazine and terbacil were both too phytotoxic to the nursery stock evaluated, especially terbacil.

As a follow-up to these studies, Smith and Treaster in 1988 (8) published a report with the same compounds at 50% lower rates in an attempt to achieve acceptable weed control without the phytotoxicity. Again, weed control was acceptable for 10 weeks but injury persisted on cotoneaster and azalea with both herbicides. As

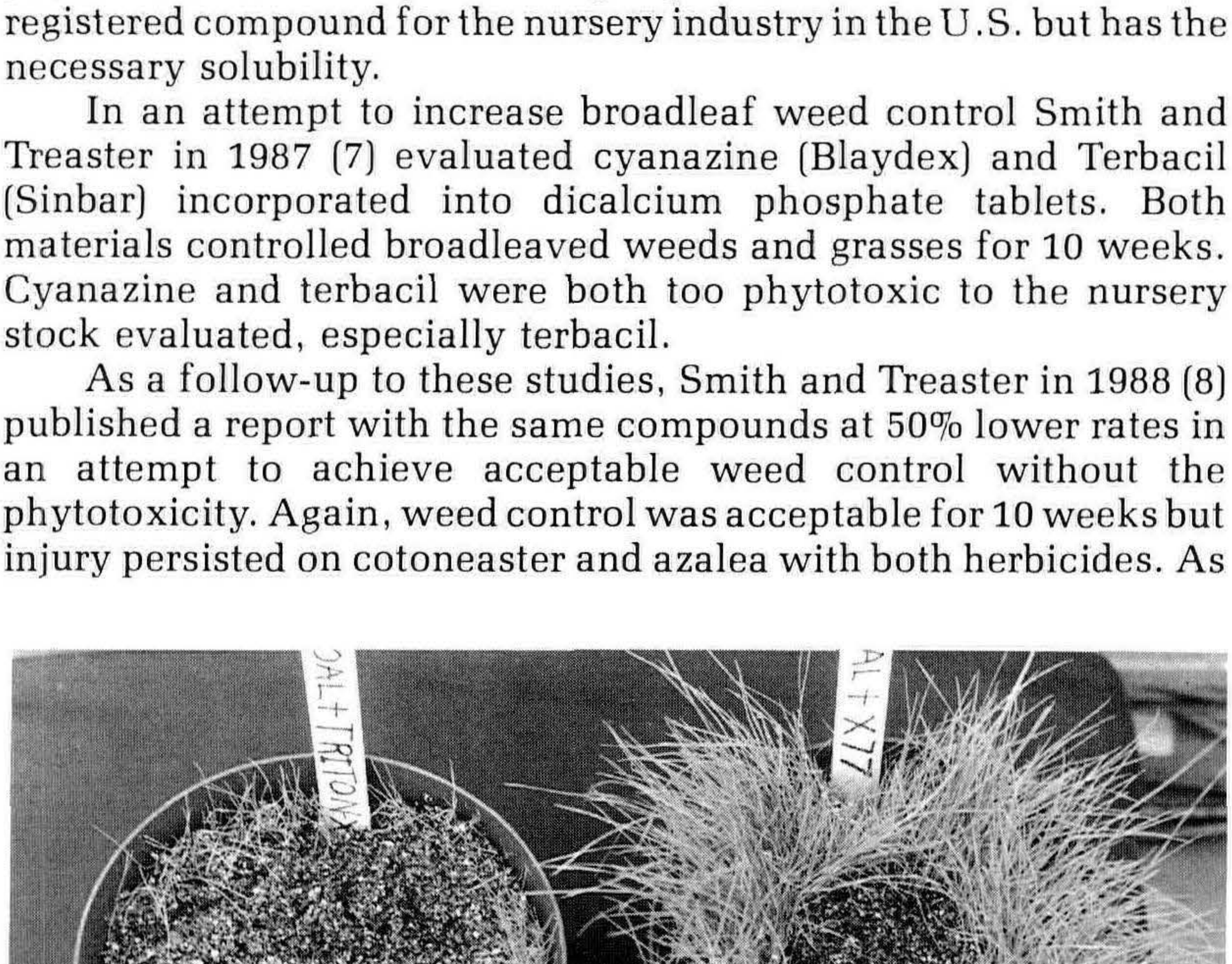

Figure 1. Weed control from slow release herbicide tablets containing: *Foreground*—oxyfluorfen (Goal), *Back Left*—oxyfluorfen (Goal) plus Triton X-100, and *Back Right*—oxyfluorfen (Goal) plus X-77.

a comparison, metolachlor tablets were non-injurious to all test species. Neither cyanazine or terbacil are registered for nursery crops.

Despite the extended time period of effective weed control achieved with metolachlor-impregnated slow-release tablets, introduction into the commercial trade seemed premature. The reason for not seeking introduction is that granular oxadiazon and oxyfluorfen compounds are superior herbicides particularly in respect to controlling specific weeds such as lesser bittercress, yellow wood sorrel, groundsel, and creeping spurge.

During the summer of 1988, Menashe Horowitz, at the Ohio State University while on sabbatical leave from the Department of Ornamental Horticultural Research Organization, Bet Dagan, Israel, pursued the process of using surfactants in the tablets to increase the solubility of the herbicides. He found that oxyfluorfen (Goal) with a solubility of 0.1 ppm could be made to move out of the tablet with the incorporation of surfactants such as X-77 or Triton X-100 (2). In general, Triton X-100 proved superior as a surfactant and did result in achieving some release of both oxyfluorfen and oxadiazon when incorporated as technical grade material into the tablet. The release is not as extensive as the more highly soluble metolachlor thus more than one tablet may be needed for a one gal. container.

These results with surfactants are encouraging. Hopefully, in the near future the right combination of pre-emergence herbicide–surfactant will be developed that is safe to plants and society in general and result in long term wide spectrum weed control in the nursery industry.

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THE STORY OF VIRUSES IN ROSES IN NEW ZEALAND[1]

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The term "high health", as used here, means "free of known virus and virus-like diseases (FKV)". Where the term "virus" is subsequently used in a general sense, it includes virus-like diseases.

THE VIRUS AND VIRUS-LIKE DISEASES

Three viruses have been serologically detected and partially characterised from roses in New Zealand. These are *Prunus* necrotic ringspot virus (PNRSV), apple mosaic virus (ApMV), and *Arabis* mosaic virus (ArMV). Of these only the first, PNRSV, has become widespread. ApMV was detected in only one plant and ArMV was detected in a few plants of one cultivar.

Two virus-like diseases affecting rose flowers can be indexed by double budding with a sensitive indicator cultivar. Rose petal fleck (RPF) is widespread in New Zealand but rose colour break (RCB), although not uncommon, is largely confined to greenhouse forcing roses.

A further virus, rose wilt virus (RWV), has been recorded as occurring in New Zealand but it has been subsequently shown that the symptoms attributed to RWV in New Zealand are, in fact, two completely unrelated diseases. The symptoms of short shoot growth, or rosetting and die back, which occur in mature plants have been shown to be associated with PNRSV and the symptoms known as proliferation, occurring on the first growth from grafted buds, are not caused by viral infection.

Roses infected with PNRSV show a wide range of one or more symptoms or may be symptomless. Symptoms include various

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chlorotic mottles, blotches, line patterns, vein netting, and vein banding as well as short shoots forming *rosettes* from buds on old wood, die back of old canes, general decline, and reduction of flower numbers.

The symptoms of ApMV are larger chlorotic blotches and more severe decline. Plants infected with ArMV may show a chlorotic chevron pattern about the main lateral veins on a few leaves, or they may be symptomless.

The virus-like flower diseases seriously impair the quality of the blooms. The flecking of RPF is characterised by an irregular shrinking of veins of the petals usually in areas towards the petal margins or in severe cases over most of the petals.

This is accompanied by darkening of colour of the shrunken veins in red, scarlet and most pink cultivars. In lighter coloured yellow and white flowered cultivars the symptoms may be virtually indiscernible but in all cases there is a loss of petal texture and a reduction in vase life.

The flowers of plants infected with RCB are virtually unusable. The outer petals or even the whole flower becomes grossly distorted with prominent green veins. A general virescence of the petal may make it assume the appearance of a crisp lettuce leaf. These symptoms are suggestive of a disease caused by mycoplasma-like organisms.

INTRODUCTION AND SPREAD

With roses, as has been the case with many vegetatively propagated horticultural subjects, the occasional virus infection has been perpetuated and spread by the use of infected material for propagation.

For many years it was standard nursery practice in New Zealand to bud-graft rose cultivars onto rooted cuttings of *Rosa multiflora* taken during winter from the stock tops of plants budded the previous summer. Budwood for grafting onto these understocks the following summer was also taken from the same crop as the understock cuttings. Not only may budwood from an infected plant produce a number of infected plants of that cultivar the following season, but also infected stock cuttings from that plant may be budded with buds of previously uninfected cultivars. Over a number of years this practice may result in widespread infection in the whole crop.

In those countries where roses are produced by budding onto seedling understocks, viruses have been less of a problem, whereas in countries, such as the United States, where the use of cutting-grown understocks had been normal practice, viruses became widespread.

It is interesting to speculate and difficult to prove, but cer-

tainly worth recording, some personal thoughts on the introduction and spread of these diseases in New Zealand.

Certainly by 1950 PNRSV was widespread through the understock and crops of most, if not all, nurseries in New Zealand. It was the first on the scene and was probably introduced from western United States where it was already widespread.

About this time, or shortly after, RPF started to become apparent, particularly in nurseries that propagated or had propagated old fashioned roses. Many of these old roses are 100% infected with RPF and the flecking is considered a normal characteristic of the cultivar. Almost certainly the use of infected stock tops which had been budded with old cultivars served to introduce this disease into crops of modern roses.

By the early 1960's these two diseases had built up to such an extent that not only were roses declining but also was the public's interest in them.

The other three diseases have never become widespread. Apple mosaic virus was detected in one plant of the cultivar, 'Masquerade', in a public rose garden. With respect to its possible introduction it is interesting to note that in the United States PNRSV is the predominant virus in the western states whereas ApMV occurs with greater frequency in the eastern states. 'Masquerade' was bred and distributed from the eastern states. This virus never became widespread probably because it was introduced much later than PNRSV and also because the symptoms are considerably more pronounced, hence infected plants would be less likely to be used for propagation.

The introduction of ArMV can be traced from Holland to Northern Ireland and from there to New Zealand. This virus was only found on some plants of 'Molly McGredy', propagated from budwood which had been obtained from the raiser in endeavor to obtain virus-free material. The raiser advised at the time that the material was of doubtful virus status as his only source of budwood was from standard plants budded on to *R. rugosa* understock imported from Holland. It was known that some *R. rugosa* from Holland was infected with either ArMV or strawberry latent ringspot virus. This was subsequently shown to be the case when some of the plants in New Zealand were found to be infected with ArMV, which is frequently symptomless.

The origin of RCB in New Zealand is less certain but with few exceptions it appears to be confined to greenhouse forcing cultivars. As a number of different rootstocks have been used for greenhouse forcing roses it could have been introduced from one of these other understock species.

"HIGH HEALTH"

Rose viruses are not generally transmitted by seed. By 1970 a few practical rose growers became aware that healthy budwood obtained directly from rose breeders and budded onto seedling understocks, or cuttings from seedlings, produced vastly superior plants and blooms compared to those budded onto commercial understocks. The late John Simpson did much to popularise this concept by growing a range of healthy cultivars and competing at rose shows where his blooms were obviously superior to those generally available at the time.

My own company also imported over 100 of the best cultivars from major hybridists requesting propagating wood as close to the original hybrid seedling as possible. These were, of course, budded onto healthy understocks and the four best of the resultant plants of each cultivar permanently planted as mother blocks for a source of healthy scions. Most of these mother blocks are still in use today.

In this manner a wide range of cultivars were imported from as healthy a source as possible. They were initially tested by observation for symptoms and by double budding with indicators. Subsequently with the development of a rapid, sensitive, serological test applicable to the detection of rose viruses, that is the enzyme-linked immunosorbent assay (ELISA), it has been possible to check the virus status of mother plants of the majority of commercial cultivars as well as understocks. Any found to be infected were destroyed. Virus-free propagating wood of most commercial cultivars, as well as a number of understock clones, has been readily available to the trade for the last eight years, either free or at nominal cost.

The Nursery Research Centre at Massey University offers a service to index any new cultivars or doubtful material as a precaution against reintroduction of viruses.

There is now no reason why all nurseries in New Zealand should not be selling only "High Health" or free of known viruses (FKV) roses with superior performance and better flower quality.

SO WHAT!

My own company, followed by a few others, together with strong support from the National Rose Society of New Zealand popularised the concept of planting only superior "High Health" roses.

Here is the rub. The terms"High Health" or FKV or "virus-free" are difficult to legally define. Few virused plants supplied by a nursery could be deemed to be a chance accidental infection corrected by a refund of money or replacement of plants.

The production of genuine "High Health" plants is more expensive with the maintenance of both scion and understock mother

blocks than short cut, less hygienic, production techniques. The result, knowing human nature, is probably inevitable. Cheap roses of doubtful virus status flood the market, claiming to be "High Health", or budded on "High Health" understocks. The buying public, always looking for a bargain, becomes disillusioned with the concept of "High Health", with the result that those nurseries who are endeavoring to produce the genuine article are forced to either lower their standards and compete pricewise or cater for a very limited discerning clientele.

The dream of "High Health" roses in every nursery in New Zealand becomes a nightmare.

I have told the story of viruses in roses in New Zealand because I believe no matter what line of plants you propagate you are likely to find parallel situations. Striving for worthwhile improvements in your product can easily be overcome by economic expediency.

SELECTION AND PROPAGATION OF NEW ZEALAND NATIVE PLANTS

GRAEME C. PLATT

Platt's Nursery
Albany Highway, R.D. 4, Albany

"Trust not authority, pay no heed to books, but go to the plants themselves". This quotation by Mr. R. Brown to Dr. Leonard Cochane, who prefaced his great work, "New Zealand Plants and Their Story" (1910) with it, should be permanently enshrined into the minds of all plantsmen. Furthermore, through experience I have established that it is not advisable to rely too much even on your own conclusions when it comes to dealing with plants and nature.

The inherent genetic diversity of every species makes it impossible to be precise. For example, to conclude that *Pittosporum crassifolium* seed germinates in three months is basically a sound assumption, because in most cases that is correct. However, we have had a couple of batches of seed that took 15 months. To state that you could obtain 60% strike rate in *Metrosideros excelsus* cuttings by carrying out certain propagating procedures is only correct if you are referring to a specific cultivar or clone. I have discovered, to my cost, that any superior variety that warrants special attention generally proves the hardest to propagate. The genetic diversity of a plant definitely extends to its ability to grow from cuttings. This genetic diversity, when properly understood, gives the plant propagator the opportunity to select a superior cultivar for cultivation.

One of the rewards of collecting all our own seed each year for

blocks than short cut, less hygienic, production techniques. The result, knowing human nature, is probably inevitable. Cheap roses of doubtful virus status flood the market, claiming to be "High Health", or budded on "High Health" understocks. The buying public, always looking for a bargain, becomes disillusioned with the concept of "High Health", with the result that those nurseries who are endeavoring to produce the genuine article are forced to either lower their standards and compete pricewise or cater for a very limited discerning clientele.

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One of the rewards of collecting all our own seed each year for

our nursery requirements is that I get the opportunity to travel the length and breadth of the country and inspect our native flora in its natural habitat. With one or two exceptions, I have had the opportunity to inspect the natural habitat of all our native plants that we produce. There are many benefits to be obtained by studying plants in their natural habitats—not the least of these is the opportunity to enjoy a few weeks each year unharried by the normal grind of life. Plants have been around many hundreds of millions of years, growing in the most incredible spots, wihout being subject to man's technology. The opportunity to observe how they have adapted, propagate, and grow naturally will often reveal more secrets than years of experiments in the nursery.

The following two reasons have been the purpose of my trips into the wild:

1. The opportunity to select genetically superior material for cultivation.
2. The opportunity to understand the plants's place in the natural order of progression, and its associations with other plants.

After years of experience propagating and growing plants and dealing with the gardening public, I have found that the greatest problem we have is not how to propagate a plant, but how to ensure the plants are planted correctly in the right place. There can be no doubt that over the last 30 years the ability to propagate and produce plants has increased. However, during the same time plantsmanship has dramatically decreased. Some modern supermarket garden centres have no skilled staff, and their only concern is to get the plant through the checkout counter.

I am certain that excellence in plantsmanship and landscaping can only be achieved when the concept takes precedence over the plants themselves. We often see customers select a few beautiful plants for their garden, then they spend ten minutes wandering around the garden with the plants in one hand and the spade in the other, looking for a place to plant them. The end result is what I call "the scrambled plants syndrome". It contains no natural associations—generally made up of beautiful plants totally unrelated to each other and frightfully out of any balanced order.

The more time I spend in the mountains, hills, and bush, the more inspiration I get from the treasures of nature. Plants are not isolated individuals—they grow in very specific sites and in a set order of progression, dictated by the specific needs of the species. I totally reject any suggestion that there is a balance of nature. Nature is a battle-ground, with each species doing its utmost to survive. The success of one species is invariably at the downfall of another. In association with the geophysical features of a nation, natural plant associations create a unique national character that should be the

inspiration of all plantsmen, gardeners, and landscapers. This botanical image of a nation can be very strong. Australia, for example, has a landscape full of very strong elements that constitute its natural landscape image—red earth, time-worn rock outcrops, lanky eucalyptus trees, and yellow flowering acacias. China has its karst limestone hills, bamboo thickets, spreading banyan trees and water ponds. New Zealand has it fussy hills, *Phormium*, *Cordyline*, *Cortaderia*, tree ferns, craggy rocks and extensive tussock grasslands, which are distinctive elements that contribute to our national image and landscape. These images, made up of the unique elements of a nation's landscape, should be understood by all plantsmen. It is unfortunate that local people are the last to recognise the unique national character of their local landscape, and work "devil-possessed" to change it to something other than natural. The richness of nature's rewards is readily available for all to observe, and is inseparable from other disciplines. It is not possible to study plants and not be interested in geology. If you are interested in plants and geology, you must be interested in birds and insects. Furthermore, the rain, the wind, ice, snow, and the sun—each has its place and can contribute to all aspects of the natural environment. New Zealand, with its high number of endemic plants, ensures us a unique opportunity to develop a true New Zealand landscape—a style with as much strength and character as that developed over the centuries in Japan, a style that allows the natural beauty and the uniqueness of New Zealand to be re-created.

Natural New Zealand landscaping can easily be split into six basic and separate concepts:

1. Mixed bush
2. Alpine
3. Sub-tropical ferny glade
4. Swamp and its margins
5. Woodland grove
6. Individual specimen trees

Each of these concepts is readily identifiable in the natural environment, and should be the inspiration of all plantsmen and landscapers. All of the secrets of how they grow, what they grow in, and how they are propagated, are contained in these natural associations.

1. **Mixed Bush** is an assortment of the smaller trees, from 5 to 10 metres, that can be grouped together to re-create the local vegetation and, in landscaping, can be used as a windbreak, screens along highways, and to soften the lines of harsh objects, like factories and buildings.
2. **The Alpine Rockery** takes it inspiration from above the treeline of our mountains. Properly placed rocks are the basis for any rockery. Placing rocks is an art in itself, the secrets of which can be readily explained by observing

rocky outcrops in the mountains. A rockery creates a specific area to place those small plants that would be lost elsewhere. These plants should be planted in the same balanced way as they would be found in nature. Rocks are best placed in intimate areas, where the small plants and little botanical treasures can be readily observed.

3. **The Sub-Tropical Ferny Glade** takes its inspiration from the shady and luxuriant corners of the rain-forest, with any of the lush broad-leafed green vegetation, liberally garnished with palms and tree ferns.
4. **Swamp and its Margins**—New Zealand swamps and wetlands are amongst the world's most distinctive, with the *Phormium* and *Cordyline* association, together with other wetland plants. These associations can, in fact, be planted on quite dry ground. However, they are best kept in association with wet, boggy areas. The associations and balances can be observed in any natural swamp still visible around the country.
5. **Woodland Grove**—The woodland grove is probably not a true New Zealand concept, as it did not exist until many of the trees were chopped down to clear land for farms, and small patches of natives were left in various places. Many of these patches of trees resemble more the English countryside. However, they can be seen on many farms in New Zealand. These unique groves of natives can be replanted, using the inspiration from the existing ones as a model.
6. **Individual Specimen Trees**—There is an art in placing large trees in the environment, be it in the cityscape or in the country. The most striking trees are generally those in the most unlikely places. Trees should always look as though they have been there since the beginning of time. There are plenty of examples of large natural trees, both in the countryside and in the city, that help to soften the harshness of man's creation by showing a certain degree of disorder.

New Zealand is a country that is sinking under a sea of foreign weeds. I believe we all have a duty to preserve our natural heritage, and that includes the natural landscape. If we do not, no one else will. Our natural landscape is just as endangered as are many of our plants. I am often asked why do we bother, by people who do not perceive some of our rare plants to have any appeal. There are many reasons, but the most important is that the measure of a man or a woman is for their compassion and protection of the defenceless things that need our help. It is unfortunate that we are inclined to admire most the acquisition of wealth, often by destroying the things most dear to us. There must be a place in our soul for all of nature's creation.

PROPAGATION THROUGH TO PROMOTION—AN ENGLISH NURSERYMAN'S VIEW

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Why propagate? An obvious question, but apart from the obvious answer, to reproduce plants, why do we take cuttings, make grafts, and sow seeds. Well, if you are an amateur, you do it most probably for interest. If you are a professional do you do it for interest? It may be an interesting craft but it is not just interest that engages hundreds of people in a full time occupation from which they earn their livelihood. The reason, of course, is that plants are propagated commercially which when grown into larger plants are sold to the general public. These people buy plants because they either don't have the time or skill or the interest to grow plants from a seed or a cutting and yet for various social and economic reasons they wish to have plants around them.

How long we have been reproducing plants? Man has been propagating plants which have fed him for many thousands of years. At first these were from seeds but as civilization became more sophisticated then propagation by vegative means was undertaken. Firstly, mainly for plants such as herbs which had curative properties.

Later, and certainly it has been recorded in the fourteenth and fifteenth century in the U.K., plants were propagated for use as ornamentals. Many of the plants which we currently grow in the U.K. were collected by the great plant collectors in the late eighteenth and early nineteenth centuries and, therefore, have been propagated for well over a hundred years.

There has been, of course, a certain amount of selection, particularly in woody ornamentals, undertaken by various people from the landed gentry to commercial plantsmen—who have selected a better flowering form or a weeping form, or a form that colours better in the autumn, or a type that is dwarfer, and so on. This, of course, still happens today.

It is interesting, I think, to compare the development of the product, for that is what it is, which we produce compared with other like products. You will be hard pressed to even think of any other commodity that was being manufactured 100 years ago that bears any resemblance today to its original concept. Virtually everything you can think of will have been modified or adjusted, improved, or adapted to meet a change in the market place. Many products have been completely redesigned; in fact there has been an evolution process going on in most products that we find in today's market place.

As nurserymen we still sell plants such as *Acer saccharinum* (the sugar maple) which was introduced from Eastern United States into the United Kingdom in 1725; *Tilia* × *euchlora*, a much planted and excellent amenity tree, was first recorded in cultivation in the U.K. in 1860. Lavender was first brought from the Mediterranean to the U.K. in the 1600's. We have, in fact, been extremely fortunate that the product which we manufacture has stood the test of time for so long. In fairness there are, of course, some genera which have been extensively redeveloped by hybridization, such as camellias and roses.

In the production of ornamental plants we have seen enormous changes and improvements in the last twenty years. We have also seen the advent of the garden centre, which compared to two decades ago, has brought about a dramatic change in the retailing of plants. There is no doubt that the garden centre and the production of plants in containers has in the U.K. helped to ensure a prosperous business environment for many nurserymen. But will this continue if we accept that everything in commerce is changing, which is fact—as can be seen from looking at any history book? Then surely we should ask ourselves how these changes are likely to effect us and what should we do about them?

Firstly, let us ask ourselves in what part of the market place we are in. It is essential to clearly establish this. I believe it is now recognised that the ornamental plant is considered a product supplied to the leisure market. So what is this leisure market? Is it possible to define? What are the competitors to our product within the leisure market. As I understand it, leisure can be any activity which people undertake at a time they are not working. This is a vast range. It is also a multi-million pound industry: many of the manufacturers and suppliers have many more pounds to spend on letting the general public know about the product they manufacture than we have.

We do, of course, have some outstanding attributes to our products that other leisure products do not have. For example, we have a living product which generally improves with age. We have a product that lasts a long time. We have a product that improves the environment in which we live. We have a product which harms no one. We have a product that has a multitude of different natural forms. If we have such a marvellous product should we be concerned? Surely people will carry on buying our products for ever and ever. How can they not do so, we may ask if it has so many positive qualities.

It is not that simple. Firstly, we have to examine where, and how the product is used. You don't buy a tennis racquet or a set of golf clubs to look at, you buy them to use in a leisure activity. Plants are broadly the same. We must put them into context—hardy outdoor plants are bought to support a pastime. At this time we are

talking about gardening. So we must examine the pastime, compare it in all aspects to other pastimes in which the general public is involved. The product has a lot going for it, but has the pastime? Like so many other things, a great deal depends from which angle you view it, your own personal interests and aspirations, and to some extent what you want to see. To some, gardening will appear boring or frustrating and to others interesting and satisfying. Others will look on the physical aspects of gardening as healthy and good exercise while others will view the same physical content as just plain hard work that must be avoided at all costs. We must also consider fashion and ask ourselves is gardening a fashionable pastime. It has been a hobby for a long, long time. Is is still fashionable as one of the new pastimes, or is it out of fashion? Does it, as an activity, offer what people want as a leisure activity in the 1990's?

Recent market research in the U.K. has clearly indicated that the British attitude to gardening has changed. Nearly 50% of the population said they would prefer to spend their money on other leisure activities.

This attitude was most strongly held by those in the population with the highest disposable income—the under 45's age group. So what is to be done—do we let the product which we propagate and grow, and from which we all earn our livelihood, rest on its undoubted laurels? If we do, we stand the risk that other leisure pursuits could gain even more of our market share. There is now more choice available in leisure activities, irrespective of income or class than at any other time. The leisure industry, which is increasing in size and variety each year is a multi-million pound industry, with a multitude of activities many of which are manufactured, backed and supplied to the public by international companies.

In my opinion there is no choice. We have to adopt the same techniques as our competitors in the leisure industry and "Promote our Product". If we don't, then it is certain that we shall see our market slip away from us.

We now must address ourselves to two other questions: *What* and *How*? Firstly, what do we promote? There are two: (1) the Product: plants; and (2) the Hobby: gardening. They can and should be promoted and marketed both independently and together. How? In every conceivable way, at every conceivable time by as many people and by as many organisations as is possible. There are hundreds of ways in which gardening and plants can be promoted. Some, of course, can and will be expensive, for example television and press advertising. Many others can be undertaken with a far less ambitious budget. Others, like an enthusiastic conversation with your customer, costs nothing.

Let us now look at some specific ways in which we can retain and increase our market share. Don't keep relying on the odd

favourites. As I have stated earlier many of our products are now up to 100 years old. How much longer will they continue to sell?

Consider packing and presenting the old favourites in new ways to give sparkle.

Exploit the nostalgia which surrounds some of these old and loved plants. Look at ways in which you are not only attracting the captive customer but the potential customer—new gardeners, such as first time house buyers, even schoolchildren; one day they will, if attracted to gardening, also be good customers.

Support, in all possible ways, the T.V. producers and the gardening journalists; send them interesting facts and figures about you and the plants you grow and the industry of which we are part of. Whether a wholesaler or retailer, consider spending a greater percentage of your turnover on selling your product to the end consumer.

Support generic promotion campaigns—The "Autumn Nature's Natural Time for Planting", which started in the UK in 1986 has not in three seasons changed the buying habits of gardeners. It has, however, started to alert a whole generation of young gardeners to the fact that you can plant in autumn as well as the spring.

Look for, and if you can find them—promote new plants to the best of your ability, or find someone who has the interest and resources to do so. Above all, be committed and enthusiastic to the industry that gives you your livelihood.

OBSERVATIONS, SELECTIONS, AND PROPAGATION OF NEW ZEALAND FERNS

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Where the copse wood is the greenest,
Where the fountain glistens sheenest,
Where the morning dew lies longest,
There the lady fern grows strongest.
Sir Walter Scott.

New Zealand ferns and their history. New Zealand is a country of ferns. We have acres and acres of ferns, lofty, graceful tree ferns, hanging ferns, climbing ferns, pellucent filmy ferns, and terrestrial ferns carpeting forest floors, and miles and miles of roadsides lined with *Blechnum*. There were no browsing animals in New Zealand before the arrival of man and our climate is conducive to the growth of ferns.

Ferns such as *Marattia salicina* (king fern) were cultivated in plots by the Maoris and their starchy rhizomes were used to provide food, while some ferns were collected and used for medicinal puposes; the unfurling croziers of *Cyathea medullaris* were used to sustain warriors and hunters alike. Everywhere cut fronds have been used for decoration and ferns have been immortalised in carvings.

Some reasons why more of our ferns do not appear in the majority of garden centres are the lack of knowledge of the existence of the great range of ferns available in New Zealand, the hesitancy with which newly introduced products are approached, and the understandable ignorance of conditions necessary to grow ferns successfully.

They are a rewarding plant to grow, have tremendous aesthetic appeal, and there is a range of proven, reliable, and easily propagated ferns available.

Observations and experiences with propagation. It can be argued that all plants can be propagated, but considerable difficulty has been experienced trying to propagate our native ferns in sufficient commercial quantities. To date I have been unable to locate much literature on fern cultivation in New Zealand, so the task for me has been to try and understand our many and varied climatic and soil conditions to facilitate greater understanding of different fern growth habits.

I do not claim to have all the answers but I can share with you some of my observations and experiences of the last five years of fern propagation. Spore planting is the method favoured because it

is cheap, fairly quick, and reliable. I do use vegetative propagation with *Asplenium bulbiferum* because plantlets are ready made and easily available. Spore is collected off selected mother plants either from my own garden or from the bush.

The mother plants are selected for two reasons: one, proven viability of spore, and two, strong luxuriant growth and foliage.

Repeated trials with spore have shown me that spore collected on humid days tends to have a higher failure rate, usually because of fungal infections. Likewise, spore collected from fronds on roadsides and bush verges, are usually heavily contaminated with dust and are very hard to get satisfactorily clean. Day, date, and weather are always noted at the time of collection.

The fresher the spore, the higher the success rate with germination, the quicker the germination, and the lesser the chances of fungi, mosses, and liverworts overcoming the developing prothalli.

I have successfully germinated spore on clay or earthenware pots, bricks, sphagnum moss and, in fact, anything that will allow the retention of moisture without stagnancy occurring.

The preferred mixes are bark-peat, bark-sphagnum moss or straight bark, depending on the spore about to be planted. The mix is prepared by pouring boiling water through it and then leaving it to cool for a couple of hours. Then spores are shaken over the surface, the tray is labelled and sealed in a plastic bag.

Signs of germination are usually evident in two to three weeks and the prothalli of most fern species are well developed (if not too thickly planted) in about five months. If too thickly planted they are moved on in small clumps to another tray and, by reducing the light and watering heavily, stress is decreased while they become established again, usually after about three weeks. Watering is important when the prothalli are mature because fertilization takes place in the presence of water. However, with too much water the prothalli lose condition and become soggy looking; with too little water fertilization takes place very slowly or not at all.

Watering can vary from every few hours for filmy ferns to only twice a week for *Dicksonias*.

At the same time, light levels and heat seem to play an important part in successful fertilization, so light is increased as fertilization increases in the trays. Heat on the other hand, is lowered accordingly. When the sporophyte or young fern emerges the production of the anchor root is stimulated followed by the adventitious roots. The continuing growth of the young fern inhibits further development of the prothalli and it gradually withers away at this stage with the breakdown of tissue. *Botrytis* moulds can be a problem so that captan spray is used as necessary with some success.

Plants are hardened off and then left to develop until they are

ready to be tubed.

Tubed plants are generally problem-free, although some ferns such as *Blechnum* and *Cyathea* are prone to wilting.

Hot, humid weather seems to cause excessive sweating on some types of ferns; however humidity must be maintained so it becomes almost a "Catch 22" situation.

New Zealand ferns are generally not bothered by many insect pests. However, systemic insecticides can be used for slugs, aphids, white fly, and scales with some success. Fungus gnat larvae can be a nuisance in trays of prothalli and here, Diazinon is a fairly effective control.

Selection of lesser known species. Some of New Zealand's ferns are real collectors' items.

Leptopteris superba (Prince of Wales fern) is acknowledged as one of the world's most beautiful ferns. It is a filmy fern, which in its natural habitat requires high rainfall, high humidity and low light. Its application in an ordinary garden situation is unimaginable.

Asplenium haurakense is a charming, little-known fern with tough fronds. It requires less humid conditions and is an undemanding pot plant.

Asplenium shuttleworthianum is a fairly rare fern found naturally on the Kermadec Islands. It is a hardy species which makes quite an unusual, spectacular pot plant.

Dicksonia lanata is little known and rarely cultivated. It is fairly difficult to raise from spore, but is well worth the effort, growing slowly to a height of about 1½ metres. It is an excellent tree fern for smaller gardens and pot culture.

Polystichum richardii, the shore shield fern, is ideal for coastal gardens. It has tough, leathery fronds and will withstand a high level of sunlight. It also does well indoors where it rewards with dark-green, glossy foliage.

The cultivars available for garden situations and indoor culture have, so far not been explored to any great extent in New Zealand.

CONCLUSIONS

I wish to stress from my observations, that no two fern species seem to require the same growing conditions and post-fertilization care. However, limited success can be achieved by following specifically laid growing principles and further understanding can only be achieved through observation and perseverence. It is both a rewarding and frustrating experience to cultivate ferns as, each year, I add new facts and discount others. The more I learn, the more I realize there is to learn.

PRELIMINARY EVALUATION OF THE DWARF WHITE CALLA LILY AS A POTTED PLANT

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The introduction of new floricultural crops has been the lifeblood of floricultural industries throughout the world. As an exporting country New Zealand is gaining a reputation for new crops such as, improved selections of endemic plants, unusual bulbous crops, and new fruit cultivars. New crops are attractive to marketers and may yield a higher profit margin than existing crops. However, the lack of production experience and absence of background research, mean that risks are greater with new crops.

New crops are currently under investigation at the New Zealand Nursery Research Centre at Massey University, Palmerston North. Crops selected for evaluation fall into three main categories: i) new cultivars from existing crops, ii) new uses for common species, and iii) plants taken from obscurity.

A systems approach to potplant evaluations in the new crops programme has been adopted to test various aspects of plant performance (1). The system acts to eliminate selections with obvious shortcomings in any of the evaluation phases. Promising plants are subjected to three phases of research. In Phase I plants are examined for ease of initial production and their postproduction keeping qualities. In Phase II production strategies and scheduling are examined in detail to develop optimal procedures for commercial production. In Phase III marketing opportunities are investigated.

Research is presently being conducted on a dwarf form of the common white calla lily, *Zantedeschia aethiopica* (L.) K. Spreng. cv. Childsiana (2) (Figure 1) 'Childsiana' is dwarf, floriferous, evergreen in habit, and produces rhizomes which are readily divided.

This cultivar was introduced into New Zealand from the USA by an enthusiastic amateur horticulturalist in Auckland. It was identified as having considerable potential by a commercial propagator and is currently being grown and exported as a cutflower.

The initial selection of this cultivar for use as a potted plant was based on the following criteria.

1. *Easy multiplication.* *Zantedeschia aethiopica,* including the various cultivars within this species, grows from a rhizome which freely produces offsets. For this reason the species has naturalised in many countries with mild climates. A 2 cm rhizome of

Figure 1. Various cultivars of *Zantedeschia aethiopica:* 'Green Goddess' (*above left*), 'Giant Calla' or wild type (*above right*), and 'Childsiana' (three blooms in foreground).

Figure 2. The yield of offsets of various sizes from a 2 cm rhizome of *Zantedeschia aethiopica* 'Childsiana' grown in New Zealand in a 125 mm pot for 5 to 6 months.

'Childsiana' yields 25 to 30 offsets of various sizes when grown in a 125 mm pot for 5 to 6 months in New Zealand (Figure 2). Multiplication rates of 35 to 55 offsets from mother stock planted in 200 mm pots have been reported by research in Florida (5). While the species has been successfully propagated by tissue culture (3) the high rate of division by offsests makes the expense of tissue culture unnecessary.

2. *Floriferousness.* The cultivar Childsiana is naturally more free flowering than the wild type. The natural flowering period extends from autumn until late spring. Commercial cut flower growers in New Zealand have reported yields up to 24 flowers per season from a two year old clump.

3. *Disease tolerance.* The summer-flowering, coloured calla hybrids of *Zantedeschia* can suffer from bacterial diseases (*Erwinia* spp.). *Z. aethiopica* and cultivars are seldom affected.

4. *Tolerance to low light.* Being a winter flowering plant, natural flowering occurs during times of low light intensity. Wild type *Z. aethiopica* also grow and flower under the shade of trees or buildings. 'Childsiana' shares these characteristics. Post-production keeping quality has been assessed and 'Childsiana' flowers have a shelf life of 26 days on the plant and flowers open under low light from the macrobud stage (4).

5. *Form*. 'Childsiana' is naturally dwarf when compared with other Z. *aethiopica* cultivars and the wild type (Figure 1). Established 2-year-old plants at the Massey University Bedding Plant Trial Garden have an average flower height of 80 cm and foliage height of 70 cm. This compares to a flower height of 150 cm and foliage height of 110 cm for the wild type.

6. *Fashion*. The calla lily is currently enjoying the attention of designers as it once did earlier this century. The stylised flowers often appear in popular magazines as backgrounds for home design and fashion. The resurgence of Art Nouveau is a contributing factor to the calla lily's current status in the fashion world. No longer are they seen as a funeral flower.

With these features 'Childsiana' possesses great potential for pot culture.

Observations from the natural growing cycle indicated the potential for winter production as a cool temperature crop (10°C min. nights). The main aims of the experiments were to determine the influence of: i) rhizome size, ii) lifting and drying rhizomes, and iii) the presence of offsets on flowers and foliage.

MATERIALS AND METHODS

Dry rhizomes. Plants grown in 150 mm pots had irrigation withheld on 15th December, 1987. They were removed from the potting medium on 24th January, 1988 with divisions being graded according to rhizome diameter. Rhizomes were then allowed to cure at 18°C until remaining leaves and roots had withered. Rhizomes were replanted on 4th March, 1988.

Green rhizomes. Plants grown in 70 mm pots were lifted and divided into grades on 4th March, 1988. Leaves were trimmed to 70 mm from the top of the rhizome and roots were also trimmed (Figure 2) before replanting on the same day.

Planting. Graded rhizomes (1, 2, and 3 cm in diameter), with and without offsets, were planted into pots (70, 100, and 150 mm, respectively) using a 70% sphagnum peat, 30% sand medium. Fertiliser was incorporated into the mix using 5 kg m^{-3} dolomite, 600 g m^{-3} Micromax®, 1 kg m^{-3} 3–4 month Osmocote® and 1 kg m^{-3} 8–9 month Osmocote®. Ten replicates of each treatment were used and pots were spaced and randomised. Potted plants were placed outside on coarse metal with overhead irrigation for 7 weeks during the cool autumn months (March–April). On 21st April, 1988 plants were shifted into a greenhouse for forcing into flower. Temperatures were maintained at 10°C minimum nights and 30°C maximum days under natural light.

Assessment. Flower and foliage parameters were measured when the spathe of the first flower was open but before was pollen shed. The mean time to this stage of flowering was 102 days from planting. Flower size was measured by diameter across the top of

the spathe. Peduncle length from the medium surface to the base of the spathe was used to measure flower height, hence the spathe was born above this height. Foliage height was determined measuring the length of the tallest petiole from the medium surface to the leaf lamina. Leaves were erect during elongation and expansion, when they added little to foliage appearance, but the lamina became horizontal following expansion. Leaves were cut off at the medium level; those arising from the main rhizome were separated from those derived from offsets. Both groups were counted, the laminas were then removed and the surface areas measured.

RESULTS

Rhizome size influenced growth of flowers and foliage. Small rhizomes (1 cm) produced smaller flowers, which were shorter than those produced by larger (2 cm and 3 cm) rhizomes (Table 1). Foliage height also increased with rhizome size. This was accompanied by an increase in both the number of leaves per plant and leaf surface area produced (Table 1).

Plants grown from dried rhizomes produced more leaves than plants grown from freshly lifted, green rhizomes (Table 2). This pattern was consistent regardless of whether offsets were intact or removed (Table 2). Neither planting rhizomes before or after drying

Table 1. The influence of rhizome size on flowers and foliage in plants grown from dry rhizomes without offsets of *Zantedeschia aethiopica* 'Childsiana'. (Mean ± standard error)

Rhizome size (cm)	Flower width (cm)	Flower height (cm)	Foliage height (cm)	Leaf area (cm^2)	Leaf number
1	3±1	8±3	7±1	72±13	4±.6
2	7±.3	19±2	11±.7	318±83	8±1
3	8±.5	25±2	18±.8	719±62	13±1

Table 2. The influence of drying and the presence of offsets on foliage height, leaf number, and leaf area in plants grown from 2 cm rhizomes of *Zantedeschia aethiopica* 'Childsiana'. Different letters within columns designate significant differences (p=0.05).

Treatment	Foliage height	Leaf number	Leaf area
Offsets removed			
Dry	11±.7x	8± 1a	318±83j
Green	7±.6y	4±.5b	88± 8k
Offsets attached			
Main rhizome			
Dry	15±.9z	6±.7a	250±31j
Green	11± 1x	4±.4b	176±11jk
Offsets			
Dry	—	25± 5c	386±83j
Green	—	15± 2c	237±37j

nor the presence of offsets influenced flower size or height (results not shown).

Similarly, dry rhizomes always resulted in larger leaf area and more leaves than green rhizomes regardless of the presence or absence of offsets (Table 2).

DISCUSSION

'Childsiana' can be successfully grown as a pot plant from freshly lifted or dried rhizomes. All rhizome sizes tested produced flowers. Flower and foliage dimensions increased with larger rhizomes but the proportions of the plant were maintained. The plant proportions were generally adequate for pot culture (1) and would probably not require the use of growth retardants. Flowers were always borne above the foliage regardless of rhizome size. 'Childsiana' has also been shown to have good keeping qualities (4), a feature highly desirable for pot plant production.

Dried rhizomes produced more foliage than plants grown from freshly lifted, green rhizomes. Rhizomes become quiescent under dry conditions and the data indicates that they may perhaps benefit from a period of rest. Both the main rhizome and offsets contributed to the foliage but leaves from offsets were considerably smaller.

White callas are currently being used as pot plants to a limited degree in overseas countries. The development of a production blueprint for 'Childsiana' to be grown as a compact potplant will help to create a useful plant for the potted flower market. This will create opportunities for New Zealand growers to produce rhizomes for export and the domestic market. Work continues with the production and marketing phases as part of the new crops programme at the New Zealand Nursery Research Centre.

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EFFECT OF 6-BENZYLAMINOPURINE AND 1-NAPHTHYLACETIC ACID ON *IN VITRO* AXILLARY BUD DEVELOPMENT OF MATURE *ACACIA MELANOXYLON*

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Abstract Mature *Acacia melanoxylon* nodal stem pieces of one clone showed improved *in vitro* axillary bud development after a single treatment of 4.44 μM benzylaminopurine (BAP) alone, or in combination with 2.68 μM naphthylacetic acid (NAA), when compared to segments placed upon a medium without plant growth regulators. Control and NAA treatments alone produced shoots with fewer leaves and had fewer leaves exhibiting juvenile form. BAP treatments increased the formation of juvenile and mature leaves. Shoots did not maintain leaf number with serial transfer *in vitro* and did not root *in vivo* following 16 weeks *in vitro*.

INTRODUCTION

Interest has been shown in *A. melanoxylon* as a forest species as it has a rapid growth rate and is an attractive, fine grained timber suitable for furniture (1). At present New Zealand does not have any identified clones, i.e., with suitable stem form and disease resistance, but clonal selection has been carried out in Australia and South Africa. Tissue culture techniques may provide early amplification of limited explant material.

Juvenile *Acacia melanoxylon* grows well *in vitro*, showing shoot multiplication and spontaneous root production. Plantlets survive well upon transfer to glasshouse and nursery environments. They do not require plant growth regulators (PGR) during any phase of growth (2).

Mature nodal segments placed *in vitro* initially respond with axillary bud outgrowth and develop leaves with mature morphology, but after 6 to 8 weeks, leaves abscise leaving a stem unsuitable for rooting.

The addition of single doses of PGR as a pulse treatment, or in a sustained medium addition, often enhances growth of many plant species *in vitro*. Meyer and Van Staden (3) reported that 1.0 μM benzyladenine and 1 μM indole-acetic acid enhanced development of callus which gave rise to multiple bud formation in coppice material from *A. melanoxylon*.

The aim of our study was to obtain vigorous axillary bud outgrowth from nodal segments of mature *A. melanoxylon*. Nodal segments were maintained *in vitro* for 16 weeks in order to assess the long-term effect of a PGR pulse treatment.

METHODS

Plant material. Explants were taken from a single clone of *Acacia melanoxylon* which was imported as cuttings from South Africa in 1985. Rooted cuttings have been maintained as potted plants in the glasshouse. These were sprayed fortnightly with the

fungicides, Euparen at 0.4 g l^{-1} and Benlate at 2 g l^{-1} alternately. New lateral and terminal shoots (up to 30 cm) were cut into 5 to 10 mm nodal segments for *in vitro* studies.

Tissue disinfestation. The following procedure was used to disinfest explants:

1. Silwet 7607 (non-ionic organosilicone surfactant): 150 microlitres in 200 ml of sterile water for 20 min. with intermittent agitation.
2. Calcium hypochlorite (5% chlorine)/sterile water, (20:80) for 15 min.
3. Rinse in sterile water.
4. Hydrogen peroxide (100 vol.)/sterile water, 6:100 for 10 min.
5. Rinse in sterile water 2 times.

Nodal segments were placed on a proprietary Acacia Medium (AM) without any PGR. After 14 days, nodal segments were assessed for contamination and clean material was transferred to treatment media.

Treatment. Media used:

(a) AM
(b) AM plus 2.68 μM 1-naphthylaceticacid (NAA);
(c) AM plus 4.44 μM benzylaminopurine (BAP);
(d) AM plus 2.68 μM NAA+4.44 μM BAP.

Medium solidified with 1% Difco Bacto agar was poured into 600 ml Agee jars (100 ml/jar). Five stem segments were placed in each jar with 5 to 7 jars per treatment. Lids were clear plastic petri dish tops held in place with plastic film (Gladwrap) wrapped around the jar rim. After 4 weeks on the media, nodal segments were transferred to basal AM media. They were subsequently transferred to fresh AM media at 4 weekly intervals.

A 16-hour photoperiod was maintained with a photosynthetic photon flux density of 100–120 μmol $m^{-2}s^{-1}$ provided by fluorescent tubes. The *day* temperature was 21 to 25°C and the *night* temperature was 18 to 19°C.

Prior to each transfer, developing axillary shoots were assessed for leaf number and leaf morphology (mature phyllode and juvenile bipinate forms, Figures 1 and 2). Assessments were made of leaf abscission which occurred in all treatments. No stems were discarded from any treatment during the experiment. Experiment 1 had 4 transfers; experiment 2 had 2 transfers.

Data was analysed using ANOVA after performing a $\log_e (x + 20)$ transformation. A transformation was required as the distribution of results was skewed rather than normal due to the effect of abscission on numbers of leaves measured. Means were separated using the least significant difference test with = 0.01. The experiment was repeated once.

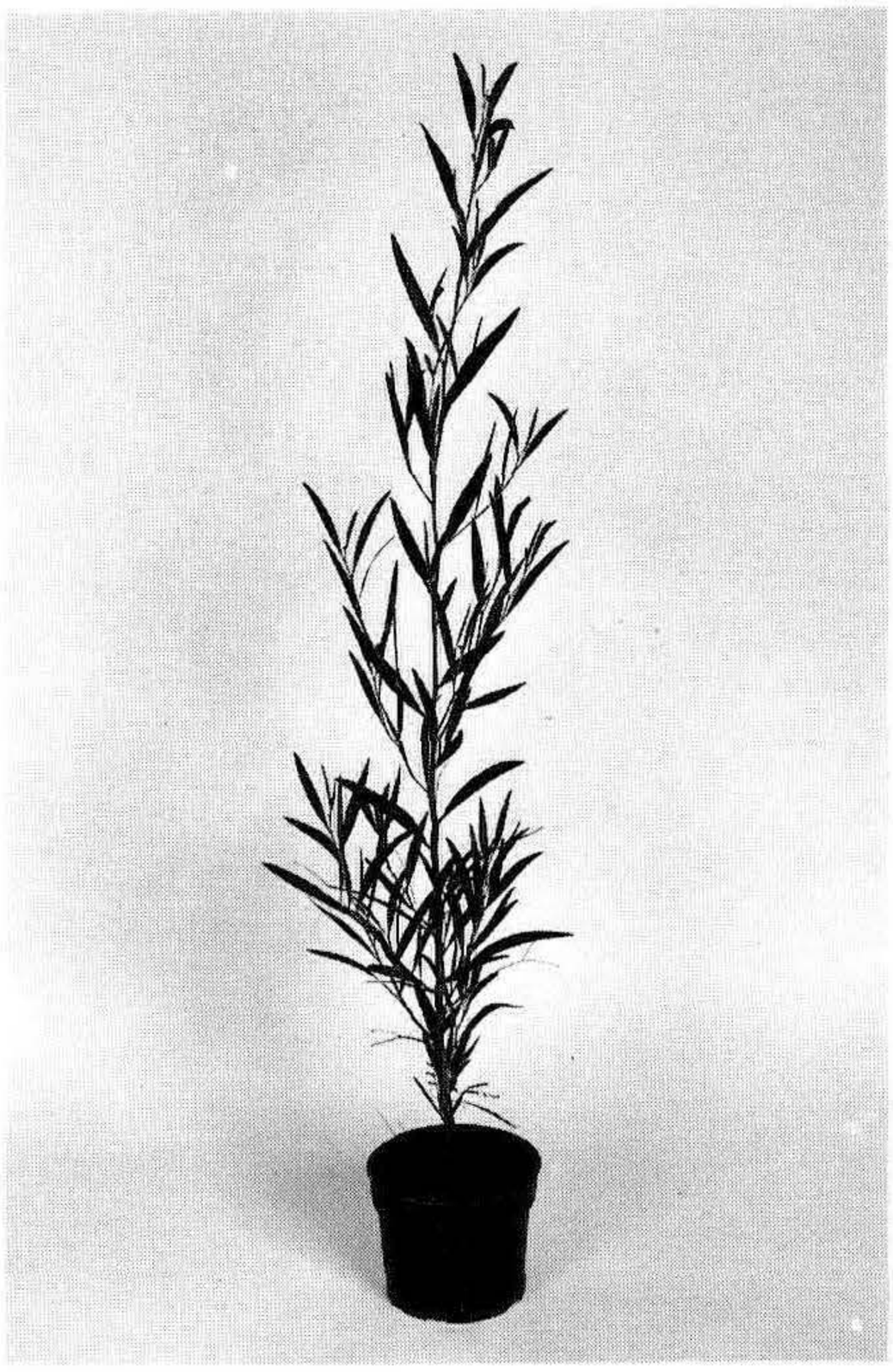

Figure 1. *Acacia melanoxylon* showing mature phyllode foliage

Figure 2. Juvenile bipinnate foliage *in vitro* from same clone as in Figure 1.

RESULTS

At the time stem pieces were first placed in culture, all leaves were excised, but each piece had an axillary bud. The axillary buds started to grow out while on AM media. When on AM plus PGR medium, leaf outgrowth was slow in Experiment 1, (Table 1). In subsequent transfers, the percentage of shoots showing leaf abscission *in vitro* was lower for PGR pulsed shoots than for controls. Although the number of stems with total of leaf abscission *in vitro* between T3 and T4 was much lower for BAP pulsed shoots in Experiment 1, the differences were not statistically significant. This was due to a large variability among replicates. Because of the increasing level of abscission with successive transfers in Experiment 1, fewer transfers were used in Experiment 2 before shoots were placed in a rooting environment.

In Experiment 2, only the stems treated with both NAA and BAP showed no leaf development at T1. At T2 only the controls and stems treated with only NAA showed abscission.

Table 1. *In vitro* leaf abscission in a mature clone of *Acacia melanoxylon*.

	Percent stems with no leaves			
	Transfer number[1]			
PGR pulse medium	T1	T2	T3	T4
Experiment 1				
AM[2]	6.7	3.3	16.7	43.3
AM + NAA[3]	33.3	0	13.3	26.7
AM + BAP[4]	20.0	0	8.0	16.0
AM + NAA + BAP	25.7	0	8.6	17.9
Experiment 2				
AM	0	33.3	—	—
AM + NAA	0	14.3	—	—
AM + BAP	0	0	—	—
AM + NAA + BAP	10.3	0	—	—

[1]Transfer number = number of 4 weekly transfers to AM following PGR pulse of 4 weeks on medium indicated. T1 = Time of transfer to AM from AM + PGR medium.
[2]AM—Acacia medium
[3]NAA—naphthylacetic acid, 2.68 μM
[4]BAP—benzylaminopurine, 4.44 μM

Treatment with PGR had significant effects on the stem mean leaf number over subsequent transfers (Table 2). In both experiments, BAP increased the formation of juvenile and mature leaf forms on the same stem piece.

A BAP pulse alone, or in combination with NAA, significantly increased the mean number of leaves per stem shown over successive transfers. This trend was reflected in both juvenile and mature leaves per stem, although the results were statistically significant only for juvenile leaves.

No root formation was seen in shoots from either experiment when they were subsequently placed in a non-sterile high humidity environment.

DISCUSSION

These experiments show clearly that a four week pulse with 4.44 μM benzylaminopurine had a sustained effect on leaf formation in subsequent transfers of a mature clone of *Acacia melanoxylon*. There also appeared to be reduced leaf abscission compared with the non-PGR control, even though this did not prove to be statistically significant due to the large variation among replicates. Since all shoots were of a single clone, genotypic variability can be excluded as a causative factor.

Although a clear cytokinin effect on leaf formation has been demonstrated (Figures 1 and 2), further work is necessary to define the optimum concentration and time of application so that shoots are of sufficiently high health to form rooted plants.

Table 2. Patterns of leaf formation *in vitro* in a mature clone of *Acacia melanoxylon*.

	Mean leaves per stem[1]				Mean leaves per stem[2]	
	Transfer Number					
PGR pulse medium	T1	T2	T3	T4	Juvenile	Mature
Experiment 1						
					(At T4)	
AM	2.1 na	2.8 na	2.3 na	1.8 a	1.5 a	1.7 a
AM + NAA	2.4 na	2.7 na	2.3 na	2.1 ab	1.8 a	1.6 a
AM + BAP	2.9 na	4.4 na	5.2 na	3.5 b	2.0 b	4.5 a
AM + NAA + BAP	3.6 na	4.2 na	5.0 na	3.5 b	3.5 b	2.0 a
Experiment 2						
					(At T2)	
AM	2.1 na	1.8 a[2]	—	—	0 a	1.8 a
AM + NAA	1.8 na	2.1 a	—	—	0 a	2.1 a
AM + BAP	1.6 na	3.9 b	—	—	2.1 b	3.1 a
AM + NAA + BAP	1.8 na	3.8 b	—	—	2.9 b	2.9 a

[1]Mean number of leaves per stem (excluding shoots with total leaf abscission). Values bearing the same subscript in each column for each experiment do not differ significantly at $p \geq 0.01$. na = not analysed.

[2]Significant at $p \geq 0.05$ for increased leaf number in the BAP treatments.

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EXFLASKING HIGH HEALTH DAPHNE PLANTLETS

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Abstract. Experiments were aimed to improve *in vivo* rooting and survival of *Daphne odora* 'Leucanthe' and *Daphne odora* 'Rubra' shoots produced *in vitro*. The results indicated that daphne microcuttings were competent to form roots regardless of their size and weight. The quick-dip method of treatment with IBA or NAA did not promote root formation. Soaking the cutting bases for 2 or 5 days prior to transplanting, in a solution containing 5ppm IBA, 5ppm NAA, and 50ppm hydroxyquinoline citrate (HQC) resulted in 74.9% rooting.

REVIEW OF LITERATURE

Daphne has been a popular garden plant in many parts of the world, especially in the Northern Hemisphere where many of the 70 plus species of the genus originate. Our experience with daphne in New Zealand is comparatively limited, as only *Daphne* × *burkwoodii*, *D. cneorum*, *D. genkwa*, *D. mezereum*, and *D. odora* are generally available commercially. The most important species in cultivation is the evergreen *Daphne odora* and its cultivars, particularly *D. odora* 'Leucanthe' and *D. odora* 'Rubra'. This species was being grown extensively in New Zealand and being exported to Australia by Kingsbeers' Nursery in Palmerston North prior to 1930 (9).

Most daphne grown in New Zealand are comparatively short-lived as garden plants. They seldom exceed 10 years and many survive for much less time. The rapid collapse of apparently healthy plants was thought to be caused by a virus. Viruses were first detected in daphne in 1941 by Chamberlain and Mathews (4), following a rejected shipment of daphne plants to Australia in 1938. These plants had mottled leaves, but at the time this was not considered to be the cause of the short plant life. It is now known that all cultivars of *D. odora* have become badly infected with a complex of viruses that cause mottling and streaking of the normally dark green leaves. This causes premature senescence of mature leaves and new leaves become narrower and are clustered at the shoot tips. As these symptoms develop nursery people were concerned about the short life of daphne plants and daphne plants were considered a difficult plant to propagate (3) although this view was not held universally (8).

Prior to the 1970's only three viruses were reported in *D. odora*, but by 1974 eleven viruses had been detected by Forster and Milne (7). A survey conducted about this time revealed that these viruses were widespread. This was considered an economically important problem as approximately 50,000 *D. odora* plants could be sold each

year in New Zealand alone without considering the export potential. A joint programme between Massey University and the Plant Physiology Division of The Department of Scientific and Industrial Research, (DSIR), Palmerston North, was initiated to eliminate the viruses by thermotherapy and plant tissue culture techniques. Clean plants from this program were repeatedly indexed and when proven to be consistently free of known viruses the plant material was passed onto the New Zealand Nursery Research Centre. Plants were then bulked-up and maintained in an insect proof screenhouse. Distribution of "high health" daphne material to licensed propagators in New Zealand commenced in 1979 and plants were released to the retail trade in 1983.

Consumer interest in "high health" daphne has been good and demand for plant material has often exceeded the supply of conventionally propagated plant material. At the same time, commercial interest was developing in a micropropagation technique (5) for rapid multiplication and maintenance of "high health" plant material.

The early reports with limited trials did not suggest there were any major difficulties in the transfer of plantlets from tissue culture back to the greenhouse environment (5). Feedback from commercial laboratories however, suggested that the process was not straightforward and that the hardening-off step was limiting further utilisation of this system. Micropropagation would be more viable if the variable *in vitro* rooting step could be moved to the greenhouse. In many other kinds of plants microcuttings can be hardened-off and rooted at the same time which reduces the need for one of the costly steps in tissue culture (6,11,12).

MATERIALS AND METHODS

Three experiments have been conducted with unrooted micropropagated daphne shoots provided by the Plant Physiology Division, DSIR. Experiments were carried out in the autumn through to early summer in a greenhouse at the Plant Growth Unit at Massey University. They were aimed to improve the rooting and survival of plant material during the hardening-off stage. A range of auxin treatments was used (1).

Experiment 1.

Treatments:

(i) control: 5 sec. dip in water
(ii) 5 sec. dip in 500 ppm IBA
(iii) 5 sec. dip in 500 ppm NAA
(iv) 5 sec dip in IBA+NAA (250 ppm+250 ppm)

The length and number of leaves of 384 microcuttings of *D. odora* 'Leucanthe' and *D. odora* 'Rubra' were recorded. In each treatment 96 cuttings of each cultivar were used. Following treatment

they were planted in punnets (8 per punnet) filled with peat/pumice (50/50). The punnets were placed in 4 randomized blocks, on a capillary mat with bottom heat (20°C.) within a high humidity tent. The rooting of the cuttings was assessed after 12 weeks.

Experiment 2.

Treatments:

(v) control(1) : spray with water
(vi) control(2) : 5 sec. dip in water
(vii) 5 sec. dip in 500 ppm IBA
(viii) spray with 500 ppm IBA

The procedures used in the second experiment were similar to Experiment one except leaf number was not recorded, but weight was measured. Observations were made after 12 weeks.

In both experiments the response of the microcuttings was too variable to detect any differences. In contrast to other reports with other genera (6,11), these experiments showed that successful rooting and survival were poorly correlated with size or weight of the microcuttings (data not shown). Plantlets were very sensitive to moisture stress and some leaf damage was apparent 2 to 3 days after transplanting. Although many shoots failed to root they were photosynthetically active and persisted in the moist medium.

Experiment 3.

Zimmerman and Fordham (12) described an efficient system for rooting apple shoots *in vitro*. In our experiment a similar system was developed to pretreat cutting bases *in vivo* to determine if there was a critical exposure time for chemical treatments. Both auxins and phloridzin have been reported to stimulate rooting (10).

In each treatment 16 micro cuttings were given a basal soak in microtitre plates. Microcuttings were maintained in high humidity with a 16 hr photoperiod for 2 or 5 days. Each solution contained 50 ppm 8 hydroxyquinoline citrate (8HQC) as a microbial inhibitor. Cuttings were planted out in punnets of 70/30 pumice/peat, covered with white plastic and placed on a capillary mat in a high humidity tent. Plants were assessed after 8 weeks.

Results are shown in Tables 1, 2, and 3.

RESULTS AND DISCUSSION

The period of preplant soaking did not influence rooting in either cultivar. Auxin combinations improved rooting more than the single auxin treatments. HQC and high auxin (5.0ppm) levels promoted the best rooting.

The poly sheet laid over the plantlets in the polythene tent appeared to reduce moisture stress in microcuttings and improve survival. This supports observations made in Europe where polythene tents and fogging are used successfully to wean daphne plantlets back to the greenhouse environment.

Plantlet rooting was improved by treatments used in this experiment but the proportion that remained unrooted was unacceptably high for immediate commercial application.

Table 1. The percentages of rooted, unrooted, and dead cuttings of *Daphne odora* 'Leucanthe' and D. 'Rubra' 12 weeks after treatment with IBA(500ppm), NAA(500ppm) or a combination of IBA and NAA(250ppm + 250ppm).

5 sec. dip	*D. odora* 'Leucanthe'			*D. odora* 'Rubra'		
treatment	rooted	unrooted	dead	rooted	unrooted	dead
control	10.4%	69.8%	19.9%	2.1%	66.7%	31.2%
IBA	4.2	64.6	31.3	8.3	63.5	28.1
NAA	2.1	46.9	51.0	1.0	58.3	40.6
IBA + NAA	7.3	49.0	43.8	0.0	59.4	40.6

Table 2. The percentages of rooted, unrooted, and dead cuttings of *Daphne odora* 'Leucanthe' and *D.* 'Rubra' 12 weeks after treatment with 500 ppm IBA applied as either a dip or a spray.

Treatment	*D. odora* 'Leucanthe' rooted	unrooted	dead	*D. odora* 'Rubra' rooted	unrooted	dead
control 1	16.7%	57.3%	26.0%	2.1%	72.9%	25.0%
control 2	16.7	59.4	24.0	3.2	75.0	21.9
IBA dip	7.3	50.0	42.7	4.2	79.2	16.7
IBA spray	30.2	49.0	20.8	4.2	78.1	17.7

Table 3. Cuttings of both *D. odora* 'Leucanthe' and *D.* 'Rubra' were left for 2 or 5 days with their bases in the following solutions: (Combined treatment means are included.)

Treatment	Percentage Rooting
1. water + 50ppm 8HQC	4.7a
2. 1% sugar + 50ppm 8HQC	14.6ab
3. 0.1 ppm IBA + 50ppm 8HQC	25.0b
4. 1 ppm IBA + 50ppm 8HQC	14.1ab
5. 10 ppm IBA + 50ppm 8HQC	9.4ab
6. 0.1 ppm NAA + 50ppm 8HQC	12.5ab
7. 0.5 ppm IBA + 0.5ppm NAA + 50ppm 8HQC	19.0b
8. 0.5 ppm NAA + 0.5 ppm IBA + 2 ppm phloridzin + 50ppm 8HQC	65.2cd
9. 0.5 ppm NAA + 0.5 ppm IBA + 10 ppm phloridzin + 50ppm 8HQC	56.3cd
10. 5 ppm NAA + 5 ppm IBA + 50 ppm 8HQC	74.9d
11. Control, no pretreatment	9.4ab

Means with similar letters are not significantly different (P=0.05).

CONCLUSIONS

Daphne microcuttings were competent to form roots and responded to auxin treatments even after prolonged *in vitro* culture. The best treatments suggested that the combination of IBA and NAA could promote rooting in 74.9% of the microcuttings. The results suggest that further improvement in rooting may be obtained by using higher concentrations of the growth regulators. Regulation of moisture stress was a significant factor determining shoot survival and should be examined more fully in further experiments.

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THE SCIENCE OF URBAN HORTICULTURE: THE COMING OF AGE IN USING PLANTS IN AN URBAN ENVIRONMENT

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Changes in horticulture often appear simultaneously around the world, although significant leadership develops in specific locations. With the new science of urban horticulture, the University of Washinton's creation of the Center for Urban Horticulture is already recognized for its leadership in this field.

BACKGROUND

On November 1, 1976, the University of Washington issued a comprehensive Master Plan for the establishment of a new research, teaching, and arboretum facility to be situated on the east edge of its urban campus (4). The entity actually began in 1980 when Dr. Harold B. Tukey, Jr., became its Director. Its mission was to study and define the functional uses of plants in order to maintain and improve urban environments, not only for their aesthetic virtues but as cost-effective and distinctive added values. Defining even a broad coarse of action in a totally new and uncharted scientific field can be both perplexing as well as exciting. Achievements to date can attest to this.

The early history and development of the Center has been chronicled in horticultural publications (1). The recruitment of faculty and staff began in 1981, and in 1984, the Center moved into the first of its new buildings situated on the site of a previous Seattle landfill. Fueled by an intense interest by the horticultural community of the Pacific Northwest, this facility now encompasses 6 new buildings and is responsible for the management of the 55-acre east campus site as well as the 200-acre Washington Park Arboretum. Even more spectacular is the fact that almost $9 million of private funds has been raised to build and fund these efforts. And the support continues to grow.

Today, there are six Ph.D. faculty members and approximately 60 full-time staff members. In addition, there are numerous part-time employees, and a volunteer corps of 300 which does every thing from weeding, guiding, cataloging, computer entry, to mounting of herbarium specimens. The Elisabeth Carey Miller Horticultural Library has 5000 volumes to serve the horticultural public and scientists of the Northwest. A Development Staff member works in funding efforts. The self-supporting Continuing Education Program reached over 25,000 people in 1987.

The following are a few program accomplishments:

ENVIRONMENTAL PHYSIOLOGY

Plant Stress Related to Root Physiology. A tree's roots need oxygen, and a deficiency of oxygen is just as destructive to plants as to animals. In work with a fast-growing popular (*Populus trichocarpa* × *P. deltoides* (Hybrid 11-11), studies are determining how plants respond to stress. Initially it was shown that within hours after roots of a small popular were deprived of oxygen, the growth of the leaves slowed down. The researchers are looking for some chemical signal, perhaps in the form of a growth regulating hormone produced in the roots and transmitted upward in the sap, which "tells" the leaves to slow growth and conserve water (9). The extent of reduction in the final size of the leaf depended on the developmental stage of the leaf as well as the duration of the stress at the time the water stress occurred in the root zone. Results meant that even small shortages of water in the root zone of plants may have more influence on plant growth and adaptation then previously thought (7).

ENVIRONMENTAL HORTICULTURE

Selection of Street Trees. A long-term research goal is to develop rigorous criteria for selection, and management of trees for urban areas. But first, scientists must be able to characterize the specific environment around a tree. Then appropriate species can be selected. An intensive study using sweet gum (*Liquidambar styraciflua*) in 3 sites (park, plaza, and canyon) found significant growth variations. The canyon (city center corridor) site received only 50% of the amount of radiation (sunlight) found at the other two sites. Thus far, conclusions indicate the sweet gum should not be planted under plaza conditions. However, it does grow adequately under low light conditions which are often usual urban conditions (4). Future research will help us select better trees.

HORTICULTURAL TAXONOMY

Classification of Horticultural Plants. Studies have been initiated in the evolution, classification, and nomenclature of plants of present and potential landscape significance, particularly of the Pacific Northwest. The new Otis Douglas Hyde Hortorum is the second herbarium collection in the United States devoted to horticultural plants. The 60-year old collection of trees and shrubs of the Washington Park Arboretum is now being re-evaluated. Special studies of plants such as *Escallonia* and *Drimys*, two species with landscape potential, have begun.

New Plant Introduction. Introduction of plants from areas of the world with a climate similar to the Pacific Northwest have begun through field studies in south-central Chile and central New Zealand. With further global emphasis on water conservation as

well as native vegetation, the importance of environmentally tolerant species will increase. But often germplasms already known are overlooked, and/or need to be collected anew.

Climate Analysis. The analysis of climatic factors that determine plant success (whole-plant physiological ecology), e.g. annual minimum temperature, absolute precipitation, annual precipitation pattern, timing, and severity of drought, have culminated in studies which have used the Walter System in initially selecting potential plants (2). The importance of microclimate for plant adaptation cannot be overlooked in future selection processes.

URBAN ECOLOGY

Air Pollution Studies. News media continually emphasize the changes occurring in the earth's environment. Our urban populations continue to grow, our fossil fuels continue to turn out large amounts of carbon dioxide into the atmosphere, and the earth's ozone layers continue to increase. Scientists are now speculating as to what is happening to our planet and what affect this will have on humans as well as plants. In order to understand this, scientists must begin to understand what is happening in smaller areas. The significance of plants in our possible environmental stabilization is of utmost importance (11).

Urban Interface. Do we really know what happens when we build a new home in a forested area? Do we know how much lawn area we have in each city? How does this affect the need for water? Can trees and shrubs really purify the air? Even though each of us may only be concerned with a small yard or garden, what happens when you add a city block, then expand this to a neighborhood, onto an entire community, or even larger.

With the advent of computer technology, studies can be instituted on entire ecosystems as well as each of its parts, e.g. parks, gardens, and open spaces. Ecology has never been applied to these types of urban systems. Ultimately the results of these studies could have a great impact on the number or type of plants we should be producing and consequently planting in our urban environments.

PLANT COLLECTIONS

Plant Collections. Washington Park Arboretum contains over 5,500 taxa which can be grown in the Mediterranean Northwest U.S.A. climate. Renewed emphasis is being placed on updating these collections for field as well as laboratory research. Although emphasis will be on plants for northwest conditions, a collection policy including plant conservation and education has been established. Renovation projects have already begun in the Arboretum, and display gardens at the east campus site are being planted. Horticulture in the northwest includes a much broader interest in natural history and environmental issues (3).

PEOPLE-PLANT ISSUES

In a study of four area transit parking lots, problems were identified in the original design and in the construction practices, all of which influenced the future management strategies for these lots. Long-term maintenance problems could be avoided with proper plant selection/specification review and maintenance requirement/cost projections during the design stage (8).

Another study investigated the possible aesthetic thresholds at which professionals, rhododendron enthusiasts, Master Gardeners, and the general public would tolerate rhododendron leaves damaged by the feeding of the rhododendron root weevil. In all instances, there was little tolerance for insect damage. The groups did have different aesthetic thresholds for taking any type of action and/or using a chemical application. This knowledge could have future implications as integrated pest management programs (IPM) are instituted (6).

PUBLIC SERVICE AND CONTINUING EDUCATION

Education. In 1987, over 25,000 people attended horticultural classes, lectures, tours, special seminars, and exhibits in our facilities. All of these activities are self-supporting. There are 100 plant societies, 400 garden clubs, and over 50 horticultural-related professional organizations in the area. Cooperative efforts with other groups on activities has lead to programs with retail food importers, public utilities, open-space planners, land developers—all truly urban utilizers of plants. In the Arboretum, weekly tours led by a corps of 200 trained volunteers, offer insight to visitors. Horticultural Support Organizations provide not only enthusiasm and "people-power" but have raised as much as $44,000 in a single plant sale. The intensity of interest in horticulture and the environment is exceptional.

Conference Facilities. The 220-seat Conference Hall, adjacent classrooms, and the Graham Visitors Center in the Washington Park Arboretum, are now used by over 40,000 visitors per year for all types of activities. Conference facilitators help the organizations arrange for meetings as well as special shows. All users pay a fee.

ADDITIONAL AREAS OF EMPHASIS

Additional faculty positions are anticipated in the areas of pest management and horticultural psychology. The ideas of integrated pest management and the need to safely control pests in our urban environment is of utmost importance. Recent studies also point out the importance of plants in our homes, our offices, and even in our hospitals. Putting together research teams of psychologists and horticultural scientists to conduct precise studies will continue to be a challenge for the future (10).

FUTURE

The success of the Center for Urban Horticulture in such a short period of time is astounding. Starting at basic research levels, both from a plant and human viewpoint, and continuing on to whole plant interactions, adaptations, and selections, these studies will continue to be of utmost importance as we enter the next century. Making the best use of any of this information and getting it to our public is always a challenge for a major university.

Through the use of scientific studies, we are now proving that plants do enrich human environments in many ways. The challenge is to decide which ones, in which place, and by whom. The Center for Urban Horticulture will continue to pursue these efforts through excellence in research, teaching, and continuing education.

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OKI NURSERY: INDOOR—OUTDOOR

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Oki Nursery was started in Sacramento by Mr. Magoichi Oki. At that time, the nursery was both a producer of fruit trees and a retail nursery.

The Oki Nursery that we know today began in 1947 after Mr. Magoichi Oki and his two sons, Richard and George, returned from the Relocation Camp after World War II. As some of you may have heard, many Japanese families in the U.S. were interned in Relocation Camps during the war.

Being without adequate funding, it was very critical for the family to start a retail nursery immediately for quick cash flow and rely on the father's ability to produce fruit trees for a long term crop.

Shortly after, the sons found a nitch for re-wholesaling bedding plants bought in Southern California and resold in Sacramento. Before long, production of general ornamentals in containers began.

In 1956, the retail nursery was sold and all effort was placed on production for the needs of the wholesale customers.

With emphasis on specialization of general ornamentals in containers, it became apparent that the need for better cash flow and more even sales throughout the year was of utmost importance. With this in mind, in the early 60's, we began a search for crops for diversification. We attended the Eastern Region I.P.P.S. meetings on a regular basis as well as visiting different greenhouse complexes during the winter months searching for crops that would fill our needs for diversification. By the mid 60's, the decision to start a greenhouse division was made.

Now we have an indoor-outdoor nursery to fulfill our cash requirements with:

—Strong emphasis on greenhouse crops during fall, winter and spring, and

—Strong emphasis on outdoor crops during spring and summer

In Sacramento, we have now approximately 1,000,000 sq. ft. of environmentally controlled greenhouses, 286 acres of general ornamental container-grown plants, and 90 acres of container and greenhosue production in Oregon.

The crops grown at Oki Nursery are as follows:

1. Bedding plants, annuals and perrennials, plus ground cover plants

2. Foliage plants
3. Holiday plants, e.g. chrysanthemums, poinsettias, lilies, African violets, roses, cyclamens, and hydrangeas,
4. Hardy garden mums

In our outdoor division, we grow broadleaf and conifer plants in sizes of: 1, 2, 3, 5, 7, 15 gal. plus 24 in. boxes.

As in every aspect of business, there are advantages as well as disadvantages in our operation.

Some of the advantages are as follows:

1. Good cash flow, which is of utmost importance.
2. Good bench utilization.
3. Money items for salesmen to sell. This helps in retaining good sales people.
4. Wide selection of plants.
5. One-stop shopping for our customers.
6. Maximizing loading of our trucks.
7. Less vulnerability to market fluctuations.
8. More flexible to changes.
9. Broader market for customer potential.
10. More effective utilization of transportation equipment.
11. More effective usage of labor.

Some of the disadvantages are as follows:

1. Logistics and handling.
2. Consistent quality in all cultivars.
3. Qualified growers to grow wider range of plants.
4. Qualified sales people to sell wider range of plants.
5. Coordination of multiple locations.
6. Difficulty in loading trucks with different sizes of containers, flats, and cartons.
7. Depth in quantity.
8. Inventory control.
9. Difficulty in focusing on crops to sell.

For Oki Nursery, the advantages far outweigh the disadvantages!!

RESPONSE *IN VITRO* OF EXPLANTS CHEMICALLY TREATED VIA FORCING SOLUTIONS

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Abstract. Stems of deciduous trees and shrubs were effectively forced into growth by immersing the basal ends of cut stems in a solution of 200 ppm 8-hydroxyquinoline citrate (8-HQC) and 2% sucrose. The new growth is an excellent source of explant material for micropropagation. Growth regulating chemicals placed in the forcing solution both influenced the forcing rate and the *in vitro* performance of explants produced in this fashion. In addition, a pre-forcing NaOCl soak accelerated bud break and size and number of shoots available for propagation.

INTRODUCTION

Commercial florists have for many years used solutions containing an energy source (sucrose) and an anti-microbial agent (8-HQC or other chemicals) to increase the longevity of cut flowers such as roses, carnations, and gladiolus (2,3,5). In addition, forcing cut stems of flowering shrubs has been a common practice to obtain winter color in an inexpensive fashion (6). The system we use combines these technologies to obtain softwood tissue for *in vitro* studies.

MATERIALS AND METHODS

The system employed for this research is as described above and in our recent publication (4). Cut stems were disinfested by soaking for 15 minutes in bleach (0.78% NaOCl) plus 6 drops/liter of a wetting agent (Tween-20). A comparison was made between such bleach treatments and no treatment. Data were taken on days to bud break, percent bud break, and length of forced shoots. The basal parts were then freshly cut and immersed in a solution containing 200 ppm 8-HQC and 2% sucrose. For growth regulator studies, 0, 1, 10, or 50 ppm GA_3 or 0, 1, or 10 ppm benzyladenine (BA) were placed in the forcing solution. Influence on shoot elongation from the forced buds was noted and effects on subsequent *in vitro* culture were recorded. The *in vitro* system was as described by Garton, et al. (1) for *Alnus glutinosa*. Vanhoutte's spiraea, privet (*Ligustrum vulgare*) and lilac (*Syringa vulgaris*) stems cut from established landscape plants were the plant materials employed.

RESULTS AND DISCUSSION

Bleach treatment increased percent bud break and shoot length while reducing days to bud break for lilac and privet (Tables 1, 2, 3). In contrast, the opposite effects were observed for spiraea, pos-

sibly because of tissue damage from the bleach due to the thinner bud scales of spiraea. It seems clear that a bleach treatment can enhance the production of potential explant material, but tests will have to be conducted to determine appropriate rates and timing for various species.

Low rates (1 or 10 ppm) of GA_3 in the forcing solution caused elongation of shoots two to three times that of non-treated stems (data not shown). Higher rates of GA_3 (10 or 50 ppm) caused a reduction of *in vitro* performance, however. When BA was included in the forcing solution, an increased number of explants produced shoots *in vitro* and a greater number of shoots were produced per explant (Table 4). Although these data are somewhat preliminary, we have found responses to be similar for several other plant species. Further study of use of the forcing solution to influence *in vitro* performance of explants taken from forced woody stems is therefore warranted.

Table 1. Effect of a pre-forcing bleach wash on percent bud break of woody stems forced for 10 to 14 days in a solution containing 200 ppm 8-HQC and 2% sucrose.

Plant Species	Percent bud break		Difference (%)
	Bleach Wash	No Wash	
Lilac	90.1	82.9	+ 8.2
Privet	32.0 a	12.0 b	+20.0
Spiraea	77.5	81.2	− 3.7

Table 2. Effect of a pre-forcing bleach wash on shoot elongation from woody stems forced for 10 to 14 days in a solution containing 200 ppm 8-HQC plus 2% sucrose.

Plant Species	Shoot Length (cm)		Significant at
	Bleach Wash	No Wash	
Lilac	2.15 a	1.85 b	0.10
Privet	1.73 a	0.86 b	0.01
Spiraea	0.79 a	0.61 b	0.05

Table 3. Effect of a pre-forcing bleach wash on days to bud break of forced woody stems held in a solution containing 200 ppm 8-HQC plus 2% sucrose.

Plant species	Days needed to bud break		Difference (day)
	Bleach wash	No wash	
Lilac	3.5 b	5.9 a	+ 2.4
Privet	5.6 b	7.7 a	+ 2.1
Spiraea	4.8 a	3.5 b	− 1.3

Table 4. Effect of BA in the forcing solution on shoot initiation and elongation of Vanhoutte's spiraea explants cultural *in vitro*.

BA (ppm)	Percent of explants producing shoots	Number of shoots/explant
10	54.2 a	2.46 a
1	37.2 b	1.24 b

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TIE YOUR PROPAGATION TO SALES

SIDNEY MEADOWS

Flowerwood Nursery, Inc.
6470 Dauphin Island Parkway
Mobile, Alabama 36605

Simply put, if you can sell it at a profit, root it. If not, then forget it. Put another way, just be sure your marketing program is equal to your production.

THE PAST

The nursery industry has experienced remarkable growth during the past 20 years, particularly in the last 10 years. During this period great progress has been made in the expertise of nursery stock propagation and production. There have also been big increases in the number of plants produced for the market each year.

Fortunately for all nurseries there has been enough growth in the nursery stock market to accommodate all this added production. There have been no problems of serious consequence.

During the fall of 1983 the word "glut" was becoming commonplace and the big price skid was on. All of this came to a halt on December 25, 1983 when the biggest freeze of all time wiped out all traces of surplus nursery stock.

Generally speaking, the years following were good ones for both retail and wholesale nurseries. There were enough plants around to get the job done, yet there were not enough to muddy up the water on prices.

THE PRESENT

Now, five years after the big freeze of '83, it will be well for everyone to pause for a moment to see if their production program and their position in the marketplace are in focus.

Marketing nursery stock is an individual matter. Your market will be the product of your actions. If there are no actions there is no market. The challenge of the future will definitely be in marketing.

Evaluate Your Market

Actually, marketing begins the day planting begins. It is not enough to plant and hope a buyer shows up when the plants are ready for sale. The market must be identified; contacts have to be made and pursued so sales can be made when the plants are ready to go.

It is also well to bear in mind that it is much easier to sell a plant someone is looking for than it is to be looking for someone to buy the plant because you have it.

There will always be some hot items and some cool ones. Just do your best not to get overloaded with those out of the limelight.

On the production side, first you evaluate your market. Second, you stick the cuttings, cultivar and number to fit the market. Third, you plant out the liners. If you still think you can sell the finished product, plant it. If not, sell the liner, or throw it away. You do not have to plant a liner just because you have it. If a plant has to go to the dump there is no better time than when it is a liner.

Determining Production Levels

We can call this a guessing game if we wish. If it has to be—then certainly we can minimize the guessing.

Currently we are right in the middle of the computer era. We can have instant itemized information on sales for the past two or three years, plus year-to-date figures, plus good inventory information. From these figures we will:

1. Know what our market has been
2. Be able to spot trends
3. Know what is on hand

This information puts one in a good position to make a judgment on future production. Each item can be examined from the standpoint of increase, decrease, or left the same. In cases of increases be sure there is solid reason behind the move. It should not be the subject of a whim.

Certainly all of this is not refined to a science, but it does reduce the margin of error to manageable levels. We will always have the unknowns of weather hazards, preferences of people, and other variables to deal with. If we will properly handle the known factors, we will be able to handle the unknown.

After the decision has been made on what to grow and in what numbers, four things need to be done:

1. Produce a quality product. The nation is clearly on a quality kick. The days of a profit with a second quality product are gone.

2. You must have a competitive price. You do not need to have the cheapest price in town, it just needs to be comparable, fair, and economic for all parties.

3. You must have a service to go with your product. Service has become a way of life in the United States and the nursery business is no exception.

4. You must develop a relationship with your customers. It has been said that people do not generally buy plants from strangers. Never were truer words spoken. The nursery business is a game requiring confidence and confidence feeds on relationships.

Everything in the business world revolves around two things, resources and relationships. Both take time and an effort. Give them your best shot. You must establish yourself as a dependable supplier. It is much easier to hold old customers than to get new ones.

THE FUTURE

Predicting the economics of the future is at best hazardous. Even so, it has to be done. Not only do we have to look at the total picture nationwide, we have to assess the situation in our individual trade area. If things will be booming we will need to play it that way. If things are not booming, the game needs to be played that way.

This past year we had some boom towns and also some of the other kind. That boils down to individual situations. Play yours the way you see it.

At this point the signals are varied for 1989. Part of this is geographic, and part is the natural confusion from the jungle of information and individual interpretations.

There is enough evidence around to indicate that new construction has slowed in many areas. Indications are that it will continue to slow down so it is only reasonable to expect the sale of landscape materials to do the same.

It will be good strategy to focus more on the home gardener and on the maintenance and upgrading of existing landscapes. If we promote the idea of improving our surroundings, we must carry the ball by providing materials suitable for homes as well as commercial establishments. This involves flower and leaf color, special shapes, and distinctive appearances. There is increasing interest in blooming plants. Just have them ready to go when they are in bud and have them gone by the time they bloom. Timing has always figured prominently in the nursery business and it gets more important every year.

There was a time when the nurseries were prone to grow plants and expect customers to buy them. This can still happen but don't make the mistake of depending on it. Today it takes equal focus on production and sales. This takes a comprehensive program from the beginning to the end. After all, a plant must be grown, sold, delivered, and the money collected for there to be a successful operation.

All of the above relates specifically to established nurseries. New nurseries without a track record can use this same information with one additional comment, "Be careful."

In addition to our individual marketing strategy there is a great need for a national promotion program. Right now the best bet we have is the Garden Council. It is in place and functioning. The concept is a sound and proven one. It will only fail if we fail in our support and direction.

We have a universal product. Everyone sees it. There has been increasing interest in plants and the last 10 years have been good. Now that selling promises to be harder, don't give up and quit. Sharpen up your procedures and compete.

INTRODUCING NEW AND RECOMMENDED PLANTS—THE BRITISH COLUMBIA WAY

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DESCRIPTION OF THE PROGRAM

The University of British Columbia's Botanical Garden Plant Introduction Scheme (P.I.S.B.G.) issued its first three public releases in 1985. These were *Genista pilosa* 'Vancouver Gold', *Arctostaphylos uva-ursi* 'Vancouver Jade', and *Microbiota decussata* (UBC Clone #12701). Each of these plants has made a major contribution in stimulating plant production in the Province's wholesale production, as well as in retail and landscape sales. A further six releases have been introduced since 1985: *Anagallis monelli* 'Pacific Blue', *Diascia rigescens, Ribes sanguineum* 'White Icicle', *Rubus calycinoides* 'Emerald Carpet', *Teucrium scorodonia* 'Crispum' and *Viburnum plicatum* 'Summer Snowflake'. To date, over two million plants in total have been produced of these nine introductions.

The objectives, formulation, and management of this introduction program have been described previously in the IPPS Proceedings (1, 2, 3).

CRITERIA OF THE PROGRAM

Our experience has shown that there are essentially five criteria for a successful plant introduction program. These are:

1. The major groups involved in the professional growing of plants and in their design and utilization in the landscape must be involved in both the evaluation of the plants and in the decision making at committee level. These groups include the wholesale growers, retailers, landscape architects and contractors, parks board members, and botanical garden personnel.

2. The procedure by which plants are evaluated must include such criteria as ease of propagation, suitability for large-scale production, resistance and tolerance to pests and diseases, winter hardiness, ability to withstand hot-dry and warm-humid summers, and determination of both domestic and export sales outlets. It is important that the final choice of a plant to be introduced under the program be made by the professional horticultural industry, not by the botanical garden.

3. One mistake made by some institutional plant introduction

[1] Director

programs is that there has been insufficient effort made on the proper promotion of the plants after introduction. Important criteria for promotion include selecting a cultivar name that has international appeal (plant naming is often too parochial); providing publicity through booths at trade shows and the radio and television media; placing articles in both professional journals and newspapers; producing colored information sheets; and attaching easily identifiable point-of-sale tags to the plants for retail sales.

4. Use of impartial test sites, including ones showing extremes in both winter and summer temperatures. Our plant introduction program presently has some seven test sites in Canada and six in the United States. The information from these sites is collated and evaluated and is then distributed through newsletters and presentations.

5. A contract must be signed between the institution and the nurseries growing and selling the plants to ensure that revenue is obtained both to maintain and to develop the plant-introduction program. In Canada, plants cannot be patented or trademarked so we register the plant with, and utilize, the Canadian Ornamental Plant Foundation (COPF). This operates essentially as a "gentleman's agreement" program in which a royalty is paid per cutting stuck. We currently receive a royalty income of some $30,000 Can. per annum through this program. The P.I.S.B.G. program commenced with some ten nurseries and we now have 31. We have been very pleased with their cooperation in the payment of royalties. In addition, a number of nurseries in the United States and Britain that also belong to COPF have been very responsible in honoring the COPF royalty system. However, once the plants are exported from Canada, in particular to some European countries, it is extremely difficult to monitor the program and to ensure that royalties are being paid. To try to overcome this problem, we are now considering the formulation of contracts and licenses with nurseries in the United States, Europe, Australia, and New Zealand that propagate plants developed and introduced by our plant-introduction program.. Unless increasing revenue can be produced, it is difficult to ensure that new and improved plant material can continue to be developed by a public institution.

NEW INTRODUCTIONS FROM THE PROGRAM

P.I.S.B.G. release for fall, 1988: *Sorbus hupehensis* 'Pink Pagoda'.

Sorbus hupehensis 'Pink Pagoda' is a shade tree that has many attributes, and is registered with COPF. The wild species is native to China, and this selection was chosen from the plant collections in the David C. Lam Asian Garden component of the Botanical Garden. It is a deciduous tree growing to about 10 m (35 ft.). The new spring growth is a very attractive reddish-bronze, with the com-

pound leaves turning blue-green shortly afterwards and then becoming an orange-red in the fall. The white flowers arise as clusters during the spring. The outstanding feature of this tree in Vancouver, B.C. is the fall and winter color of the fruits, which turn a glowing pink in late summer and remain on the tree until December. The fruits turn soft and white in late December to early January. This is the only *Sorbus* in our plant collections at the Botanical Garden to retain the fruits for such a long period.

'Pink Pagoda' grows well in full sun or partial shade on average, well-drained soils. Its uses in the landscape are as a specimen tree in lawns for home gardens and for parks, medians and boulevards. The fall and winter color of the fruits will be very eye-catching if the trees are planted in groups adjacent to highways. This tree is not recommended for areas where fireblight (*Erwinia amylovora*) is a problem. It is hardy to USDA Zone 6, but further testing is required in order to evaluate whether it can successfully overwinter in zones lower than this.

The tree can be propagated in the open ground by T- or chip-budding onto rootstocks of *Sorbus aucuparia*. Whip and tongue grafting can be used in late winter should the buds fail. Alternatively, a useful method for container-plant production is bench grafting, using a whip or splice graft, during January to February onto bare-root or pot-grown rootstocks of *S. aucuparia*. The tree's ability to produce the colorful pink fruits during the second season of growth from budding or grafting means that *Sorbus hupehensis* 'Pink Pagoda' has considerable potential for garden-center sales.

P.I.S.B.G. release for fall, 1989—*Sorbus reducta* (Chinese dwarf mountain ash)

This dwarf deciduous shrub is not a new plant but is virtually unknown in the Pacific Northwest and many other regions of North America. It was selected by the evaluation panel because it is easily produced from seed and makes an ideal container plant for wholesale and retail sales.

Sorbus reducta is native to western China and northern Burma and was introduced into cultivation in 1943 by F. Kingdon Ward. It is a deciduous shrub growing to nearly 1 m (3½ ft.) in height and producing suckers to form a multistemmed plant 1 m (3½ ft.) or more across. The suckering is not rampant, and so it is not invasive. The glossy dark-green leaves turn bright red-bronze in the fall. The white flowers are produced in the spring and are followed by attractive pink fruits that are especially visible after the leaves fall. The species is apomictic and thus fruits without pollination or fertilization.

Sorbus reducta grows well in full sun or partial shade in average well-drained but moist soils. The growth is inhibited in hot dry locations so that it forms a much more open habit. The shrub is unsuitable for hot, humid locations. It is an effective plant for

massing on highway berms and slopes but should be sited near the front of borders in parks and home gardens. The shrub is hardy to USDA Zone 3 and has been grown successfully in Edmonton, Canada (USDA Zone 2) with snow cover.

Sorbus reducta propagates readily from seed. The fruits should be collected in the fall as soon as they are ripe and the seed extracted by maceration followed by flotation. The seed can be stored in a refrigerator until required. It should receive a 3-month period of cold moist stratification (chilling) at 3°C (38°F) in a medium of 4:1 granulated sphagnum peat and perlite before sowing. Milled sphagnum moss may be used as an alternative stratification medium. It is important to turn the medium and seed and to check regularly for very dry areas. The seed must be sown immediately if the radicle begins to emerge towards the end of the stratification period. Our experiments, and the experience of participator nurseries growing forest and native seedlings under polyethylene greenhouses, have shown that the most efficient way to handle *Sorbus reducta* seed is to direct sow into styrofoam blocks with 198 cavities, each cavity containing one seed. This assumes that the viability rate of the seeds is 90 to 100 percent (the viability rate should be checked before sowing commences). Sowing in early to mid-March produces compact bushy liners ready for potting into 1-gal. containers by mid- to late May. In the lower mainland area of B.C., most of the plants should be salable as quality 1-gal. container plants by October of the same year.

The nursery industry of British Columbia has greatly assisted the U.B.C. Botanical Garden recently by ensuring that there will be new and improved plant material in the years ahead. This cooperation has resulted in the formation of the Henry M. Eddie Plant Development Foundation, named in honor of one of British Columbia's pioneer nurserymen and plant breeders. Fund raising has commenced, and the interest from the endowment fund will be used to support plant breeding, clonal selection, and field collections in the wild. This will go a long way to ensure that the University of British Columbia Botanical Garden will be able to demonstrate international leadership with its innovative plant introduction scheme.

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NURSERY RUNOFF: A FUTURE CHALLENGE

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While visiting a container nursery recently, I jokingly stated that I was there to check on the presence of potential groundwater pollutants in the runoff water from the nursery. The nurseryman, immediately and without hesitation, informed me that he had no runoff water problems. Well, during the course of the visit, I collected a water sample from a drain that was leaving the nursery and found the water to contain levels of nitrate nitrogen well above EPA standards. Since that time, a more detailed study of nutrient levels in runoff water from container nurseries by this author and others in the eastern United States has revealed that the finding in the above nursery was no exception. Another study has indicated runoff water from nurseries also contains pesticides. The concern over findings such as these is that surface runoff water containing nutrients and pesticides may enter streams and lakes and eventually contaminate the groundwater.

The issue of groundwater pollution raises a flood of questions with few answers. Groundwater is not visible; therefore, it is difficult to evaluate and follow its movement. Contaminated water may be the result of chemical spills years earlier. Thus, certain questions are important: What are the conditions that contribute to groundwater pollution? Which pollutants and at what levels of contamination constitute a threat to human health? Groundwater contamination by substances such as pesticides and fertilizers is a very real problem. It has become a national issue facing federal, state, and local governments.

Scientists in the past believed that groundwater was purified as surface water percolated through the soil. The soil was believed to filter out all man-made impurities. This, of course, is incorrect. A 1985 U.S. Geological Survey study indicated that at least 20 percent of the nation's wells are contaminated with nitrate nitrogen from nitrogen fertilizers (2). Also, 17 different pesticides have been detected in groundwater in 23 states, according to a 1986 EPA study (4). Production agriculture has been labelled as one of the prime contributors to groundwater pollution. In a study by the Iowa Geological Survey, it was demonstrated that recent nitrate nitrogen increases in groundwater in a purely agricultural region parallels an increased use of nitrogen for crop production in that area (1).

The EPA has recently published a strategic plan for coping with the groundwater pollution and has for the most part relegated the responsibility of legislation and enforcement to state and local

governments (5). The EPA, however, will attempt to ensure some degree of uniformity in the laws from state to state. The problem may develop that some states have stiff laws while others pass less stringent legislation. Many states have already enacted legislation that will affect the nurseries as enforcement of the laws is carried out. It is just a matter of time until each state enacts and enforces similar legislation. The state agency responsible for the inspection of nurseries for plant pests might also have the responsibility of monitoring test wells and runoff water from nurseries for the presence of pesticides and mineral nutrients. If contaminants are above federal or state standards, a violation will be recorded with possible fines unless the condition is rectified.

Currently, enforcement is more of a reaction to complaints rather than action toward overall enforcement. Unhappy neighbors could, for example, register a complaint to the state or local water control board that your nursery is contaminating their well water with pesticides or fertilizers. The burden of proof is on you. Determining whether you are or are not becomes your responsibility. If the evidence indicates that you are contributing to pollution, you must take action to correct the problem or be faced with a lawsuit and fines.

The following are suggestions that nurserymen might consider *in order to reduce their contribution to surface and groundwater* pollution:

1. Apply pesticides strictly in accordance with the label. Who is liable for groundwater contamination when pesticides are applied in accordance with the label is not clear.

2. Apply pesticides only when needed and never above recommended rates. Plant pest laws requiring nurserymen to market only pest-free plants may have to be modified in favor of less pesticide usage. A balance between the retailer's demand for perfect plant specimens with no apparent pest damage and cleaner water may have to be considered.

3. Use proper cultural practices since plants under stress are more likely to be attacked by disease and insects.

4. Irrigate only as needed, based upon different plant species and sizes.

5. Fertilize according to plant demands with the most efficient source of nutrients. In the interest of clean water, we can probably *reduce fertilizer application rates with a limited amount of growth* reduction. This is possible because as one approaches maximum growth, incremental increases in growth become progressively smaller with each incremental increase in fertilizer applied. A combination of slow-release fertilizers and liquid supplements through the irrigation water for container-grown plants may reduce nutrient runoff but still provide for adequate growth.

Nurserymen who grow plants in containers should design the

surface drainage system in the nursery in such a way that all runoff water is captured before it leaves the property. If it contains pesticides or nutrients at levels above EPA limits, efforts should be made to remove these contaminants before it leaves the property. While runoff water from nurseries in all states is not currently monitored, it may be a matter of time until it will. Monrovia Nursery in California was mandated in 1975 to regulate the level of certain contaminants in the runoff water from the nursery (3). After considerable study, the nursery decided to collect, treat, and recycle all irrigation water. The results have been very encouraging for the nursery from the standpoint of water conservation, reduction in fertilizer usage, and control of pathogens. Although the feasibility of a small nursery's being able to accomplish such a task may seem questionable, a small nursery in Virginia is economically accomplishing the same thing in order to conserve water. Thus, if necessary, it appears that nurseries of any size will be able to control water runoff.

In any case, I would recommend that nurserymen monitor the level of nutrients and pesticides in water as it drains into collection basins or leaves the property. I would also recommend that test wells be dug in order to monitor any contamination of the groundwater under the growing area. With this information in hand, you can take steps to reduce groundwater pollution at your nursery and help to enact state and local legislation based upon facts and not emotion.

Nursery operators take pride in their profession because they are producing plants that beautify the environment and improve the quality of life. Let us also be responsible stewards of the environment and leaders when it comes to preserving the quality of an invisible resource like groundwater.

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CONTROL OF *PHYTOPHTHORA* AND *PYTHIUM* BY CHLORINATION OF IRRIGATION WATER

BILL DAUGHTRY

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Lancaster Farms is a 100-acre container nursery operation that is located in southeastern Virginia where there is actually more water than land area. The paradox of water, water everywhere but not a drop to drink was never more true as far as our irrigation water is concerned. Our many rivers are brackish and wells are unsuitable for irrigation purposes. In order to have sufficient water, we recycle our irrigation water by draining every possible square foot of growing area and collecting this water in our ponds.

The worst part about recycling water is the buildup of pathogens and their subsequent distribution back into the nursery. *Presently, chlorination is the best and least expensive way to con*trol these organisms. It is just a matter of time before the collection and recycling of irrigation water will be forced on this industry in order to control environmental pollution by fertilizer and agricultural chemical runoff.

Chlorine gas is an extremely dangerous chemical. Therefore, we still use what we think is the safest Cl_2 injector system available on the market. We bought a series V-500 remote vacuum chlorinator manufactured by Wallace and Tiernan, a division of Pennwalt Corporation, 25 Main Street, Belleville, NJ 07019.

The injector system consists of three major parts:

1. A *vacuum pressure regulator,* that is attached directly to the top of a 150 lb. Cl_2 cylinder. It regulates the release of the chlorine gas from the cylinder only under a vacuum.
2. A *V-500 control* unit, that regulates the amount of chlorine flowing through the system.
3. An *injector.*

To automate the system we use a 1-in. irrigation control valve that is connected to the pressure side of the irrigation pump. When the pump is turned on, the valve is activated. Water from the valve goes through the injector. As soon as a flow rate of 2.1 g.p.m. (gallons per minute) of water is obtained, the injector creates a vacuum that pulls the chlorine from the cylinder into the water line. This highly chlorinated water is piped into the lake.

The water is dispersed through a header 18 in. long, with ¼ in. holes 1 in. apart. The header is above and 1 ft. in front of the intake screen. The highly chlorinated water and lake water are mixed as they are drawn into the suction line of the pump.

Our contact time is the time it takes the water to move from that point to where our fertilizer is injected. This is approximately 20 sec. It ends at that point because the fertilizer immediately ties up any remaining free available chlorine (FAC). If you are not on a fertilizer injection program, the contact time would continue until the water reaches the irrigation nozzle.

Chlorine is tied up because it reacts with any impurities in the water such as organic matter, fertilizer and colloidal materials. Chlorine demand is the difference between the amount of chlorine added to a given quantity of water and the amount of FAC remaining at the end of a given contact time.

All bodies of water have different concentrations of impurities. Therefore, the chlorine demand always varies. Because of this, no specific rate of chlorine injection can be given based solely upon the flow rate of the water. The determining factor is to insure that some FAC remains. This will tell you that there is still a quantity of FAC that can react that was not consumed by the impurities in the water, including *Phytophthora* and *Pythium*.

The levels of chlorine and the length of contact time to treat potable water supplies are much higher than what is necessary to kill *Phytophthora* and *Pythium*. Therefore, you should not think that chlorine at the rates we are using to treat irrigation water is in any way making this water suitable for drinking purposes. The following rates for chlorine injection are presented only to give you a place to begin testing a particular water supply. Adjustments will most likely have to be made to comply with your own water source.

Take the g.p.m. of your pump and divide by 15. The number that you get should be the rate of flow on the control unit, which is calibrated in pounds of chlorine per 24 hours of continuous operation.

For example: 500 g.p.m. ÷ 15 = 33.3

Therefore, 500 GPM will be treated at 33.3 lb./24 hr. This gives you a chlorine concentration of approximately 1.5 ppm.

The chlorine tester we are using is a Lovibond 2000. It is a color comparator using the D.P.D. method that is used in most swimming pool testers. However, it is extremely accurate and will measure levels of FAC as low as 0.02 ppm.

Presently we are trying to maintain an FAC level of 0.05 ppm. This level is much lower than the 0.3 ppm level presented in an earlier paper. The difference in the two levels is due to initially using an inexpensive swimming pool tester instead of a higher quality Cl_2 tester. We have not actually lowered our level of chlorine gas being used.

Chlorine equipment is referred to by the maximum pounds of chlorine per 24 hours that it can handle. When we began chlorinating nine years ago, the V-500 was the industry's standard for safety

and reliability. The price for this unit is $2100. The V-75, originally a pressure unit, was redesigned in 1980 to become a vacuum unit and is comparable to the performance of the V-500. Its cost is $1850. The V-200 (essentially a down-sized V-500) was developed five years ago and currently sells for $1650. While not as good as the more expensive model, it is still an acceptable unit.

Within the last five years several new companies have entered the chlorine equipment business mainly competing for the swimming pool trade. These companies are forcing the development of a 100-lb. unit that will sell for less than $1000. It will be considered a disposable and nonrepairable unit. Even though it will handle the Cl_2 rate required by most nurseries, it should be avoided.

Chlorine was $0.22/lb. when we started chlorination. Presently, we are paying $0.60/lb. A significant part of this cost increase has been caused by much higher insurance rates and by much stricter federal regulations of the chlorine industry. This year chlorine will cost us approximately $42 per irrigated acre.

Chlorination will control *Phytophthora* and *Pythium* in irrigation water but is not a "cure all." These organisms can be brought into the container by inoculated liners, used pots, or by recycled potting media. Chlorination will not significantly help these plants but it will reduce further spread of these organisms.

We feel that chlorination has reduced the cost of our fungicide program by approximately 30 percent. Finally, we feel that chlorination is a major key to the production of high quality container nursery stock at Lancaster Farms.

TREATING HIGH BICARBONATE WATER

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In order to discuss how to treat high bicarbonate water, it is necessary first to define what constitutes high bicarbonate water or what is high bicarbonate water. First of all, a bicarbonate is a salt obtained by the neutralization of one hydrogen in carbonic acid. Carbonic acid (H_2CO_3), in turn, is a solution of carbon dioxide (CO_2) in water (H_2O). There are two replaceable hydrogen ions in carbonic acid (H_2CO_3). The salts obtained by neutralizing only one hydrogen are called bicarbonates.

Examples: $CaHCO_3$—calcium bicarbonate;
$NaHCO_3$—sodium bicarbonate

Carbonates can be converted into bicarbonates by adding excess carbon dioxide. Example:

$$Na_2CO_2 + CO_2 + H_2O = 2NaHCO_3$$

Sodium carbonate + CO_2 + water = sodium bicarbonate

What problems does it cause? The most common problem associated with high levels of bicarbonate is that of unsightly deposits or precipitates on plant foliage. This problem lowers the visual quality of nursery stock, and thus can affect its salability.

Following closely behind this problem is the fact that, with the evaporation of water, calcium and magnesium carbonates form and can, and often do, plug small-orifice irrigation equipment.

Other problems that can occur, but usually are of less significance are: toxicity to the roots of some species of plants, increased sodium uptake by plant foliage due to imbalances in calcium and magnesium levels in relationship to sodium levels, and a gradual rise in soil pH from carbonate accumulation.

How can the water be treated? The most common treatment for high carbonates is to inject an acid directly into the water to neutralize the carbonates. This method has been used since the late 1950s and has proven to be the most cost-effective method of dealing with the problem.

Along with the sought-after benefit of neutralization of the carbonates, acid injection also allows for the introduction of one or more anions for plant nutrition purposes without appreciably increasing the salinity of the water. At Greenleaf Nursery we get sulfates as a side benefit to acid injection.

There are three acids that are usable for this purpose. The first of these is phosphoric acid, which is available in either a 75 or 85 percent concentration. When using by-product phosphoric acid one needs to be cautious as this grade of acid sometimes contains heavy

metal contaminates, such as arsenic and chromium. Thus, it is much safer to use food-grade phosphoric acid, which is relatively expensive. This acid is, however, the least dangerous of the acids to handle.

Sulfuric acid has the inherently bad quality of being dangerous to handle, but it also is the most cost-effective. If this acid is to be used, the purer the concentration, the safer it will be to handle (66° Baume/98%). The approximate cost at Greenleaf Nursery to treat 1,000 gallons of water with sulfuric acid is approximately three cents. This cost, however, is only a materials cost and does not factor in the capitalization of the equipment.

The final acid I will mention is nitric acid. This acid has a nitrogen analysis of approximately 15-0-0 and thus would supplement your nitrogen feeding. However, this acid is not available; it is the most corrosive and, consequently, the most dangerous to handle.

There are other possibilities that might be worth the effort to explore when deciding on a treatment plan. One of these products goes by the trade name of Sequest-All and is said not only to do a good job with this problem but also to be very safe to handle. Equipment costs would most likely be much reduced with a product such as this due to its relatively non-corrosive nature.

Problems and cautions concerning injection of acids: safety is of major concern with the handling and injection of any acid. Thus, it is highly advisable when planning an injection system that you enlist the services of a licensed professional engineer for the planning stage to insure that the system is properly designed and equipment properly selected to meet all safety requirements. Users should also consult with OSHA and other regulatory agencies for updated information regarding safety requirements. Sulfuric acid is on the EPA's extremely hazardous list. This means that currently it has to be reported under the new "right-to-know" laws if your supply exceeds certain "threshold planning quantities" as specified under the law. Also, it is always advisable to remember that acid can be added to water, but not water to acid. The latter reaction generates a great deal of heat and, if the heavier acid is on top, there is much less chance of splattering.

To estimate the quantity of acid required, one can follow these simple steps.

Obviously your first step is to have a reputable laboratory complete an agricultural-suitability analysis. From this information you can determine the meq./L of carbonates present. This is simply done by adding both the bicarbonates and the carbonates together. Then subtract two from the resulting sum of the carbonates. This number can then be multiplied by the "acid factor" to determine the quantity of acid required to treat 1,000 gallons (1).

Equipment needed: The equipment required to treat water with

acid varies greatly with each situation. It can range from such simple equipment as a safe, spill-proof container used to pour acid directly into a water reservoir—all the way to sophisticated flow measuring and injecting equipment.

At this point in your planning it is highly beneficial to have employed the services of a licensed professional engineer to assist in the design work and the selection of proper equipment to fit your particular needs.

CONCLUSIONS

It is not only possible but also practical and cost-effective to treat high-bicarbonate water to improve its quality. This undertaking, however, requires a careful plan to maintain proper safety as well as considerable knowledge of types and sizes of injection equipment available. For these reasons, I think it is ill-advised to proceed with a treatment plan without consulting a professional engineer who is familiar with this type of work.

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CALCIUM, MAGNESIUM, AND IRRIGATION WATER

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For years great emphasis has been placed on "proper pH" of container growing media, and dolomite (calcium and magnesium carbonate) has been used almost exclusively to raise the pH to the chosen level (1, 2). As nutrition in containers becomes more precise, calcium and magnesium nutrition must be modified. Many irrigation waters contain substantial quantities of dissolved calcium and magnesium. Whitcomb (4,5) studied this extensively in Oklahoma and found that with a water that contained 40 ppm calcium and 17 ppm magnesium, two pounds of dolomite was

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optimum for greenhouse and container nursery crops. Alternative sources of calcium and magnesium also exist. These may be especially useful in areas where the water supply contains considerable calcium but little magnesium, or vice versa.

In order to study the combinations of water quality, calcium, and magnesium nutrition, and various sources of both elements a study was conducted in two locations during 1987. Analysis of the irrigation water at the two locations was as follows, in parts per million:

	Na	Ca	Mg	HCO_3	B	Cl	SO_4	Total* salts	pH
Bennetts Creek Nsy. Suffolk, Va.	30	20	9	100	0.13	48	28	0.36	8.3
Jon's Nursery Eustis, FL.	10	60	19	88	0.01	12	174	0.39	7.3

*mmhos/cm

Treatments were:

1) no calcium or magnesium.
2) calcium only, using calcium carbonate, added at a rate equivalent to 6 pounds of dolomite per cubic yard.
3) three levels of 100 mesh dolomite.
4) olivine, which contains 14 percent magnesium as a ferrous magnesium silicate, at three levels.
5) magnesium oxide (58% Mg) at three rates.
6) fine particles of MgO, coated with molten sulfur.
7) coarse particles of MgO, coated with molten sulfur.

For all rates of olivine, calcium carbonate was used to provide a 2:1 Ca:Mg ratio. This procedure was also used for the three sources of magnesium oxide. See Table 1 for specific rates and plant response. Note that because the chemicals were weighed out in advance and the container sizes at the two locations varied (150 cubic inches in Florida and 210 cubic inches in Virginia) the rates in pounds per cubic yard also varied between locations.

Olivine has been reported as beneficial for field-grown nursery stock as a magnesium source and has a solubility roughly the same as dolomite (3). Magnesium oxide is extremely insoluble in water (0.00062 g/100 ml) and, in general, has not been effective as a magnesium source for container nursery stock. The idea of coating granules of MgO with sulfur was tried in hopes of increasing the solubility of the MgO as a result of a reaction with the sulfuric acid formed upon the degradation of the sulfur.

Container growth medium in Florida was 60 percent ground pine bark, 20 percent peat, and 20 percent sand. In Virginia 80 percent ground pine bark and composted hardwood bark and 20 per-

cent sand was used. All treatments received 1.5 pounds of Micromax per cubic yard as the micronutrient source and 18-6-12 Osmocote at the rate of 11.5 lbs/yd^3. Test species were (azalea) *Rhododendron* 'Southern Charm', (juniper) *Juniperus conferta,* 'Blue Pacific', and (holly) *Ilex cornuta* 'Dwarf Burford' in Florida; (azalea) *Rhododendron* 'Hino-crimson', (holly) *Ilex vomitoria,* 'Shillings Dwarf', and (juniper) *Juniperus horizontalis* 'Wiltonii' [also called 'Blue Rug'] in Virginia. The duration of the study was from April 17 to November 22 in Florida and May 2 to November 17 in Virginia. The plants were given a visual grade from 1 to 10 where 1 = a poor plant and 10 = an excellent plant, using a selected set of standards for a grade of 1-4-7 and 10. Top weights were also determined.

The studies were conducted in both locations in full sun and with standard practices of watering, pruning, weed control, etc. for that nursery. Each treatment was replicated six times with each species in each location. Treatments were arranged in a randomized block design. Border rows of containers filled with mix but no plants were placed on the east, south, and west sides of each block to avoid adverse temperature effects.

To ensure that each container received a precise level of all nutrients, all chemicals were weighed out prior to the study and placed in small zip-lock bags. The procedure used in mixing was as follows:

a) the nurseryman prepared the mix with no chemicals added,
b) the containers were filled and watered,
c) the mix in a container was emptied into a plastic pail,
d) the contents of the zip-lock bag were added,
e) the mix and nutrients were mixed by hand, then returned to the container. This procedure prevents any error in quantities of chemicals received in a container due to mixing.

RESULTS AND DISCUSSION

In Florida, azalea, holly, and juniper all grew best when no calcium and magnesium were added to the components of the growth medium (Table 1). The azaleas averaged a visual grade of 9.7 and 136 grams of top weight. The next best treatment was 1.2 lb. per cu. yd. of sulfur-coated fine MgO with a visual grade of 7.7 and 119 grams top weight. The current grower practice was approximately eight lb. of dolomite per cu. yd.

The holly in Florida averaged 8.2 visual grade and 118 grams top weight with no Ca or Mg. Olivine at 3.5 and 7.0 pounds, dolomite at 3.5 and 7.0 lb. and fine MgO with a sulfur coat at 2.5 lb. per cu. yd., all had similar top weights but visual grades were somewhat lower.

Table 1. Summary of calcium and magnesium study, Virginia and Florida, 1987[1].

	Virginia							Florida					
	azalea		holly		juniper			azalea		holly		juniper	
Va. rate[2]	Visual grade[2]	Top wt.	Visual grade	Top wt.	Visual grade	Top wt.	Fla. rate	Visual grade	Top wt.	Visual grade	Top wt.	Visual grade	Top wt.
0	*9.0*	*105*	*5.6*	*25*	*5.8*	*92*	*0*	*9.7*	*136*	*8.2*	*118*	*8.0*	*135**
Ca only	8.5	85	7.2	25	6.3	104	Ca only	7.3	113	6.8	107	6.3	124
Dol.[4], lb./yd.[3]													
2.5	8.7	106	7.3	25	6.5	107	3.5	5.5	108	6.8	122	5.8	120
5.0	8.2	97	7.0	24	6.7	103	7.0	6.8	119	6.8	117	5.7	125
7.5	7.0	81	6.2	17	7.2	104	10.5	5.8	100	7.0	116	5.0	112
Olivine[4], lb./yd.[3]													
2.5	7.0	83	5.5	18	8.0	110	3.5	7.2	112	5.7	116	5.3	121
5.0	8.2	89	6.5	20	7.3	104	7.0	7.0	93	7.3	120	6.5	129
7.5	8.5	88	6.7	20	5.8	100	10.5	6.5	102	6.0	94	4.0	108
Fine MgO[4],lb./yd.[3]													
0.8	7.0	74	6.8	21	7.7	102	1.2	5.8	90	5.0	110	4.3	103
1.6	7.0	72	6.8	22	7.8	99	2.4	4.7	87	5.8	105	4.8	104
2.4	5.7	60	6.2	19	6.7	98	3.6	4.5	78	3.7	87	5.2	115
Fine MgO + S, lb./yd.[3]													
1.3	9.0	103	6.3	23	6.3	98	1.7	7.7	119	5.8	84	6.5	121
2.5	9.0	103	7.2	25	5.8	97	3.5	7.5	108	6.3	120	3.8	101
3.7	8.3	99	6.8	25	5.8	91	5.3	6.0	94	4.2	89	3.5	83
Coarse MgO + S, lb./yd.[3]													
1.2	8.2	91	7.0	22	6.7	100	1.7	7.0	120	6.5	105	6.2	125
2.5	8.7	99	7.3	23	6.8	102	3.5	7.8	117	6.5	102	5.8	117
3.7	8.7	96	6.0	21	6.3	94	5.3	6.5	95	4.8	97	5.3	104

[1] Top weight and visual grade on November 19, (Florida) and November 16 (Virginia).
[2] Rates in Florida and Virginia differed due to container sizes.
[3] Visual grade based on 1 to 10, where 10 was best
[4] *Olivine was 32% iron and 14% magnesium. MgO was magnesium oxide, which* contains 58% Mg. Fine MgO + S and coarse MgO + S were magnesium oxide granules coated with molten sulfur, then reground to expose some of the MgO granule. Dolomite was 180-mesh, face-powder consistency. Olivine and MgO treatments had calcium carbonate added to make a 2:1 Ca:Mg ratio.
*Best treatment overall.

The juniper in Florida averaged 8.0 visual grade and 135 grams top weight with no Ca or Mg. Plants receiving olivine at 7.0 lb. , dolomite at 7.0 lb. and 1.2 lb. of sulfur-coated coarse MgO all had top weights approaching the best treatment. However, visual grades were 6.5, 5.7, and 6.2, respectively, and plants were distinctly lower in visual quality.

In Virginia the best treatment was approximately 2.5 lb. of dolomite. However, the difference between 2.5 and 5 lb. was small for all three species. In addition, in Virginia there were several good treatments and a less well defined clear "winner". For example,

visual grade was 9.0 and top weight 105 for azalea with no calcium or magnesium, vs. 8.7 and 106 with 2.5 pounds of dolomite. Likewise, plants receiving fine MgO + sulfur at 1.2 and 2.5 pounds per cubic yard had 9.0 and 103 visual grade and weight. However, for holly, only 2.5 pounds fine MgO + sulfur and 2.5 pounds coarse MgO + sulfur gave visual grade and top weights equal to the 2.5 pounds of dolomite. With juniper, 5.0 and 7.5 pounds of dolomite, 2.5 and 5.0 pounds of olivine, 0.8 pounds fine MgO + sulfur and 1.2 and 2.5 pounds coarse MgO + sulfur all had comparable visual grades and top weights.

The reason for the less well-defined results in Virginia may be due to the presence of some 10 to 20 percent composted hardwood bark in with the pine bark of the mix. Hardwood bark contains considerably more calcium than pine bark, which probably affected the plant response to the treatments and somewhat clouded the results.

It is interesting to note that the lowest pH of the mix at the end of the growing season in either location was 5.4, where no calcium or magnesium were added. The highest pH was 5.9 where 10.5 pounds of dolomite had been added to the mix in Florida. In both locations, pH change of the mix was buffered from change, but for different reasons. In Florida, the calcium, magnesium, and bicarbonates in the water prevented the pH of the mix from becoming extremely acid. In Virginia the buffer effect was provided by the hardwood bark portion of the mix and to a lesser extent by the calcium, magnesium, and bicarbonates.

The results of these studies support the hypothesis that it is the level of calcium and magnesium available to the plant that is important and not pH (4, 5). At the same time it should be noted that if the levels of these two elements are generally correct, the pH will also be in the "desirable" range.

In other locations, using other mix components and quality of irrigation water, olivine and/or magnesium oxide may be useful, although they provided no advantage in this study.

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HOLDING CONTAINER-GROWN PLANTS: LIQUID VS. SLOW-RELEASE FERTILIZERS

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Ask retail nurserymen what factors most influence their decisions when buying plants and they will generally say price, availability, and quality. Ask retailers what quality plants are and they will generally say plants that have a good appearance, that hold up well on a sales lot, and that will sell well.

CHARACTERISTICS OF QUALITY PLANTS

Several specific characteristics contribute to "quality" plant appearance including good foliage color, adequate foliage density, appropriate flower (and fruit) size, color, and number; appropriate overall plant size and form, an adequate growth rate, absence of any major pests or damage, an attractive overall appearance with a clean, undamaged container or root ball, and an appropriate and attractive name or information label.

Though a grower may produce plants that reflect these various quality characteristics, there are often problems once the plants leave the grower. Rarely is an increase in quality seen as plants are held for sale on retail lots, and more often quality begins to decline, sometimes quite rapidly, after the plants leave the grower.

QUALITY MAINTENANCE—POST HARVEST PHYSIOLOGY

For many horticultural crops the transition stage from the grower to the retailer has been well researched. Referred to as post harvest physiology, we think of controlled environment storage that keeps apples from becoming soft and grainy, and rapid cooling that keeps broccoli heads from turning yellow and the buds from opening prematurely, as good examples of "maintaining quality."

With landscape plants, more so trees and shrubs than bedding plants (where considerable "keeping" work has been done), there is a void with regard to helpful information concerning the transition period from the grower to the retailer. Growers need to know what to do to help insure that quality is maintained once their plants are shipped, and retailers need to know what to do to maintain the growers' quality when plants arrive and are held for sale.

HOW GROWERS CAN HELP MAINTAIN PLANT QUALITY

For the grower, there are several important "quality maintenance" factors: Using the best quality liners available, providing optimum growing conditions, hardening-off or conditioning plants for the harsher conditions encountered on retail lots, selling plants at their peak, handling and shipping plants in a way that will minimize damage and stress; and sharing with retailers cultural practices that can affect quality maintenance.

Due to increased competition and demand for quality, growers can no longer afford to stop worrying about their crops once they are trucked out their front gates. While, in all fairness, growers cannot bear the greater part of the responsibility for maintaining the quality of their plants once they leave their property, they can greatly help retailers by providing certain production information.

THE EFFECTS OF FERTILIZATION ON QUALITY MAINTENANCE

One of the most important items to share is the fertilization regime that is used. Fertility practices can have a profound effect on retail quality maintenance of container-grown plants. Most growers will use either a slow-release fertilizer, a liquid-feed system, or a combination of both. Therefore the effect of these two fertility programs on retail quality maintenance has been investigated at our Experiment Station with the cooperation of two Virginia container nurseries. One of these nurseries uses a slow-release feeding program, the other the Virginia Tech liquid fertilizer system.

With certain test species (azalea and Japanese holly, but not juniper), dramatic visual foliar color decline was observed on liquid-feed plants once they had been removed from the grower's liquid-feed system for several weeks. This visual decline was paralleled by drops in tissue nitrogen content and medium soluble salt extractions. A corresponding decline was not visually observed for the slow-release-fed plants, and tissue and medium nutrient content level decline was far less rapid.

When liquid-feed plants were provided with supplemental fertilizer at the time they were removed from the liquid-feed system, all evaluation criteria declined less rapidly, with variation dependent upon whether the supplemental fertilizer used was short-term quick-release or slow-release.

GROWER-RETAILER COMMUNICATION

If information about production fertilization is supplied by growers to retailers, it will allow retailers to make educated decisions about how to handle plants grown on different fertility regimes so that they can help to minimize fertility-related quality

decline. It is our recommendation that if a liquid feed system is used, either the grower or the retailer supplement with some other fertilizer. The application of supplemental fertilizer should be done either immediately, if the plants are to be held for several months prior to sale, or after one to two months, if plants have not yet sold. Also, with slow-release-produced plants, growers and retailers should be sure that the slow-release fertilizer has not been completely depleted, and if it has, or is near the end of its release period, supplemental fertilizer should also be applied.

Fertilization information, coupled with other information such as how to water the different types of media used in container production, and what pest problems the grower has been treating, will be of great benefit to the retailer. The grower will benefit by maintaining greater retailer loyalty and by having a superior quality plant on the market.

INFLUENCE OF NUTRITION AND CARBOHYDRATES ON ROOTING OF CUTTINGS

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It has been difficult to correlate nutrition and carbohydrates to the rooting of cuttings. However, nutrition and carbohydrate status certainly do play an important role in the rooting process.

Carbohydrate pools. There are three carbohydrate pools or sources in the plant system (14). These three pools consist of: 1. free reducing sugars (soluble carbohydrates such as glucose, fructose, sucrose), 2. storage carbohydrates (starches, insoluble carbohydrates), and 3. cell wall polysaccharides. Reducing sugars and storage carbohydrates are the most important for the rooting process.

Carbohydrates are used as building blocks for complex macromolecules in chemical pathways, and also serve as building blocks for structural elements. Keep in mind that in root initiation and development new cell walls are being formed from macromolecules largely composed of carbohydrates.

Carbohydrates are also energy sources. Primary requirements for rooting are: 1. parenchyma cells with the genetic capability to dedifferentiate into root primordia; 2. presence of auxins plus rooting cofactors such as phenolics and essential enzyme systems;

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Carbohydrates are also energy sources. Primary requirements for rooting are: 1. parenchyma cells with the genetic capability to dedifferentiate into root primordia; 2. presence of auxins plus rooting cofactors such as phenolics and essential enzyme systems;

and 3. a substrate energy source of carbohydrates. Essentially carbohydrates are what fuel the engine of rooting.

Nitrogen. Nitrogen is an important component of nucleic acids, DNA, and RNA, which are critical to mitosis and cell division that must occur if adventitious roots are to form. Nitrogen also is a structural component of amino acids that combine to form proteins. Proteins form enzymes that help drive chemical reactions. Thousands of chemical reactions go on at the base of a cutting in the formation of roots.

Competing sinks with rooting. Carbohydrates and nutrition are closely related to rooting when the competition for nutrients, metabolites, carbohydrates and phytohormones occurs among different growth areas of a plant. These other growth areas are "competing sinks" with rooting, which is analogous to the kitchen sink drain through which everything passes when the plug is pulled. In essence, a competing sink is a meristematic region where growth of a flower bud (reproductive primordia) or vigorous vegetative growth (vegetative bud or rapid shoot elongation) competes with the ability of adventitious roots to be initiated and developed at the cutting base.

It is a good practice to pinch flower buds from cuttings to remove this competing sink with rooting. Likewise rapid vegetative growth of axillary buds of leafless hardwood cutting can be a drain on the plant reserves and not only lead to reduced rooting but also to death of the cutting. (8).

Carbohydrate/Nitrogen (C/N) ratios. The importance of carbohydrate/nitrogen levels on flowering, vegetative growth, and rooting has been known since the research of Kraus and Kraybill (2). A high carbohydrate:high nitrogen level of stock plants results in more vigorous nonreproductive vegetative growth with green foliage. This favors rooting of cuttings under intermittent mist. A high carbohydrate:low-to-moderate nitrogen ration of stock plants favors rooting of dormant, leafless hardwood cuttings. Without leaves photosynthesis can not occur. Consequently the cutting must rely on stored carbohydrate reserves for rooting.

A problem in C/N ratios is determining exactly what a high or low carbohydrate/nitrogen level is. This depends upon the plant species, seasonal timing of the year, and type of cutting. Herbaceous cuttings have nitrogen levels of 3 to 5 percent N on a dry weight basis, while woody cuttings have 2 to 2.5 percent N.

One of the few studies to show a correlation with C/N ratios and rooting was with *Rosa multiflora* 'Brooks 56' understock. Production of field roses is a two-year cycle in east Texas that begins with the collection and sticking of dormant hardwood cuttings in late fall. The cuttings are rooted in field beds without irrigation and later T-budded in the following spring (4). During periods of high rooting, the C/N ratio of stock plant cuttings are high, and conversely during

low rooting C/N levels decrease (8). Both starch and total carbohydrates contribute to the carbohydrate component of the C/N ratio, but there was no correlation between soluble carbohydrates (glucose, fructose, sucrose) and the rooting of *Rosa multiflora*. Nitrogen was negatively correlated to rooting; that is, high nitrogen depressed rooting.

Manipulation of C/N ratio. There are a number of ways to manipulate the C/N ratio of stock plants from which cuttings are taken. Nitrogen can be manipulated through fertility practices. Fertility of stock plants prior to harvesting cuttings can be reduced.

The carbohydrate component can be altered through light manipulation. Light can be increased by high-pressure sodium vapor lamps, or reduced by the use of shade cloth or saran placed over the stock plants. With selected *Rhododendron* species, growing stock plants under shade suppressed the competing sink of flowering and enhanced rooting of cuttings (10).

Etiolation is an extreme case of C/N manipulation. Changes in morphology and pigmentation occur and rooting success is enhanced. Etiolation and blanching of stock plants can be done under 95 percent shade (11).

The location of a propagule on a stock plant can influence C/N status. Terminal cuttings tend to have greater vegetative growth, which uses up more carbohydrate reserves. Nitrogen levels are higher so that they have a lower C/N ratio when compared to basal cuttings. Spacing stock plants close together reduces vegetative growth and allows accumulation of higher carbohydrate reserves in potential propagules. Pruning practices that reduce reproductive growth divert carbohydrate reserves for potential root formation. Girdling of stock plants prior to taking cuttings has been an effective method to allow carbohydrate accumulation and subsequent enhancement of rooting.

Nutrition. Few studies have approached the effect of nutrition on the various developmental stages of rooting: dedifferentiation, root initial formation, primordia development and elongation. It is quite difficult to conduct these type of developmental rooting studies.

Nutritional analysis has normally been related to the whole cutting tissue or the base of the cutting. Unfortunately this does not tell us what is happening with the nutritional levels of those few cells that are involved in dedifferentiation. Sampling large tissue areas may mask critical nutritional changes going on in those cells that are crucial to the rooting process.

Zinc is an example of how nutrients are directly involved in rooting. Zinc is a microelement and cofactor that helps trigger enzyme systems to convert tryptophan, the immediate precursor of auxin, to IAA.

Boron can enhance adventitious root formation by mobilizing citric and isocitric acids necessary to rooting and by increasing the uptake/absorption of auxin into the cutting. Boron can also decrease rooting by enhancing IAA oxidase activity, which metabolizes and breaks down endogenous auxin.

Manganese is another microelement that activates IAA oxidase to the detriment of endogenous auxin. In one of the few studies where there was a direct relationship between nutrient levels and rooting, easy-to-root clones of avocado had low Mn levels whereas difficult-to-root avocado clones had high Mn levels (12).

Most containerized nursery growers do not have the luxury of stock plant blocks, which means that cuttings are harvested from containerized plants. These may be under optimal nutritional conditions for production but not ideal conditions for rooting. It would be best in maintaining the momentum of the cutting that moderate nitrogen levels be maintained rather than high production levels. It is equally important that nutrient deficiency be avoided since the only nutrients a cutting has to rely on are endogenous levels at the time when cuttings are harvested from stock plants. A nutritionally deficient cutting creates cultural problems that are compounded throughout the whole production system. The result is an inferior product and increased cost due to a longer production time.

Leaching of nutrients with intermittent mist. Intermittent mist can severely leach nutrients from cutting leaves. Nitrogen and manganese are readily leached; calcium, magnesium, sulfur and potassium are moderately leached; and iron, zinc and phosphorus are leached with difficulty (5). When leafy cuttings are detached from the stock plant and placed under mist, the only nutrients available to the cutting will be its internal supply until after it has initiated roots. This means that with the rapid leaching that occurs under mist, a cutting can "run empty" very quickly. A difficult-to-root cutting usually takes much longer to form roots, and it is not surprising that nutritional deficiencies and disease problems compound the rooting problem.

Foliar deficiencies of cuttings can become quite apparent due to leaching, depending on the cuticle and wax thickness of the species and the growth stage of the cutting material. Leafy, semi-hardwood cuttings are more susceptible to leaching than softwood or herbaceous cuttings. A greater portion of nutrients is in an exchangeable form than in young growing tissues that more quickly metabolize nutrients within cells and cell walls (1). Foliar deficiencies can also occur with the redistribution or mobilization of nutrients within the cutting.

Reducing nutritional problems caused by mist. There are ways to improve nutrition of cutting after roots are formed (15). One way is by reincorporating a slow-release fertilizer such as Osmocote

18-6-12 at 2 to 6 lbs. per cu. yd. in the propagation medium. Some growers use as high as 8 lbs. but each producer needs to try small tests to determine what works best with his particular propagation system and species. Osmocote at ¼ to ½ ounce per square foot has also been top dressed on propagation media (7).

Dilute liquid fertilizer can also be applied after cuttings have formed roots. Using nutrient mist has not been an effective method since algae form on the medium and create aeration, drainage, and subsequent disease problems for cuttings.

There is little evidence to indicate that adding nutrients aids root initiation. Instead fertilization after root initiation can improve cutting root development and help speed up the production of rooted liners. The response of cuttings to fertilization is species specific. Cuttings of *Cotoneaster* spp. (3), *Ilex crenata* (15), *Juniperus conferta*, and *Ligustrum japonicum* (9) had increased root development, whereas *Syringa villosa* and *Thuja occidentalis* (3) showed no response. Some species are difficult to overwinter as rooted cuttings. *Acer palmatum* and *Cornus florida* cuttings may be adversely affected if nitrogen fertilizer is added to rooted cuttings in the fall prior to overwintering (6). On the other hand, growth flushes of rooted cuttings in late summer-early fall or with artificial long-day conditions may restore carbohydrate reserves important for good winter survival of cuttings taken late in the season (13).

Another method to avoid nutrient leaching problems is to use propagation systems other than conventional open mist. A closed mist system encased in a frame supporting polyethylene results in higher relative humidity. The actual amount of mist applied and, therefore, leaching can be reduced. Contact polyethylene sheets where semi-hardwood and hardwood cuttings are rooted without mist also avoid nutrient leaching problems. Fog systems with small-sized water droplets (<50μ) use less water and also avoid nutrient leaching.

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GROUND BEDS VS. CONTAINERS FOR SEEDS AND CUTTINGS

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Greenleaf Nursery, located in Park Hill, Oklahoma, is a wholesale nursery specializing in production of "Predictable Quality" container-grown ornamentals. Besides ornamental shrubs and trees we also grow annual and perennial color crops for fall and spring.

At Greenleaf we produce about 10 million liners annually. Most are propagated by cuttings, but we also propagate by seeds, grafting, budding and division. Our liners are grown either in ground beds or in containers, depending on the type program we have for production of that crop.

In our production the most economical method of liner production is through the utilization of raised ground beds rather than containers. Cuttings are rooted in ground beds, grown in this method

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Route 1, Box 163
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Greenleaf Nursery, located in Park Hill, Oklahoma, is a wholesale nursery specializing in production of "Predictable Quality" container-grown ornamentals. Besides ornamental shrubs and trees we also grow annual and perennial color crops for fall and spring.

At Greenleaf we produce about 10 million liners annually. Most are propagated by cuttings, but we also propagate by seeds, grafting, budding and division. Our liners are grown either in ground beds or in containers, depending on the type program we have for production of that crop.

In our production the most economical method of liner production is through the utilization of raised ground beds rather than containers. Cuttings are rooted in ground beds, grown in this method

and planted bareroot into 1- and 2-gal. containers. Using ground beds and planting bareroot we can reduce the cost of our liners, compared to propagating in containers, by about 8 to 10 cents per plant. The following are some methods that we use to propagate and grow our liners.

JUNIPER PRODUCTION

Our juniper production is in raised ground beds with a medium of ½ pine bark and ½ sand. The cuttings are taken from November through March using dormant hardwood cuttings. They are then placed in quonset-type houses that are covered with one layer of plastic and heated to 32°F. The cuttings callus during the winter months. Rooting occurs as spring temperatures rise. They are bed-grown one growing season and are planted about February 15th. By planting in early spring while it is cool we can plant bareroot with excellent success. Not only does this method eliminate the cost of plastic trays or pots, it also requires less production space. Less labor is needed in ground-bed production than with container liner production. Ground-bed production is the most economical method to produce our juniper liners.

BROADLEAF AND DECIDUOUS SHRUB PRODUCTION

Most of our broadleaf and deciduous shrub liners are produced in containers. Our severe spring freezes require that we wait until April 15th to plant our liners. Planting bareroot at this time of year with most plants results in poor survivability and slow takeoff after planting. By using containers we get good survival and almost immediate growth after planting.

In the past, cuttings were stuck in ground beds during summer months. The rooted cuttings were dug in the fall and potted into peat pots. They were plunged back into quonsets for winter and planted in spring. This method required considerable labor because we handled the plants so many times. The peat pots caused damage by inhibiting rooting into the surrounding medium in the larger container.

Liners are now grown in plastic cell paks. First the cell paks are filled with medium using a Gleason Model 30 flat filler. The cell paks are then taken to the greenhouse and set in place. The trays are set on a gravel base with a layer of Supac between the tray and gravel. Cuttings are then direct stuck into the individual cells in the trays. As rooting occurs the Supac allows the roots that emerge from the drain holes to penetrate into the gravel. However, the roots are girdled at the area where they pass through the Supac and it is easy to move the trays because the roots break off at the girdled areas. The plastic cell pak holds 24 liners and can be hauled to the field as a unit. This eliminates having to flat individual pots for hauling.

The cell paks cost 27 cents per unit or 1.13 cents per cavity as

compared to peat pots at a cost of 2.3 cents each. The cell pak is a disposable unit. It is used once and discarded. We use 45,000 trays per year so it is very expensive to sterilize and store that number of units each year. Another advantage over peat pots is that the roots are not inhibited and grow into the surrounding medium very quickly.

SEEDLING PRODUCTION

Seedling production is through the use of both ground beds and containers. Ground beds are used for cultivars that can be transplanted bareroot. Cultivars that do not transplant very well are grown in containers on raised wire benches; air pruning is used to get a good fibrous root systems. The use of raised benches and containers is more costly than ground beds, therefore most of our seedling production is in ground beds.

BARE ROOT VS. MILK CARTON SEEDLINGS

CHRIS C. THREADGILL
Sierra Chemical Company
12101 Woodcrest Executive Drive, #190
St. Louis, Missouri 63141

Historically, tree seedlings have been grown in raised ground beds in the field. High production densities and low production costs are associated with these methods of production.

Over several years a new concept in seedling production has emerged that warrants consideration by the nursery industry. In this system tree seedlings are produced in bottomless containers or "milk cartons." I have been asked to present the advantages and disadvantages of both systems. Some of the differences are included below:

BARE ROOT

Advantages: Relatively low initial cost, high production in limited area, light weight (shipping and handling), and ease of planting.

Disadvantages: Harvest season restricted, refrigerated storage required, one crop per season, greater transplant shock, certain species difficult to store, subject to spring frosts, weaker stems due to crowding, and more disease- and insect-prone due to crowding.

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MILK CARTON (AIR ROOT PRUNED)

Advantages (1,2,3): Produces superior root system, higher quality liner, accelerated growth characteristics, much more flexibility in handling and transplanting, multiple crops per year, larger stem caliper.

Disadvantages: High initial cost, not commercially available, non-uniformity due to seedling variation, and crowding.

Although field-produced bare-root seedlings are the standard in the industry, alternatives are available. For example, conifers are grown in assorted containers, typically tubes or plugs, primarily for forestry applications. While these containers take advantage of the extended planting season and increased survival associated with container-grown seedlings, these types of containers do not develop a root system like a bottomless container. When tree seedlings are grown in bottomless containers, each time a root tip grows through the bottom of the medium and out into the air, the tip desiccates and dies. This has the effect of repeated root-tip pruning and is very effective in stimulating lateral branches, not only on the primary root but on secondary roots as well (1). The resulting root system primes the seedling for accelerated growth with little or no transplant shock. In addition to the superior root system of the milk-carton-grown seedling, the flexibility of planting and harvest as well as the ability to produce several crops per season are important advantages over field growing.

However, the merits of bare-root tree seedlings need to be mentioned. First and foremost is that they are less expensive to produce when compared to air-root-pruned seedlings. Often a high population can be grown per unit area (>200,000/A). This can be both good and bad. The incidence of pests and disease is increased due to these plant densities. In addition, this spacing does not allow for adequate stem strength to develop. This is often corrected by pruning the tree down to a 4 to 6 in. height, and forcing a lateral bud to be trained as the central leader. This technique is dependent on a good root system and proper timing for satisfactory results.

The use of bare-root tree seedlings as rootstocks in grafting has a long history. It is unlikely that milk-carton grown seedlings could become a viable substitute to bare-root seedlings due to the high degree of success and ease of handling, but container-grown seedlings could make some headway with the difficult-to-transplant items such as *Carya* and *Cornus*.

The ability to store bare-root tree seedlings successfully is somewhat species dependent. Cultivars that fall into this group are often left in the field and spring dug, but conditions do not always permit prompt digging as the field may be too wet or frozen. Cultivars that do not store well but are in demand by the nursery industry represent potential for milk-carton growing.

The development and refinement of the air-root-pruning container was conducted by Dr. Carl Whitcomb and his students (2,3). The objective of this research was to grow a tree seedling that maximized growth in the shortest possible time. These milk-carton seedlings were potted to larger containers to realize the potential of super seedlings.

This system of potting milk-carton-grown seedlings to larger containers takes maximum advantage of the potential of milk-carton-grown seedlings. Not until more container growers evaluate this system of production and achieve salable sizes in much less time than with bare-root seedlings, will the milk carton container reach its potential.

LITERATURE CITED

1 Davis, Ben II. 1986. Utilizing air root pruning in nursery seedling propagation. *Proc Inter Plant Prop Soc* 36:399–402.

2. Whitcomb, Carl E 1981. Growing tree seedlings in containers. *Okla Agri. Exp Sta Bull* 755.

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TREES FROM CUTTINGS VS. THOSE FROM SEEDLINGS

DON COVAN

Simpson Nurseries
P.O. Box 160
Monticello, Florida 32344

Much research has been conducted in recent years in an effort to obtain accelerated growth from plants. Some of the work has centered upon the development of a better root system through the utilization of different hormone combinations. Other research has focused upon the development of containers that encourage well-branched root systems without spiraling.

From my experience in the production of trees using both cuttings and seeds, I believe that accelerated growth can best be obtained by giving special attention to the development of a well-branched fibrous root system and to the timely shifting up of the liner. At Simpson Nurseries we grow trees from bareroot liners, seed, softwood cuttings, hardwood cuttings, and from buds and grafts. However, the softwood production of trees compared to seedling production in bottomless containers is emphasized in the following information.

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TREE SEEDLING PRODUCTION IN BOTTOMLESS POTS

We grow 16 different cultivars of trees in our bottomless pot liner production. Production begins with direct seeding in 2¼ × 2¼ × 5 in. bottomless pots during October inside greenhouses. We start with disinfected pots, filling them with potting soil containing 65 percent bark, 20 percent Canadian peat, and 15 percent sand (6B gravel). To each cubic yard of soil, 10 pounds of Osmocote 18-6-12, 1½ pounds of Micromax, and 10 pounds of lime are added.

The trays are then placed on racks approximately 12 in. above the floor of the greenhouse. This distance above the floor enables good air root pruning. It is my belief that root pruning is one of the factors that gives us accelerated growth. It results in the development of a root system that is superior to root systems formed in conventional pots with bottoms.

When the seeds are ready or made available they are sown directly into the bottomless pots. The number of seeds planted in each pot is determined through past experience and success and, of course, depends upon the cultivar. After seed germination the seedlings are thinned to one per pot, leaving the largest seedling possible. The liners are grown in an unheated greenhouse through the winter and into the spring. We wait until the liners have grown to approximately 12 to 15 in. tall and have filled the bottomless container with enough roots that we can shift them up easily without loss of soil and without shock. The shift-up timing is crucial. If we can move up our seedlings by the first two weeks of June, we can grow a salable tree 5 to 6 ft. tall by fall. Unfortunately, this kind of growth does not occur with all cultivars.

Timing is not the only crucial factor when shifting up liners. Soil mix is also vital to successful transfer. When we shift our liners to 4-gal. pots, the soil mix used is exactly the same as the soil used to produce the liners. Soil compatibility ensures a smooth transition. In addition, we prefer to dibble a tablespoon of Osmocote 18-6-12 under the liner. This ensures that fertilizer is available when and where the plant needs it.

It is extremely difficult to determine which factor gives the greatest accelerated growth. We do feel, however, that the greatest improvement in growth has been due to the use of the bottomless pots, resulting in the development of a well-branched, fibrous root system.

TREE PRODUCTION FROM CUTTINGS

At Simpson Nurseries the majority of our softwood cutting production takes place in 2¼ × 2¼ × 3-in. rose pots with bottoms. Although some of our production from cuttings is taking place in bottomless pots, it is only a small percentage at this time. Most of our softwood cuttings are taken between the end of May and the

middle of August. Our propagation mix consists of 50 percent bark, 25 percent perlite, 15 percent Canadian peat, and 10 percent sand (6B gravel). To each cubic yard of this soil we add 5 pounds Osmocote 18-6-12, and 1 pound Micromax. After rooting has taken place and top growth is visible, we move certain cultivars of the liners up to 4-gal. containers. However, some cultivars, which will be discussed later, are held in the propagation area through the first winter.

Proper timing is essential when moving the first group of liners up to larger containers. First, the pot should be filled with roots but not to the point of spiraling. Second, only those liners that are ready by the first week of September are shifted up. This precise timing ensures good growth of the top and of the root system by fall so that natural hardening off can occur. For the liners we were able to shift in early July, we dibble a tablespoon of Osmocote 18-6-12 under the liner. Again, timing is crucial. If the liner is dibbled under too late in the summer, natural hardening off will not occur in the fall, increasing our chance of loss due to freezing that winter.

Basically, the growth of the softwood-propagated tree depends on timing. A small percent of the liners potted during the summer will reach full salable maturity by fall. The balance will be ready the following year. As mentioned earlier, some cultivars of liners, particularly red dogwood, *Cornus florida* 'Rubra,' and Bradford pear, *Pyrus calleryana* 'Bradford,' are not moved up the first year. These liners are held in the propagation area throughout the first winter to provide protection from hard freezes. We overwinter our dogwood liners in a greenhouse where supplemental heat and light are provided. Heat is supplied when the temperature is likely to drop below freezing in the greenhouse. Supplemental light is provided to extend the light hours each day until December 25. When the last killing freeze is over, these liners are transferred to 2- or 4-gal. containers, depending on the cultivar. As the liners are shifted up, 1 tablespoon of Osmocote 18-6-12 is dibbled under each one. Again, this helps to ensure optimum growth of the trees.

CONCLUSION

It is extremely difficult to compare the method of growing trees from cuttings with growing trees from seedlings. The time schedules are different, and the reasons for growing different cultivars using either of the two methods vary greatly. However, it is possible to achieve accelerated growth by using each of the methods if the following procedures are incorporated into the propagation process: 1) Use a propagation container that will allow a good fibrous, well-branched root system; and 2) pay close attention to shifting the liner up when the root system has just filled the pot. These two conditions are extremely important in the timely production of quality trees.

PROPAGATION OF UNDER-USED FLOWERING TREES

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Our nursery is located in Keystone Heights, Florida about 45 miles southwest of Jacksonville, which puts us in the middle of Hardiness Zone 9. We grow a standard line of shade and flowering trees in containers. Over the years we have tried to collect and evaluate different trees for our area with emphasis on flowering trees. We presently have several trees that show good potential.

Introducing new plants to the trade is difficult for any nursery and for a small nursery with a limited marketing budget it is especially difficult. Many retail nurseries and landscapers are reluctant to try new plant materials citing lack of demand or unfamiliarity with the plants. Therefore, we feel the ability of a tree to flower at an early age is a major consideration when evaluating them for commercial potential. Most nurserymen will agree that a plant in flower has much more salability than one that is not, especially when the customer is not familiar with the plant. This approach may eliminate the introduction of some very good trees but it is a start. We hope it will lead to a greater appreciation of different trees and ultimately a demand for the trees that require more time to flower.

There is really no difference between the techniques for propagating flowering trees and other trees. The only difference is the effect the method of propagation can have on the age that the tree will flower. Frequently trees that are vegetatively propagated from mature stock will flower at an early age, but this is not always the case. Some species and even cultivars within a species require many years to flower even when grafted or when grown from cuttings. The following is a brief description of the propagation techniques we use on some flowering trees and my observations regarding the effect of this technique on their flowering.

Chionanthus virginicus, our native fringetree, and *Chionanthus retusus*, the Chinese fringetree, are both excellent flowering trees for our area. Both bloom around late March or early April. Curiously, neither is readily available in our local nurseries. I believe *Chionanthus virginicus* is almost impossible to grow from cuttings. However seed propagation is quite satisfactory. There are no listed cultivars. Seedling trees can flower as early as two years of age. The seeds have a double dormancy and may require two years to germinate. We have tried to simulate the recommended stratification schedule in the nursery with little success. We find it to be easier either to collect seedlings that have sprouted in the wild or collect seeds, sow them in the field and let nature take its course.

We produce *Chionanthus retusus* from cuttings. While not the easiest tree to root we generally get 40 to 50 percent rooting when we take recently hardened terminal and subterminal new growth in July and treat with 1 percent KIBA quick-dip. Cutting-grown trees will bloom in their first spring. The biggest problem we have with cutting-grown trees is that they tend to produce a very shrubby growth and do not head up into a tree form. To correct for this in the future we intend to try seed propagation and see if *C. retusus* will flower as early as *C. virginicus* seedlings. We also intend to cut back some trees severely hoping to generate vigorous new growth.

Most *Cornus florida* selections that are in the trade come from regions farther north than our area and do not prove satisfactory for us. Therefore, trees sold in our local nurseries are almost exclusively seedlings. We have not found any red or pink cultivars that will flower consistently for us. An old white selection, 'Weaver', which was introduced by the Glen St. Mary Nursery, is the best white dogwood we have tested to date. It is very vigorous, has large, pure white blooms every year and will bloom consistently in central Florida. We have had good success producing it from cuttings.

We take terminal cuttings as soon as they are hard enough to stay erect when stuck. We use a 0.5 percent KIBA quick-dip and bunch stick them in beds of perlite. The cuttings are drenched with captan at sticking time and every two weeks thereafter. In 4 to 5 weeks we pull the cuttings out of the bed and remove those that are rooted. Rooted cuttings are potted in individual liner pots, and the remainder are restuck in perlite. Every two weeks we repeat this procedure. Cuttings that have been potted are left in the mist for about two weeks and then placed in another greenhouse under lights that extend the daylength by four hours. As soon as they develop new growth they are potted into gallon containers and placed out on beds. 'Weaver' and several others selections will flower their first year. A few other we are trying seem to take a few years.

Most flowering cherries in the trade require too much chilling for our area where we average around 300 hours. There are two, however, that have very low chilling requirements and flower consistently for us. These are *Prunus campanulata* and *Prunus* × 'Okame'.

Prunus campanulata, the Taiwan cherry, blooms in late winter along with *Cercis canadensis.* Its deep rose blooms are almost iridescent and put on a real show. The tree grows easily from seed with no stratification required. However seedlings do not flower for 7 or 8 years. We have had limited success producing *P. campanulata* from cuttings or from budding, and the resulting trees still seem to require quite a few years to bloom, therefore, it's difficult to get Taiwan cherry introduced into the trade. *Prunus* 'Okame' is easily

grown from cuttings and will flower the following winter. It shows the greatest immediate promise for us.

One very nice flowering tree that has been overlooked by the nursery industry is *Rhodoleia championii*. This evergreen tree, which is native to China, has thick leathery dark-green leaves with reflective silver undersides. It produces clusters of rose-colored camellia-like flowers in late winter.

Vegetative propagation of a few trees in the Gainesville, Florida, area proved almost impossible over many years of attempts. Cuttings from a group of seedlings that we started four years ago rooted at rates from 0 to 95 percent. Of the better rooting ones, we are selecting those with the best form. A few of the original seedlings flowered sparsely at three years and several more flowered the following year. The few cutting-grown trees we have observed appear to flower in one or two years. Interestingly the cutting-grown trees tend to grow more upright than seedlings, which start off quite shrubby. Because of this and the scarcity of seeds it appears vegetative propagation will be prefereable. Rooting seems to be best in late summer using 1 to 2 percent IBA.

We are working with several trees of the genus *Michellia* that show considerable ornamental potential. *Michellia doltsopa* and *Michellia doltsopa* × *M. figo* hybrids are faster and larger growing than *M. figo*. They bear fragrant white to cream magnolia-like flowers in December in our area. The flowers are around 3 in. in diameter and much more conspicuous than those of *M. figo*. Cuttings root readily throughout the summer using 0.5 to 1 percent KIBA quick-dip, and all flower at an early age.

Michelia maudei is a small evergreen tree that for us is in bloom almost half of the year. It has 5- to 6 in. pure white magnolia-like flowers that are very fragrant. It blooms mid-December through mid-March and then again from early June through late July. Our original seedling trees flowered at the age of 5 years. We rooted cuttings from the tree before it reached maturity. However, since it started flowering it has been difficult to get good cutting wood as there is a large flower bud at almost every node of the new growth. We were able to get some cuttings without buds from the last of this summer's new growth and will hopefully have success rooting them as this tree certainly has much ornamental potential.

LINER PRODUCTION OF *ACER RUBRUM* 'RED SUNSET' AND *MALUS* 'SNOWDRIFT' PROPAGATED IN VITRO

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Abstract. Potted liners of *Acer rubrum* 'Red Sunset' and *Malus* 'Snowdrift' grown from rooted microcuttings were planted January 21, 1988 in the greenhouse. The liners were transplanted to 10-gal. containers or to the field between June 5 and 10, 1988. They were grown with single stems, were drip irrigated and given one of seven fertilizer treatments. Container treatments were 150 ppm N, or 300 ppm N 20-10-20, applied 2X/week as a drip and 18-6-12 slow release as a topdressing at 160 g/container Field treatments were no fertilizer, 100 ppm N, 200 ppm N, and 400 ppm N 20-10-20 injected through drip irrigation at 1X/week. Data recorded in late August showed that container-grown plants had significantly taller stems and greater stem caliper than field-grown plants. Container-grown maple stem heights for 150 ppm N, 300 ppm N, and 18-6-12 slow release treatments were 68.3 in., 67.9 in , and 57 0 in , respectively. Crabapple stem heights for the same treatments were 40.5 in., 38.4 in. and 28.4 in. Stem heights of field-grown plants ranged from 48.2 in. to 35.9 in. for maples, and 21.3 in. to 20 6 in. for crabapples. Stem caliper (basal) was significantly greater for container-grown crabapples; some maple treatments were equal to field treatments Survival was 100 percent for the 210 plants in the experiment and quality was good to excellent.

REVIEW OF LITERATURE

In vitro lab techniques have been described for a number of woody ornamental plants, including economically important tree genera. Successful commercial production of trees propagated *in vitro* is equally dependent upon subsequent acclimation and nursery production stages. A number of authors have described general environmental parameters and cultural techniques for acclimating tissue-cultured plants, but important details concerning fertilization, light intensity, irrigation, and other postpropagation production tasks have generally been lacking. Recent reports (1, 2) showed that size and quality of several *Acer rubrum* cultivars and *Betula nigra* 'Heritage' are significantly affected by cultural variables such as shade regime during acclimation, fertilizer rate and plantlet size. For example, fertilizer injection with 100 ppm N resulted in high quality plants of 'Heritage' birch whereas 300 ppm N caused severe burn and stunting. However, 'Red Sunset' maples fertilized with 300 ppm N were of excellent quality and superior to those fertilized with 100 N ppm. Finished liners of maple, birch, and crabapple were better quality when grown from plantlets subjectively judged to be of higher quality prior to planting. The purpose of this study was to observe the performance of micropropagated ornamental trees in standard nursery production systems and to record the effects of various fertilizer treatments. This information would establish

basic guidelines for growers interested in using micropropagated plants.

MATERIALS AND METHODS

Greenhouse-acclimated liners of *Acer rubrum* 'Red Sunset' and *Malus* 'Snowdrift' planted January 21, 1988 as rooted micro-cuttings were transplanted into 4 field and 3 container treatments the first week of June, 1988 (Table 1). Field soil was an Etowa silt loam with pH 6.2, low phosphorus, and high potassium. The container medium was 3:1 (v/v) pine bark: peat, amended with 7 lbs. dolomite, 2 lbs. treble superphosphate, 2 lbs. 10-10-10-granular fertilizer, 2.5 lbs. gypsum, and 1.5 lbs micronutrients per cubic yard. The medium was about pH 5.0 at planting. Container and field plants were fertilized for 2 weeks after planting with 100 ppm N 20-10-20. Treatment fertilizer was initiated June 14 and performed 1×/week for field treatments (4 hours irrigation then 1 hour fertilizer) and 2×/week for container treatments (1 hour irrigation then 1 hour fertilizer). Plants were irrigated as needed based on daily observations. Soluble salt levels were determined each week throughout the experiment. The experiment was arranged in a randomized design with 5 replications and 3 plants/cultivar/replication. Stem height and caliper 3.5 in. above the medium were measured at the end of August, 1988 and mean separations determined using the SAS analysis procedures.

Table 1. Descriptions of field container treatments.

Field treatments
Control: Drip irrigation 1× per week. No fertilizer applied.
100 ppm N 20-10-20 applied 1× per week with drip irrigation as needed
200 ppm N 20-10-20 applied 1× per week with drip irrigation as needed
400 ppm N 20-10-20 applied 1× per week with drip irrigation as needed
Container treatments
150 ppm 20-10-20 applied 2× per week with drip irrigation as needed
300 ppm 20-10-20 applied 2× per week with drip irrigation as needed
18-6-12 slow release at 160 g/10 gal. container as a top dressing

RESULTS

Stem height for 'Red Sunset' maple and 'Snowdrift' crabapple was significantly affected by fertilizer treatment and production method (Table 2). Maples and crabapples grown in containers at 150 and 300 ppm N (20-10-20) were equal in height but significantly taller than all other treatments. The 18-6-12 slow-release container treatment was significantly better than field treatments for both maple and crabapple. Field-grown maples receiving no fertilizer or 100 ppm N were taller than those grown at the higher fertilizer rates.

Table 2. The effect of fertilizer treatment and production method on stem height of 'Red Sunset' maple and 'Snowdrift' crabapple.

Treatment	'Red Sunset' maple	'Snowdrift' crabapple
Container-grown (10 gal)	*Mean height[1] (in)*	
150 ppm 20-10-20	68.3a	40 5a
300 ppm 20-10-20	67.9a	38.4a
18-6-12 slow release	57 0b	28.4b
Field grown		
100 ppm 20-10-20	48 2c	20.6c
No fertilizer	46.7c	21.3c
200 ppm 20-10-20	36.6d	20.6c
400 ppm 20-10-20	35.9d	21 3c

[1]Means within a group followed by the same letter are not significantly different at the 5% level of probability according to Duncan's New Multiple Range Test.

Stem caliper for maple and crabapple in container treatments was significantly greater than those of field treatments (Table 3). Caliper of container maples receiving 150 ppm or 300 ppm was equal or greater than those in the 18-6-12 slow release treatment. There was no difference between caliper for field-grown crabapple treatments.

Table 3. The effect of fertilizer treatment and production method on stem caliper (mm) of 'Red Sunset' maple and 'Snowdrift' crabapple.

Treatment	'Red Sunset' maple	'Snowdrift' crabapple
Container-grown (10 gal)	*mean caliper[1] (mm)*	
150 ppm N 20-10-20	13 7a	8.4a
300 ppm N 20-10-20	13.5a	8.1a
18-6-12 slow release	11.5b	7 7a
Field grown		
100 ppm N 20-10-20	10.7bc	6.8b
No fertilizer	10 3cd	6 5b
200 ppm N 20-10-20	9.2de	6.5b
400 ppm N 20-10-20	9.1de	6 5b

[1]Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's New Multiple Range Test.

DISCUSSION

Maples and crabapples grown in containers were significantly taller than plants grown in the field. Both liquid-feed treatments (150 ppm N [20-10-20] and 300 ppm N [20-10-20]) produced taller plants than 160g/container 18-6-12 slow-release. Fertilizer treatments in the field had no effect on the height of crabapple, but the two highest rates (200 ppm N [20-10-20] and 400 ppm N [20-10-20]) suppressed the height of maples. Caliper followed the same trends as plant height except there was no difference in caliper of

crabapples grown in containers in any of the three fertilizer treatments.

Plant growth in the field was significantly less than growth in containers and may have been influenced by soil drainage conditions. The starting pH of 6.2 dropped to about 6.0 in the no fertilizer or 100 ppm N treatments, but to about 5.0 in the higher fertilization treatments. Soluble salt concentrations in the field soil tended to be low, 50 to 100 micromhos in the no fertilizer treatment, and 80 to 150 micromhos for the 400 ppm N treatment. The higher values were recorded near the end of the experiment. Container pH was 0.5 to 1.0 units greater at the end of the experiment, probably due to the alkaline city water supply. Container soluble salts were higher (250+/− micromhos) than in the field.

Soil and container temperature may have reduced plant growth in this experiment. Container-medium temperatures as high as 104°F were recorded on the west side of containers in the 18-6-12 slow-release treatment. The remaining container treatments were shaded to some extent, which may have contributed to their superior performance. Soil surface temperatures as high as 100°F were recorded adjacent to field plants.

Better growth might have been realized if liners had been planted 4 to 6 weeks earlier. Although plants apparently never suffered drought stress, the extremely hot summer may have delayed bud break in crabapple causing many plants to stop growth prematurely. Maple and 'Heritage' birch (not reported) had continuous growth throughout the growing period.

This work shows that rooted microcuttings propagated in a typical polyhouse using a midwinter production system and standard nursery production procedures can be used to produce satisfactory growth.

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PROS AND CONS OF TREES FROM TISSUE CULTURE

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We at Bracken Tree Growers are convinced that tissue culture will revolutionize the future of tree propagation. Admittedly this technology is still in its infancy with many liabilities yet to be resolved. Our experience with the procedure leads us to believe that the positives of improved product quality and speed of production will soon make tissue culture an industry standard.

Our experience is strictly from a grower's viewpoint. We buy our material at stage three from several tissue-culture laboratories and acclimate it ourselves. We have been producing tree liners from tissue culture for two years—patented red maples, three cultivars of birch, amelanchier, flowering cherry, and crab apples. Beginning production for our field-grown liners, we now sell 20 percent of our tissue cultures as acclimated micropropagated liners.

While we still propagate from cuttings, our substantial commitment to tissue culture has given us a broad base for assessing the pros and cons of this technology. The advantages lie in the areas of greatly increased product quality and quantity.

The superior quality of tissue-culture plants appears in three main areas:

1. **Production of virus and disease-free plants.** Recent research has revealed the need to control viral and bacterial growths in plants, which are much more extensive than previously known. Such factors as ice nucleation figure prominently in this area. Our actively growing tissue-culture plants taken from the greenhouse to the field on September 26th experienced a 16°F freeze on October 15th. They showed no sign of injury while our non-tissue culture field-grown plants were severely damaged. Could the lack of bacteria in the tissue-culture plants have kept them from freezing? The possibilities for generating "clean" growth are only beginning to be investigated.

2. **Generally better quality and more rapidly growing plants.** Our tissue-cultured red maples did not require staking while our cutting-grown maples have. The tissue-cultured maples developed better caliper within the growing season without crooks from cutbacks. Rapid growth does make tissue cultures susceptible to stress-induced bends, but 'Heritage' birch forms clumps more easily due to juvenility and more basal buds.

3. **Uniformity of crop.** As plants are genetically identical, variance is due to water, fertilizer, insects and disease. These factors we can control.

Two further advantages can boost your profit margin:

1. **Elimination of a stock block.** With tissue culture there is no need to develop and maintain a stock block to provide cuttings. This entire overhead expense is eliminated.

2. **The speed of reproduction.** Once the formula is worked out in the lab, the number of trees produced is virtually unlimited. A liner producer can get "hot" market items into production and capitalize on the peaks of market trends.

In considering the advantages of tissue culture mentioned, some of the disadvantages are readily apparent. Most of these problems arise from the newness of the technology and will be solved through practice and research.

Tissue culture today is what mist propagation was in the 1950s. As then, one of the major concerns with new technologies is *overproduction*. The industry adjusted to certain gluts produced by previous "breakthroughs"; tissue culture presents no greater threat. Actually not all plants respond readily to tissue culture, though new cultivars are available almost monthly. Perhaps the initial deterring factor with tissue culture is *cost*: micropropagated rooted plantlets are expensive—40¢ to 66¢ per plant. More exacting facilities are required for handling tissue culture. Sanitation procedures include weekly disinfecting, methodical washing of hands and feet, Clorox dips, to name a few. These routines quickly escalate production costs. In addition, plant loss can be high. Our rate is 100 percent to 30 percent livability. Add to this the pots, soil mix, bench space, and potting labor and you have made a substantial investment.

The major difficulties encountered involve dependence on the laboratories. We experienced several problems with the cultures themselves:

1. **Incorrect chemical mix.** We received a shipment in which half the plants appeared anemic. Upon inquiring, we learned that they had not received the right chemical mix but had been top dressed to compensate. They never responded. Our reimbursement for the plants did not compensate for loss of time and materials.

2. **Incorrect plants.** We had one large order of plants not true to name, a fact not recognizable until they produced mature leaves. As the trees were pre-sold, we were left trying to make up a 6,000 plant shortage.

3. **Uncertain delivery.** Dependency on the laboratory for your production cycle is the most debilitating aspect of tissue cultures. In 1987 we received plants April 1st, acclimated fully, went to the field in May, and made 5- to 6 ft. trees by October. But some of our 1988 order did not arrive until July. Intense heat reduced our livability and prevented transfer to the field, costing us not only one year's growth but one year's sales as well. The scenario could be worse: if a lab becomes contaminated, you receive nothing.

With all of its present liabilities, tissue culture is already a

viable part of our industry and with maturity will become a standard. Though far from a "magic bullet" it offers solutions to many propagation problems. All serious propagators need to investigate this expanding field and experiment to determine if it will work for their operation. Our advice is to hedge your bets: We know of several who went totally with tissue culture and lost 100 percent of their plants.

Bracken Tree Growers has given information and assistance to researchers, governmental agencies, and numerous individuals regarding the actual implementation of tissue culture propagation in a working environment. We trust our experience can aid the industry in assimilating this valuable new technology.

PROPAGATING NEW MAGNOLIA CULTIVARS

DAVID G. ELLIS
Magnolia Nursery and Display Gardens
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Roberts Road
Chunchula, Alabama 36521

Todd Gresham, the City Parks Director for Santa Cruz, California, hybridized Asian magnolia species and cultivars intensively during the 1960s. Some of the names Gresham gave earlier hybrids are 'Rouge Alabaster', 'Leatherleaf'. 'Raspberry Ice', 'Royal Crown', 'Crimson Stipple' and 'Royal Flush'. Specific information about these hybrids may be cited in *Magnolias* by Neil Treseder. Before his death Gresham dispersed 1600 of his seedlings, which had not yet bloomed, to the Gloster Arboretum located in Gloster, Mississippi. In the late 1970s these seedlings began to reach blooming age. Several enthusiasts began to select and number magnolias that had particular beauty. Ken Durio, owner of Louisiana Nursery in Opoleusas, Louisiana, named the following cultivars: 'Tina Durio', 'Darrell Dean' and 'Mary Nelle', named for the wife of the late Joe McDaniel. 'Sweet Sixteen' and 'Elisa' are two other early selections. Professor Joe McDaniel, Dr. John Giordano, and Dr. John Allen Smith made approximately 50 selections, which were propagated by cuttings and planted in their respective gardens. As these plants matured, their commercial value became apparent. Further observation and selection by Magnolia Nursery resulted in the following cultivars:

Magnolia 'Sangreal'. Cup-shaped, red-purple flowers, up to 8 in. across, open early and continue into the bloom season.

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Magnolia 'Sangreal'. Cup-shaped, red-purple flowers, up to 8 in. across, open early and continue into the bloom season.

M 'Dark Shadow'. This compact tree makes an excellent presentation of very deep colored red-purple flowers. Buds just before opening are 2⅓ in. long.
M 'Full Eclipse'. Early blooming with erect pointed tepals, which reflex slightly to produce a carefree effect. Long slender tepals are red-purple outside, whitish inside. Tree has columnar growth habit.
M 'Winelight'. Large 8-in. flowers open somewhat later than most. Thick tepals, even distribution of blush covering ⅓ of the tepal fading to white at the tips.
M 'Candy Cane'. Somewhat early blooming the 6-in. flower is marked by thin stripes arising from the base. These stripes are deep rose. They are very stark and hence suggest the name.
M. 'Jon Jon'. Late flowering, almost in a season within itself. Flowers profuse, quite large 10 to 12 in. The flower is essentially white with a slight rose coloration at the base. Excellent branching habit forms a rounded crown.
M 'Pink Goblet'. Midseason bloomer with bloom lasting well into the season. Ten- to 11-in. flower holds a classic goblet shape. Flowers are evenly spaced and from a distance appear to be solid pink. A vigorous grower with a regal classic appearance.
M. 'Deep Purple Dream'. The darkest red-purple of all our magnolias. Tree is slow growing and small in habit. Blooms when small. Not a prolific bloomer yet continues sporadically throughout the growing season. Blooms are not affected by frost or late freezes.

Initially we intended to propagate by chip budding. However, we discovered that rooting these magnolias was relatively easy. We prefer plants on their own roots, of course. Initial efforts were with buttersoft cuttings transported by cooler from Gloster. They were wounded on one side and stuck under heavy mist. Root development took place on one side and often in the air above the rooting medium due perhaps to lack of oxygen in the rooting medium. However, rooting was excellent.

In 1985 Magnolia Nursery began building up stock of all 50 selections by cutting propagation. The rooting agent used initially was Woods Rooting Compound at the rate of 1:5. The rooting medium was pure pine bark amended on a per cubic yard basis with a 1.5 lbs. of Micromax; 9 lbs. of Osmocote 18-6-12 (8- to 9-month formulation); 6 lbs. of dolomitic limestone; and 1.3 lbs. of gypsum.

Containers used were 4-in. pots (Lerio SR 400). Softwood cuttings were taken in early spring and wounded on two sides through the third leaf node below the terminal. Cuttings were approximately 6 in. long with two nodes exposed. Leaves were trimmed to allow air flow. Mist frequency was initially set at 6 sec. every 6 min. and backed off as rooting developed.

Close attention to detail yielded near 100 percent rooting with the exception of JG 3, later named 'Jon Jon'. Unrooted cuttings of 'Jon Jon' along with *Magnolia denudata* were pulled aside during transplanting the following June, wounded once again through the callus, dipped in Wood's 1:5 and stuck once again. Rooting percent increased to acceptable levels.

Experimentation with hormonal mixes have continued, using moderate levels of IBA and NAA as well as changes in medium. Recent efforts involved a mix with approximately 90 percent

coarse-grade perlite with 10 percent peat. Nutritional levels of rooting media have remained the same. The hormonal combination was 5,000 ppm KIBA initially on cuttings taken late April to mid-May. After mid-May 5,000 ppm KIBA + 1,500 ppm KNAA was used.

Mist failure resulted in 90 percent leaf desiccation on cuttings taken in April. Although the cuttings had just begun to callus, new growth had started due to the youth of the cutting material. Primary leaves were allowed to remain in order that even small amounts of photosynthesis might occur to maintain some sort of metabolism. As new growth developed old leaves were removed. Even after the catastrophe nearly 100 percent rooting occurred. Growth was excellent. Cuttings stuck later in the growing season were much slower to root, yet percentages were still good. New growth occurred mostly from the base of the cuttings. This new growth was less vigorous than that of the earlier cuttings. This experience has shown that buttersoft or near buttersoft cuttings are desirable. Cuttings of 'Jon Jon' rooted considerably better, indicating that KNAA might be helpful. Otherwise no significant effects of KNAA on later cuttings were noted. I feel that some cultivars might benefit from KNAA on early cutting.

Winter exposure of first-year container production has proven risky. Containers are overwintered in minimum-heat houses to prevent root injury. This also gives us early growth for propagation.

Efforts to propagate *Magnolia grandiflora* have indicated one major trend; results will be cultivar specific. Cuttings have typically been taken in early to mid-August. Mid- to late July would probably be better. Five magnolia selections are listed and described below with a rooting rating of 1, good—to 5, poor.

M 'Fairhope I'. Dense branching, short nodal length, large round wavy leaves with little indumentum, rounded crown (2.5).

M. 'Fairhope II'. Narrow lanceolate slightly rippled leaves. Good brown indumentum. New growth appears with silver tint. (4).

M 'Springhill'. Columnar to pyramidal in habit. Leaves are very glossy deep green and elliptic with pointed tips. Apparently not subject to leaf blotch problems. Gold-colored indumentum. Pure white blooms. (3).

Unnamed magnolia from Lillian, Alabama. Very heavy indumentum approaching chocolate brown. Leaf is moderate sized and elliptic, deep green and glossy. Bloom is typical. (5).

M 'Lakeside'. Large curvy leaf. A very fast growing tree. (1).

All selections have been rooted but with varying degrees of success as indicated. Better rooting might be achieved by earlier timing as well as improved drainage of the rooting medium. In 1986 we tried Wood's 1:1 with pine bark. We had varying degrees of success with different selections. In 1987 we had similar responses with 10,000 ppm KNAA in pure perlite. We have at present a batch of cuttings stuck with 5,000 ppm KIBA + 5,000 ppm KNAA in 90

percent perlite and 10 percent peat. Response seems good with rooting apparent as well as good callus throughout. One comment: with *Magnolia grandiflora,* good callus does not necessarily mean that rooting will occur. In any event, cutting production of *Magnolia grandiflora* is far superior to seedling propagation. Overall growth will far exceed in both rate and habit if good selections are propagated.

In conclusion, I stress the importance of timing, heavy mist, moderate hormonal levels, wounding, and excellent medium drainage to compensate for increased mist and tender wood.

IDENTIFICATION AND PROPAGATION OF VARIOUS LIRIOPES AND OPHIOPOGONS

GARY ADAMS

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IDENTIFICATION

The justification for this discussion is that liriopes and ophiopogons are used in huge numbers, that they are so easy to grow, that few people know the fine points of production, that there are cultivars of great merit which are virtually unknown. Evergreen Nursery has specialized in groundcover production, mainly ivy and liriopes, since the 1960s. At present we produce 24 cultivars of liriopes and ophiopogons.

What are the differences between liriopes and ophiopogons? The most useful point of identification is that the ophiopogon flowers hang down on their scape, while liriope flowers are held erect. Ophiopogons are slightly less hardy, are usually strongly rhizomatous, always bear the flowers down in the foliage and have a flower with a subinferior ovary. Liriope flowers bear a superior ovary. Cultural practices discussed apply equally to liriopes and ophiopogons unless otherwise indicated.

Differentiation between species and cultivars begins at the root system. There are caespitose, or clump-forming types, and rhizomatous types.

The rhizomatous species are the most common and include *Liriope muscari, Liriope spicata,* and *Ophiopogon japonicus.* Of these *Liriope muscari* is the slowest spreader and the prettiest in flower. Leaves are up to ½-in. wide and 12 to 15 in. long on established plants. The flowers are held about the same height as the foliage and are a lavender-blue.

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I know of two *L. muscari* cultivars that are rhizomatous. 'Tidwell's Big Blue,' compared to the species, is a larger plant, usually darker in color with larger fruit, which are usually abundant. This is a vigorous grower that originated at Tidwell's Nursery in Greenville, Georgia. 'Samantha' originated at Doug Young Nursery in Forest Hill, Louisiana. It's a vigorous grower with dark green foliage and a nearly-pink flower color. It is our earliest-flowering cultivar.

The species *Liriope spicata* has leaves usually under ½-in. wide and 6 to 18 in. long. Compared to *L. muscari,* the leaves are more slender and pointed. Flower display is poor. The color is very pale, and the scapes are no taller than the foliage. *L. spicata* is a vigorous spreader and in time will make a thick, even turf. It is a poor choice for a border but it's a great groundcover and soil-retainer.

I believe 'Silver Dragon' to be a *L. spicata* cultivar. Its flowers are held erect like other liriopes. It is slightly smaller and slower-growing than the species; it tends to revert to a solid green leaf sometimes and it has fruit variegated like the foliage.

What is sold for *L. muscari* and *L. spicata* is actually a conglomeration of species, hybrids, mutants, and variants. This is especially true for *L. muscari. Liriope muscari, L. exiliflora, L. graminifolia, L. intermedius, L. spicata, Ophiopogon jaburan,* and *O. japonicus* and others that have grown in the southeast U.S. for at least 150 years. Liriopes and ophiopogons are very fertile and hybridize and mutate freely. Therefore, it is not surprising to find variability within what is acceptable as a species.

A third rhizomatous species, *Ophiopogon japonicus,* is known by its Japanese name, mondo. This is a vigorous spreader and makes a thick, even mat. The flowers and jewel-like blue fruit are, unfortunately, hidden down in the foliage. The leaves are about ¼-in. wide or less and 4 to 10 in. in length. Here again, we have a good groundcover and a high-maintenance border.

There is a dwarf form that grows to about 2 in. It is slow to spread, so it is most effective in confined spaces. Dwarf mondo could be used as a grass substitute where there is little foot traffic.

We have a variegated cultivar, 'Kigimafukibuma,' which is slightly smaller and slower than the species.

Another ophiopogon species, *O. planiscapens,* is known by its cultivar, 'Nigrescens.' Black mondo is truly unique in appearance but grows with slug-like speed.

"Aztec grass" is a representative of another ophiopogon species. It is very popular in Florida but it isn't cold-hardy in northern Georgia.

The following caespitose or clumping forms of liriope are all assumed to be muscari cultivars. They are distinguished by their root systems and their superior flowering and foliage characteristics. *Liriope spicata* is often called "creeping liriope" because it

is so rhizomatous. *Liriope muscari*, to distinguish it from *L. spicata*, is often called "big blue liriope" because its flowers are bigger and bluer. This terminology creates endless confusion with muscari and its cultivar 'Big Blue', an improved type.

I say "improved type" because I know that what is offered in the trade as 'Big Blue' is not clonal stock. Non-rhizomatous seedlings of muscari with superior foliage and flower characteristics are not at all uncommon, and this seedling stock has thoroughly permeated the trade.

To deserve a higher price tag, what is sold for 'Big Blue' should be a caespitose green liriope with foliage larger and darker green than the species. The inflorescence should be displayed well above the foliage and should have flowers bluer and more numerous than muscari. Usually the inflorescence tapers to the apex. 'Majestic', 'Royal Purple', 'Lilac Beauty', 'Monroe's White' and 'Christmas Tree' have vegetative characteristics similar to 'Big Blue.' The main difference between these cultivars is in their inflorescences.

An inflorescence that seems abnormally flattened and seems to be several units fused together is said to be fasciated. Fasciation creates a cockscomb effect, as contrasted with forking, where the scape actually branches. Any muscari liriope can exhibit forked and/or fasciated inflorescences.

'Majestic' is an old cultivar that has a strong tendency to fasciate. Its scape and flowers are violet and the inflorescence is blunt or fasciated.

'Lilac Beauty' is a standout because of its lilac-purple flowers held high on scapes coming straight up from the center of the plant like a bouquet. 'Purple Bouquet' is reputedly very similar. Riegel Plant Company, Griffin, Georgia, claimed both these originations. For us 'Lilac Beauty' is the latest to flower.

'Royal Purple' comes from South Carolina. It has richly-colored flowers and a superior appearance even when not in flower.

Two good cultivars originated at Monroe Landscape Company in the 1930s and were introduced in the 1950s. 'Monroe's No. 1' or 'Monroe's White' bleaches easily in the sun. Its white flowers make a beautiful show in the shade. 'Monroe's No. 2', or 'Christmas Tree', is distinctive for its light violet, almost pink flowers in a conical shape.

Four cultivars not notable for their flowers but for their distinctive foliage and habit are 'Webster's Wideleaf', 'Densiflora', 'Evergreen Giant' and 'Green Midget'. 'Webster's Wideleaf' has the largest leaves of any liriope. It is not fast to increase. 'Densiflora' has long, slender leaves held more upright than in other cultivars. It makes a great tall, tight border or foliage accent. 'Green Midget', another Riegel introduction, is the smallest liriope. It makes a good low border or facer plant. 'Evergreen Giant' is at the other extreme in size. It grows 2 ft or more in height and has thick leathery, dark-

green leaves. 'Evergreen Giant' has been extremely popular in warmer parts of the country, but in Athens, Georgia, it isn't reliably cold-hardy.

Liriope muscari 'Variegata' grows to about the same proportions as the species but is slower. The flower display is better and the color is a bright purplish-lavender.

White-flowering variegated liriope originated at Southern States Nursery in Florida. For us, it is slower than common variegated and not as floriferous. The flower display is not as good because of the background foliage.

There is much confusion about 'Silvery Sunproof'. Buyers frequently receive 'Variegata' when they order 'Sunproof.' The two distinguishing characteristics of 'Silvery Sunproof' are its striated leaves and ascending habit. When mass planted, it does have silvery appearance. It is less floriferous than most cultivars.

Mr. Riegel originated three good variegated cultivars. 'John Burch' has the largest inflorescence of any liriope and broad leaves of dark green with golden-yellow variegation. The variegation is usually marginal.

Marginal variegation and an arching growth habit are hallmarks of 'Gold-Banded'. It has lavender flower spikes. The variegation may nearly disappear in sun or heavy shade.

The most distinctive features of 'Silvery Midget' are its small size and random golden variegation. The gold color whitens in dormancy like other variegated liriopes. The lavender flowers are held nicely above the compact plant. It's a slower grower.

Liriope identification can be next to impossible when the plants are not in flower. The size, appearance, and "feel" of the plant varies with age and growing conditions. This situation is further complicated by the extreme likelihood of encountering seedlings or misnamed plants along the way. But even with these difficulties, I feel it is worthwhile to learn these plants because their use can only refine our landscape designs.

PRODUCTION

Liriope and ophiopogon propagation and culture are nearly fool-proof, but there are some ways to improve production. Water management is critical for optimum growth. This surprises some people, given the plants' extreme drought tolerance. But the best growth is obtained when plants are never allowed to dry out or to become soggy.

Growth on liriopes in pots and in raised beds is superior, so it is easy to be convinced of the importance of good aeration. It is important not to set the crown too deep.

In the landscape liriopes may live indefinitely without supplemental fertilization, but they do respond well to feeding. At Evergreen Nursery we apply liquid 16-4-8 through the sprinklers.

Ground beds get monthly application March through September at a rate of 120 lbs. per acre. Container plants get weekly applications March into October at a rate of about 150 lbs. per acre. I am satisfied that these rates could be increased substantially, at least in the spring season, with a corresponding increase in growth.

Liriope spicata and the ophiopogons appear to grow continuously. However, *Liriope muscari* makes most of its growth in the spring, and the *L. muscari* cultivars tend to grow only in the spring. But abundant moisture and high fertility can dramatically improve the summer growth of all these.

Liriopes and ophiopogons have one disease problem, which can be cosmetically serious. An anthracnose fungus causes reddish or necrotic streaks in the leaves, beginning at the tips. This occurs on the older foliage only, beginning in midsummer and worsening as the old foliage declines in the dormant season. The problem is usually less severe where there is less overhead watering. Spray applications of Manzate fungicide are very helpful if begun in July before the fungus gets started.

The only insect problem of liriopes is a scale that hides underneath the leaf and causes yellow spots. This pest shows up in midsummer. Malathion, among other insecticides, will kill the crawler stage; dormant oil is helpful later on.

The incidence of both disease and insect problems is reduced by mowing or pruning off the old foliage in late winter, especially if the cut leaves can be removed. Here is the major difference between liriopes and ophiopogons in culture. Mondo grass does not respond well to mowing or clipping. A close mowing at certain times seems to cause stunting.

Warm weather planting seems to be more important for mondo grass than with liriopes. In warm weather the recovery time is very quick and losses to rot are minimized.

Established liriopes in the ground are apparently quite tolerant of a variety of preemergent herbicides. Sprinkler-applied herbicides I have used include Kerb, Devrinol, Princep, Surflan, and Ronstar. Granular products we have used include Ronstar, Pennant, Treflan, Southern Weedgrass Control, and simazine. A few plants should be tested before treating a large number of plants. It is important before applying any kind of preemergent spray to water the plant sufficiently to settle the soil.

For those with cold storage, plants of *L. muscari* and its cultivars store very well at 45 F, provided they are not packed wet. *Liriope spicata* and ophiopogon plants store well for days, but not for weeks, as with *L. muscari*.

Propagation may be done in three ways: by division, by seedage, and by tissue culture. I strongly prefer division for one reason—there is less variability of the product. The cause of seedling variability is obvious, but I do not understand the

variability arising in tissue culture.

Seedlings from variegated muscari can be up to 50 percent variegated. There will be differences in variegation, size, growth rate and flowering. 'Monroe's White' will produce a majority of white-flowering seedlings but there again variation will show.

The concept of propagation by division is simple—cut it up in pieces and plant it. The part that is divided is the crown, from which the leaves and roots both grow. Rhizomatous plants can be reproduced by pieces of rhizome. We cut the clump of liriope with a hatchet or knife, then pull apart the individual bibs.

In old plants the crown grows downward and eventually looks like a corn cob. These "cobs" may be cut off and planted. Chips of crown tissue smaller than a pencil eraser may be used successfully. The new growth will be slow to start, but this is a very efficient propagation method. Usually three growing seasons produce a profitable-sized plant.

We occasionally break the set of leaves off a division in the process of digging and dividing clumps. If these leaves are bound together by a ring or layer of crown tissue, they may be planted and will grow on nicely.

People are interested to know if mowing liriopes and ophiopogons speeds up the multiplication process. I think I have seen a favorable effect on rhizomatous types. I am sure that mowing during dormancy is not detrimental to the growth rate, provided that mondo grass is not "scalped." However, good soil preparation and an abundance of water and fertilizer are the keys to maximum growth.

PROPAGATION WITH KLIPKLEEN PRUNING SHEARS

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A gravity feed, fluid delivery system for use with hand-held pruning shears has been advertised in nursery trade magazines and demonstrated at nursery trade shows. A paper introducing the KlipKleen™ Pruning Systems was presented at the 1987 SNA Research Conference (1). Initially the intended use of this device was for sterilizing the base of stem cuttings prior to placing them into a rooting medium. However, it may have considerable advantages as a means of collecting and treating cuttings with root-promoting compounds at the time of severance. For nurserymen this one-step procedure could eliminate time-consuming cutting preparation prior to sticking cuttings. Treating cuttings at the time of severance from stock plants might improve hormone movement into cuttings and increase the rooting response. In August, 1988, at the SNA Research Conference, results of two experiments completed at North Carolina State University using KlipKleen pruning shears as a propagation tool were reported (2).

The objective of this study was to compare use of quick-dip and KlipKleen propagation techniques after waiting periods between severance and hormone application or severance, recutting the stem, and hormone application.

MATERIALS AND METHODS

Application of rooting compounds with the KlipKleen™ Systems and standard cutting preparation techniques were compared. *Ilex* 'Nellie Stevens' holly cuttings were collected August 9, 1988. Cuttings were placed in Tray Masters of Florida #24 (2 ¾ × 3 ⅛ × 4 ⅜ in.) cellular trays filled with a steam-pasteurized medium of 1 part sphagnum peat moss:1 part coarse perlite (v/v). Cutting preparation and treatments were as follows:

1. Water quick-dip: Cuttings were removed from stock plants with pruning shears, the basal 1 in. (2.5 cm) immersed in distilled water and stuck immediately in propagation trays.
2. IBA quick-dip: Cuttings were removed from stock plants with pruning shears. The basal 1 in. was immersed for 5 sec. into a solution of 0.5 percent (5000 ppm) indole-3-butyric acid (IBA). (The solution was prepared by dissolving reagent-grade IBA in isopropyl alcohol and diluting with distilled water to a final IBA concentration in 35 percent isopropyl alcohol.) Cuttings were immediately stuck in propagation trays following treatment.

3. Cut-wait-IBA quick-dip (CW-IBA): Cuttings were taken with pruning shears, but were not prepared for sticking until after a two-hour waiting period. At that time, a 5-sec. immersion was made into the 5000 ppm IBA solution.
4. Cut-wait-recut IBA quick-dip (CWR-IBA): Cuttings were handled similarly to treatments two and three except after the two-hour waiting period stems were recut before immersion.
5. IBA KlipKleen: Cuttings were removed from stock plants with pruning shears fitted with the KlipKleen system. Cuttings were placed in the propagation trays after two hours.
6. IBA KlipKleen-recut: Cuttings were removed utilizing KlipKleen pruning shears and IBA solution. After two hours the basal 1 cm was recut with the KlipKleen pruning shears. Cuttings were then stuck in trays.
7. Cut-wait-KlipKleen (CW KlipKleen): Cuttings were removed from stock plants with pruning shears. After 1 hour, the basal 1 cm was recut with KlipKleen-adapted shears containing the 5000 ppm IBA solution.
8. Wood's KlipKleen: Cuttings were removed from stock plants with KlipKleen adapted shears. The reservoir was filled with a solution of 1 part Wood's Rooting Compound:1 part distilled water. Cuttings were immediately stuck in trays.

Cuttings were placed in trays in a completely randomized block design. Twenty-four replications of each treatment resulted in 196 cuttings. Trays containing cuttings were placed in a greenhouse under intermittent mist operating 5 sec. every 5 min. from 8 am to 6 pm daily. Evaluation for rooting percentage and number of primary roots per rooted cutting was made on October 14, 1988, after 9 weeks. A cutting was considered rooted if one or more roots was present and greater than 2 mm in length.

RESULTS

All treatments had 100 percent rooting, which was not unexpected. Differences in rooting response did occur in the mean number of primary roots formed. Many more primary roots developed in the IBA quick-dip treatments in comparison to the numbers produced by the KlipKleen-treated cuttings. The greatest number of primary roots developed on cuttings dipped immediately after severance. Waiting two hours before dipping cuttings reduced the number of primary roots, and was not significantly improved by recutting the stem.

Recutting stems after severance did increase primary root

development in KlipKleen treatments. There was no difference between immediate KlipKleen treatment, and after a two-hour wait before KlipKleen treatment. The Wood's Rooting Compound KlipKleen treatment gave the highest number of primary roots of KlipKleen treatments (Table 1).

Table 1. Effects of propagation technique on percent rooting and number of primary roots of *Ilex* 'Nellie Stevens'.

Treatment	Rooting percentage	Mean number roots/rooted cutting
1. Water Q-Dip	100a[y]	18.4e[y]
2. IBA Q-Dip	100a	247.4a
3. CW-IBA Q-Dip	100a	183.8b
4. CWR-IBA Q-Dip	100a	211.6b
5. IBA KlipKleen	100a	22.0e
6. CWR IBA KlipKleen	100a	65.7cd
7. CW-IBA KlipKleen	100a	46.1de
8. Wood's KlipKleen	100a	84.6c

[y]Mean separation within columns by Duncan's Multiple range test 5% level. Each value represents the mean of 24 cuttings.

These results are similar to those of the two earlier studies (2). 'Nellie Stevens' holly produced more roots on cuttings that received quick-dip application immediately after severance than those treated with the same solution at severance in the KlipKleen treatments.

The results appear to be a function of fluid movement or absorption into the stem tissue. More fluid appears to be taken up when quick-dip methods are employed. However, relatively few nursery crops have been studied, and response has been variable among species. Fluid uptake, particularly movements in the xylem, is highly dependent upon internal plant water status and could produce quite variable propagation results.

The KlipKleen Pruning System does appear to reduce time and labor involved in preparing cuttings for propagation, and results indicate that well-rooted cuttings can generally be produced with the procedure. More experimentation by nurseries and universities would be highly desirable to improve technique and propagation results.

Acknowledgements. The technical assistance of Ms. Mary Lorscheider is gratefully acknowledged.

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WHY WE CHANGED TO A PADDLE MIXER

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As we began looking at ways to increase our productivity in mixing potting media we realized we had three problems to alleviate. Our potting production requirements had outgrown our existing mixing method. It required too many man-hours to provide enough mix to keep up with our present potting production, and we were unable to blend small amounts of micronutrients and other amendments using our old system.

In the old process we used a manure spreader[1] which required many time-consuming steps. The following procedure required four persons:

1. A front-end loader was used to premix a four to one ratio of pine bark and sand.
2. The premix was loaded into the spreader.
3. Fertilizer and lime were added at the recommended rates.
4. The spreader had to be moved forward periodically as it unloaded.
5. The loader then pushed the mix into a pile.

This process became too much of a burden as our level of production increased.

To provide the quantity and quality of mix to meet our current production demands, we purchased a Davis Soil Mixer[2], model HD 40. It has a capacity of 5.5 cubic yards and is powered by a 25 h.p. electric motor. Its heavy-duty construction enables us to mix up to 40 percent sand per batch, with a gentle mixing action that will not damage the prills of slow-release fertilizer.

The paddle mixer solved our previous mixing problems with the use of only two operators. One operates the front-end loader supplying the pine bark and sand. Simultaneously, the other works from a platform applying the recommended rates of fertilizer, lime, micronutrients, and any other amendments. After all the ingredients are completely loaded, the machine is allowed to run an additional 3 min. to ensure a through mixing. At the conclusion the mixer unloads the mix through a trap door onto a conveyor that carries the mix into a holding bin.

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[1] Sperry New Holland Manure Spreader, New Holland Inc., 500 Diller Ave., New Holland, Pennsylvania 17557.

[2] Davis Soil Mixer, H. D. Davis Sons Manufacturing Co. Inc., P.O. Box 395, Bonner Springs, Kansas 66012

In our efforts to fulfill our new production demand for mix, we considered purchasing an in-line continuous mixer but decided against it for several reasons:

1. The in-line continuous mixer required a large investment in supplementary equipment such as hoppers and calibrators.
2. Time-consuming recalibrations would be necessary if the in-line continuous mixer were to be used to produce different blends.
3. The in-line mixer would not offer the flexibility we needed to provide mix for different potting applications.

In contrast to the continuous in-line mixer, the paddle mixer did not require expensive supplementary equipment or complicated recalibrations, and it provides the flexibility we need. We can easily provide mix for the following applications:

1. Potting up containers on the potting carousel
2. Potting up any size container in the field from trailers
3. Custom blending mix for other nurseries and landscapers

After six months of use, we are pleased with both the savings and performance of our paddle mixer. We save not only on the cost of labor but also on materials. With the paddle mixer we can use straight micronutrients instead of expensive micronutrients incorporated into complete fertilizers. Between these two savings we estimate that we will fully recover the cost of the mixer in three years. The paddle mixer meets all the criteria we established for our mixing requirements, making it a valuable investment.

GLEASON CONTINUOUS MEDIUM MIXER

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The growing medium is the foundation for high quality container-plant production. The mix must be uniform and consistent if one's goal is to produce plant material that keeps customers coming back for more. Many inputs go into producing a good plant, but few are more important than the growing medium. For this reason a mixer becomes an integral piece of equipment in the nursery.

To do the job, a mixer must produce a medium that is uniform, with little particle breakdown, on a consistent basis and in the volume required. We, at Jon's Nursery, realized we outgrew the "old batch mixer" when our daily needs exceeded about 30 cu. yd. per day. Several continuous mixing systems are on the market and, after much study, the Gleason equipment was purchased on the strength of the tumble drum method of mixing.

Jon's Nursery mix consists of pine bark, Canadian peat, and sand at approximately 4:2:1 by volume, amended with Osmocote NPK fertilizer at 15 lbs./yd.^{3}. Micromax micronutrients at 1.5 lbs./yd.^{3}, and dolomite lime at 8 lbs./yd.^{3}. Components are dispensed from individual Gleason bulk bins onto a central conveyor belt. The mix is carried under two fertilizer hoppers, one dispensing Osmocote, the other a blend of dolomite, micronutrients, and vermiculite. The belt dumps the pile of raw components into the mouth of a continuous drum mixer where the mix is gently tumbled and wetted. The mix is discharged onto an outfeed conveyor and deposited on a slab where a front-end loader delivers it to the potting stations. This machine is set up to deliver 40 yd.^{3}/hr.

Calibration of the machine is necessary to maintain the day in-day out consistency of the mix. Fertilizer dispensers are calibrated daily, and sometimes more frequently, when the dolomite supply is irregular. Soil component hoppers are checked for delivery weekly, but very little adjustment is required. Proper working of the automatic shutoff microswitches, located on all material-dispensing hoppers, are checked several times per day.

Our customers need healthy, well colored, vigorous landscape stock when they need it. Our goal is to provide a consistent supply of top quality stock to our customers. The growing mix is the cornerstone of quality, and a good mixer, well-maintained, insures that our plants are off to a good start.

PROPAGATION MIX USING AN INCLINE MIXER

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At Shelfer Nursery we propagate almost all of our own liners. In doing this we stick cuttings in everything from ground beds and metal trays to 2¼-in. and 3¼-in. Lerio pots. We had what we thought was a good mixture of propagation soil, but we were not getting a consistent overall mix by using the front-end loader. After some shopping around and considerable thought we decided to buy a soil mixer from Ellis Trailers of Semmes, Alabama. The mixer was an incline mixer that mixed 4 cu. yds. per batch. The mixer has met our requirement for a consistent total mix at a price we could afford. First, I will give an overall view of the mixer and how it works for us. Then I will describe some of the advantages and disadvantages of the mixer.

Shelfer Nursery is a small container nursery of approximately 26 acres. We have 3500 ft^2 of greenhouse space, used for 3¼-in. pots for azaleas and 2000 ft^2 of 2¼-in. pots used for juniper propagation. The balance of the acreage is used for growing 1-, 2- and 3-gal. container ornamentals. We do all of our own propagation and had a good mix. However, it needed to be more uniform. We decided to put in the 4-cu. yd. mixer from Ellis Trailers and found it produces an excellent mix for both the small cups and the big trays. Even though we are a small nursery, the need for a good, consistent mix justified the purchase of a soil mixer.

Let me explain how the incline mixer works. The mixer has a bottom that is built on an incline. The chain is driven by a 7½ h.p. three-phase electric motor, which, with the use of a gear reduction box, provides sufficient power. As the chain moves the mix up the incline, it begins to tumble back to the bottom in a continuous tumbling action. The door is at the top of the incline so that while the mixer is emptying, it continues to mix until all of the soil is out.

The incline mixer has many advantages. One major advantage to a small nursery is that it is affordable and has proven to be quite cost-effective. Due to the tumbling effect three 6-cu. ft. peat moss bales can be dumped directly into the mixer; it will break the moss up in 30 sec. without breaking it down.

The simplicity of the mixer is a big advantage. The chain is adjustable. There are only a few moving parts, and they are all easily replaceable. Most of the parts can be bought at any machine shop, and all replacement parts are in stock at Ellis Trailers.

The large door opening at the rear makes putting in the bales of peat moss easy. The bark and sand are put through the large top

opening. Since the mixer is a batch mixer, it is easy to change from one type of mix to another. The nice design of the door that lets the mix out is certainly an advantage. The large door hinges on the top axle and is opened easily with one handle. It allows the mixer to empty quickly, approximately 1½ min. The entire operation is fast and safe.

Even though the 4-cu. yd. incline mixer works well for us, I can still see a few disadvantages. The incline mixer is limited to mixing 4 cu. yds. at a time. For larger nurseries this might bring about a need for a continuous mixer or possibly two incline mixers, whichever would be the most cost-effective. The fertilizer and other chemicals have to be weighed and added to each batch and are not being constantly metered-in as in a continuous mixer. The more manual action required, the greater the chance for human error.

It would not be fair to discuss only the mixer since the manufacturer of the mixer also makes a flat filler that will fill trays and containers. Jim Scoggins of Wight Nurseries Division III has a flat filler in operation and reports that he can fill 950 trays per hour.

The mixer can also be mounted on an axle and towed to different potting operations on a nursery as the need arises. An incline conveyor is made that will take the mix as it is dumped out of the mixer and place it in a pile. When making two kinds of mix, it will pivot to store the different mixes in their respective storage locations. These are a few adaptions made for the mixer that might benefit your nursery.

At Shelfer Nursery we always look for ways to improve our propagation. We used a mixture of peat, perlite and sand that worked well, but needed a better way to make a consistent mix. After looking at soil mixers, we decided the 4 cu. yd. incline mixer made by Ellis Trailers was the best investment for our nursery. Both our propagation and our container operation have benefited from the improved consistency of the mix. In our opinion the incline mixer works very well and is worth the initial investment many times over.

TOP PRUNING AND ROOT GROWTH: PRACTICAL IMPLICATIONS

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Pruning is a basic and essential practice in the production of quality nursery stock. Like most production factors, pruning should be approached as a means to an end and should be manipulated like a tool chosen to accomplish a specific, predetermined goal. Indiscriminate use of pruning is a mistake. With this in mind, I would like to review some basics on why we prune, what happens when we do prune, and how these responses should be considered as we plan our production schedules.

We may prune a plant for several reasons. Most frequently we prune to increase branching. Pruning a limb temporarily reduces the auxin concentration within it and induces axillary buds to develop, producing a more dense, compact, and visually appealing plant. We may also prune to shape a plant or to control its size. We may prune out damaged or unhealthy branches. We have traditionally pruned a plant at transplanting with the expectation of improving its survivability.

All of us here understand and make use of pruning with regard to top (shoot) growth, but I suspect that many of us seldom consider the effects that pruning has on the root system. This is a mistake because the effects of shoot pruning on root growth are just as real and just as dramatic. The consequences of ignoring them can be costly.

There is no doubt that pruning actively growing plants stimulates a new flush of shoot growth. We see this every time we prune. What we do not see is that it reduces the food supply and flow of auxin to the roots, which reduces root growth and may cause the deterioration and death of some existing roots. The more severe the pruning, the greater the impact. If you doubt this, choose an established, actively growing plant and prune it severely. After two to three weeks or more compare its root system with that of an adjacent unpruned plant. The difference should be dramatic.

What does this mean? It means that after we prune we are growing a plant that is temporarily out of balance. Hormone levels, nutrients, and energy reserves within the plant have changed. Water and fertilizer uptake and usage have changed. We are supporting a lot of active new shoot growth with a reduced and less active root system. Under these conditions the plant is undoubtedly more susceptible to outside environmental and biological stresses. *Phytophthora* and other root rot diseases have an increased oppor-

tunity for infection.

This is not to suggest that pruning can be eliminated, but it does mean that we need to consider the impact pruning has on the growth, health, and production of our crops. The timing and severity of pruning should be chosen to maximize the goals of the finished plant.

We believe in the following approach: Avoid pruning at transplanting if possible so that the plant can become established before it is cut. Minimize pruning throughout the growing season, particularly during periods of stress. Choose heavily branched liners and transplants to reduce the need for subsequent pruning. Consider fungicide treatment of susceptible crops in association with pruning. Avoid pruning just prior to shipment.

These ideas are sound and make good production sense, but they do not always fit into the actual programs and schedules that we are forced to deal with. So what we do is look at each crop or block of plants individually and consider the size and type of top and root system that we want to ship within the time frame that we have to produce it. We then customize pruning, just as we do fertilization and shading, to fit each situation. For example, when we plant azaleas on schedule in early to mid-spring, we do not prune the liners until they become established in the new pots (4 to 6 weeks). We still have plenty of time to develop and shape the heads before flower bud development becomes limiting. However, if we pot our crop late we know we have less time to produce the head size required, so we focus primarily on top growth (prune immediately), recognizing that we can grow the roots in the fall. With this program we know the plants are subjected to more stress, thus we are very careful with our shading, watering, and fungicide applications, as we try to minimize stress and disease pressure.

Obviously every crop is different and should be treated individually. We try to do this, but we recognize that when we prune, whether chemically or manually, we pay a price. No matter how you look at it, pruning is expensive. Every time you cut off a branch it's like taking two steps forward and one step back. You have invested time and money to produce what you are cutting off, so there is a very real dollar value associated with labor, lost growing time, reduced size, and diminished root activity. Perhaps one day plant breeders will develop plants whose natural forms match our production goals. Until then, deciding how and when to prune is just one more part of our challenge as growers. The more we know and the more we consider the consequences, the better job we can do.

WHY PESTICIDES SOMETIMES FAIL

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There is still a wide range of chemicals for pest control in nurseries and greenhouses, even though good sense and legal restrictions have reduced the number in recent years. The chemical companies have usually tested a product extensively before it is marketed. They want to sell as much as possible and be sure that satisfied users come back for more. This makes it a little surprising that there are so many reports of poor results in pest, disease, and weed control. It should suggest that users consider their own practices before being sure that the chemical is at fault.

This paper presents a checklist of some things that can go wrong in pesticide use. Proper pest control is not easy; it requires attention to detail before, during, and after the application both for effectiveness and, of course, for safety.

APPLYING THE WRONG MATERIAL

Incorrect diagnosis of the problem. In recent years many chemicals have been developed to present as small a danger as possible to the environment. Therefore, they are very specific in their action. This means that correct diagnosis, at least to the *class* of the problem involved, becomes important. Think, for example, of how similar to a disease some of the results of micronutrient imbalance can be. And, of course, fungicides would be ineffective in combating fluoride toxicity.

A more subtle case of using the wrong product occurs when an organism has developed resistance to a particular chemical and is no longer controlled by it. This can occur with a local population or can have spread through all individuals of the species. Published information is not always available on this phenomenon, which can be extremely frustrating.

Using the product incorrectly. "Read the instructions when all else fails", has become a stock joke. However, the consequences of not being familiar with the label on pesticides can be dangerous as well as illegal. The chance of failure is increased. In addition to the gross errors from guessing what the product can do, there are the well-intentioned mistakes, "if one is good, two must be better." Sometimes very exact conditions for application must be met. Some materials are light-sensitive and must be watered into the soil. Others may work only with a spreader-sticker, or may be phytotoxic if applied under certain environmental conditions. What a pity to put the time and labor into an application that will be a near miss

because not even the large print was read!

Using an outdated or improperly stored chemical. Complex organic molecules are often far from stable. Storage in warm humid conditions in open bags or with other chemicals as contaminants will change the activity of most materials, usually in the wrong direction. The manufacturers are not just trying to sell more chemical by putting an expiration date on their bags. Take notice of these, and dispose of any outdated materials in whatever manner is legal in your state.

Problems with a tank mix. The thought of saving a pass or two with a sprayer by mixing everything in one tank is very tempting. With the complex molecules involved there may be reactions that leave no activity in the mix, or, worse still, a phytotoxic material that will destroy the crop. Many problems are documented, and there are also ways of testing compatibility and possible phytotoxicity on a small scale. And the time to do this is *before* the expensive materials are mixed, the spray time invested, and the crop put at risk.

Problems from careless cleanup. Some materials will affect others even when present as only the trace left from a poor cleaning job of the sprayer. Both phytotoxicity and inactivation can occur with unintended tank mixes.

Using the wrong formulation. Some spray systems are only effective with particular formulations of a chemical. The manufacturer knows best in this case and will give the information in the instruction booklet. Trust him!

MAKING THE APPLICATION INCORRECTLY

Applying the wrong rate. Once again the label information usually represents extensive testing by the manufacturer. It should be followed unless another rate has been shown to be better for a particular circumstance by further testing. Not only the concentration of the spray but the amount reaching the plant or a unit area is important.

Poor coverage. Most chemicals must reach the pest or the weed in order to be able to be effective. Poor coverage means that the pesticide might as well have been left in the bag in the storehouse. At least that way the cost of the application would have been saved.

Problems due to the weather. Spraying is even more effective than washing a car in bringing on rain that is not wanted. Sprinklers, too, can wash off spray before it has had time to act. Light inactivation can be a problem, and high or rising temperatures can cause trouble by drying the spray before it can penetrate or by causing phytotoxicity.

Initial application too late. Small problems are almost always easier to cure than large ones. Controlling pest infestation before the rate of increase of the organism has reached its maximum rate always means that the job will be easier and more sure of success. Often knowing the biology of a pest will allow control at a susceptible stage in its life history, when all other stages are resistant to the chemicals available for use. Applying an herbicide before a weed has set and released seed is an obvious step that is often ignored by overextended nurserymen. And the word "preemergence" on a herbicide label means what it says. If the target weed has already grown up into the light, it is too late for preemergence control.

Lack of follow-up. Follow-up application of the same or a complementary spray will often control organisms missed the first time. Some pesticides act exclusively on one stage of the pest, and follow-up applications may be needed to control a susceptible stage that hatches or germinates from resistant eggs, spores, or seeds. Rain or irrigation coming too soon after a spray application also make a follow-up essential.

Poor records of treatment. No matter how extensive the manufacturer's testing has been, the conditions on each nursery are different enough to make it essential to keep full records of what, where, when, how, and why a treatment was done. A record of how effective it turned out to be is essential. All growing operations are "systems" in the technical sense of the word. Each part relates to all the others, and each nursery operates at full efficiency only when all activities are tailored to fit its particular conditions.

Relying on chemicals alone. Even the most effective chemicals need a helping hand. All aspects of your cultural practices should be aimed at getting the healthiest and most resistant plant possible. Scouting pest levels and knowing the biology of the pest will allow treatment at the time when it will do most good. Following the program that has come to be called, "integrated pest management" will ensure that every weapon possible is being brought to bear on each problem. Properly used pesticides will rarely fail. A careful check of nursery operations will often show some small correction that will make a spray successful when it is next applied.

WEED CONTROL IN THE FIELD: PRACTICAL SUGGESTIONS

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Weed control in field-grown production requires more extensive management than in container-grown nursery stock. Field-grown nursery stock requires several years to reach salable size, and during the first one to three years, ornamental plants provide little competition with the weed species. This paper outlines several practical approaches to improving weed control in the field.

Three guidelines are useful when planning a weed control program. *First,* no one herbicide will control all weeds. *Second,* in the southeastern United States, most herbicide applications will remain effective for only 10 to 14 weeks. Finally, proper timing of the preemergence herbicide to a weed-free area is essential for good weed control. For example, in Alabama, preemergence herbicides should be applied in middle to late February, just prior to weed seed germination, and a second application should be made early to middle July. Most field producers now combine a herbicide providing control for annual grasses with a herbicide providing good broadleaf control. In Alabama the most popular preemergence herbicide combination is Surflan plus Princep.

There are a few herbicides that are widely used for preemergence weed control in field-production nurseries in the Southeast. Those selective preemergence herbicides utilized may be divided into two basic groups: annual grass herbicides and broadleaf herbicides. Among the herbicides used for annual grass control are Surflan, Pennant, and Lasso. Broadleaf herbicides include Princep and Goal. Broadleaf herbicides may result in injury to ornamental plants. Growers should consult the label before applying these or any herbicides. Plants injured by Princep in our research include Japanese holly and boxwood. Several other species are reported to be sensitive to Princep. Goal has some limited postemergence activity on weeds less than 2 to 4 in. tall and will injure ornamentals that have succulent growth. The Goal label states that it should be applied to dormant plants.

Several new herbicides are expected to be on the market during 1989. Gallery is a broadleaf herbicide that was expected to receive a label for turf in the fall of 1989 in a 75 DF formulation. In our test, Gallery has been safely applied over the top of four ornamental species twice a year for two years at 2 lbs. a.i./A with no injury. While weed control with Gallery appears no better than existing broadleaf herbicides in controlling weeds, it may be safer than either Princep or Goal to ornamental plants. Snapshot 80 DF will

possibly enter the ornamental marketplace during middle to late 1990. It is a combination product that contains 60 percent Surflan and 20 percent Gallery. In our tests, Snapshot 80 DF has provided weed control similar to that obtained with the current standard of Surflan plus Princep.

Several problems are common to many nurseries in attempting to obtain adequate weed control in the field. One of the most common problems encountered is poor calibration of the spray equipment. It is essential that growers know the amount of water being applied per acre. Without this knowledge it is impossible to determine accurately how much herbicide is being applied. Another problem that occurs is applying the herbicide to a field that is not weed-free. If the weed seed have already germinated, preemergence-applied herbicides will have little or no activity. A third problem frequently encountered is applying herbicides to plants that are not on the label. Increasing concern over the environment and proper use of pesticides will necessitate closer regulation of spray programs in the future.

Yellow nutsedge infestations are frequently encountered among nurserymen. Yellow nutsedge is difficult to control and spreads easily from field to field as equipment is moved. Field cultivation and hand hoeing may contribute to the spread of yellow nutsedge. Currently there are few labeled herbicides available, and they provide only limited control of yellow nutsedge without injuring ornamental plants. In 1986 a test was initiated evaluating several new herbicides demonstrating activity against yellow nutsedge. Herbicides evaluated include Classic, Reflex, Scepter, Zoriol, and Dual (which is currently labeled for nursery crops as Pennant 7.8 E). The latter three herbicides all provided excellent control of yellow nutsedge during the end of the first year and into the second year. However, Scepter was injurious to most of the ornamentals tested.

After two years of testing, all plots were replanted with ornamentals and treated with the industry standard herbicide program of Surflan and Princep. The purpose was twofold in that we were interested in residual control of yellow nutsedge and also wanted to determine if Scepter's residual activity would be injurious to the newly planted ornamentals. Residual activity from Zorial (3 lb. a.i./A), Scepter (1 lb. a.i./A), and Dual (4 lb. a.i./A) continued to provide excellent control for a full year after the last application. Scepter was injurious to the replanted ornamentals with severe stunting occurring on boxwood and juniper. Nurserymen should use caution in experimenting with Scepter herbicide due to long-term soil activity. Zorial is not currently labeled for ornamental use; however, it does appear to have promise in that it provided excellent control and caused no injury to the four species under evaluation. Dual (Pennant 7.8E) is labeled for field-grown nursery crops

and provided excellent preemergence control of yellow nutsedge. In our test 4 lb. a.i./A applied in early March followed by a repeat application in mid-July at the same rate resulted in excellent control of yellow nutsedge.

Not all weeds are controlled by preemergence herbicide applications. Such weeds may be controlled by postemergence herbicides. These may be classified by several different methods but for the purpose of this paper will be classified according to their effect on ornamental plants. Roundup and Gramoxone are both injurious to ornamental plants and should be applied in a directed method so that the spray material does not contact the ornamental foliage. Roundup is translocated throughout the target weed while Gramoxone is a contact herbicide that kills only that portion of the weed covered by the spray. Perennial weeds are typically not controlled by Gramoxone.

A frequent problem encountered with nursery producers is the inappropriate use of Roundup rates. For the control of annual weeds less than 6 in. in height, Roundup should be sprayed at the rate of 1 percent of solution or 1 quart per 25 gal. of water. If the annual weeds are larger than 6 in. in height, the rate should be adjusted upward to about 1½ qts of Roundup per 25 gal. of water. For perennial weeds, the rate should be increased to 3 to 5 qts per 25 gal. of water and sprayed while the weeds are in the mature stage. Applying a 1 percent solution of Roundup to perennial weeds is generally ineffective.

A second group of postemergence-applied herbicides includes Poast and Fusilade 2000. These two herbicides are generally non-injurious to ornamental plants. They are effective in the control of annual and perennial grasses and have no activity on broadleaf plants. For the control of annual grasses apply Poast at the rate of 21 oz./A and Fusilade 2000 at the rate of 16 to 24 oz./A. One application will generally remove annual grasses. For perennial weeds such as bermudagrass and johnsongrass two applications are necessary and should be applied at 10- to 14-day intervals. For perennial grass control, Poast should be applied 42 oz./A, Fusilade 2000 at 48 oz./A. The addition of a crop oil concentrate at the rate of 1 percent by volume is necessary for optimum activity of Poast. A non-ionic surfactant is needed for Fusilade 2000 and should be applied at half the rate of the crop oil concentrate (0.25 to 0.50 % by volume). Fusilade and Poast are more effective when applied to rapidly growing annual grasses. Grass under moisture stress will result in poor or inconsistent control. Relatively lower spray volumes of water have been more effective than high spray volumes. In our research, a volume of 20 gal/A is used. For tall or dense grass, the spray pressure should be increased (also resulting in increased volume and rate/acre if all other factors are held constant). In these situations, a spray pressure of 40 to 50 psi is generally adequate.

Fusilade 2000 and Poast are rapidly absorbed by the weed's foliage and, under ideal conditions of high temperature and high humidity, almost complete uptake may occur within one to two hours. This is *in contrast to Roundup where rainfall within six hours of application* may reduce its activity.

Finally, we will consider the new Federal regulations, specifically the "OSHA Hazardous Communications Standards." With these new regulations the grower must survey all chemicals used on the nursery and obtain material safety data sheets (MSDS) for each chemical. The MSDS should be placed in a location that is easily accessible for all employees. Whenever a new chemical is added to the nursery's pesticide program, an MSDS must be obtained for that chemical. Growers should have a training program for employees that are exposed to hazardous chemicals. In the training program items such as safety equipment to be worn, pesticide storage, what to do in emergency situations, and correct procedures for waste disposal should be covered. Failure to comply with these new guidelines may result in fines up to $10,000 per violation and the possibility of civil suits.

HERBICIDE USE IN PROPAGATION[1]

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INTRODUCTION

Weed control has become increasingly important during propagation, with many growers direct sticking cuttings in outdoor beds or greenhouses. Limited work has been done in propagation research evaluating herbicidal activity on stock plants and subsequent root initiation (1,2). Recent research has shown that some herbicides suppress root growth on woody plants (3). Johnson (4) evaluated the effects of herbicides on rooting percentages and root quality of four ornamental species in New Jersey and reported a significant reduction in the root quality of *Cotoneaster horizontalis* in all herbicide treatments. Rooting percentages of *C. horizontalis* were reduced by Dual, Devrinol and Ronstar treatments, while rooting percentages of *Rhododendron* were reduced only in the Surflan treatment.

The object of this study was to evaluate the effects of selected preemergence applied herbicides on the rooting of certain ornamental species grown in the southern United States.

METHODS AND MATERIALS

Experiment 1 (Auburn): On 4 September 1987, 3-in. rose pots were filled with the medium and watered to field capacity. The medium consisted of equal parts of ¼-in. screened amendment-grade pine bark and coarse sand, amended with 7 lb. of 18-6-12 Osmocote per cu. yd. Herbicides were then applied at the recommended rates and watered in. Treatments included: (1) Ronstar 2G, 4 lb/ai/A; (2) OH-2 3G, 3 lb/ai/A; (3) Rout 3G, 3 lb/ai/A; (4) Prowl 60DF, 3 lb/ai/A; (5) Prowl 2.45G, 3 lb/ai/A; and (6) non-treated control. Herbicides were applied to the medium prior to sticking the cuttings.

Plant species evaluated included *Lagerstroemia indica* 'Catawba', *Ilex crenata* 'Compacta', *Berberis* × *mentorensis* 'Rose Glow', *Ilex* × *attenuata* 'Foster No. 2', *Spiraea cantoniensis*, and *Euonymus japonica*. Data collected after 10 weeks included: rooting percentage, root length (mean of 3 longest roots), primary root number, and root rating. The root rating scale was 1 to 5 where 1 = no roots, 2 = few short, clubby, distorted roots, 3 = light rooting, 4 = medium rooting, 5 = heavy rooting.

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[1] Student paper by Mack Thetford, Graduate Research Assistant

Experiment 2 (Mobile, Ala.): Experiment 2 was conducted under conditions similar to standard nursery practices of the Mobile area. On 11 September 1987, 3¼-in. square liner pots were filled with 100% milled pinebark amended with 6 lb dolomitic limestone, 2 lb gypsum, and 1.5 lb Micromax per cu. yd.

Treatments for Experiment 2 were similar to Experiment 1. Plant species included *Gardenia jasminoides* 'Radicans' dwarf gardenia, *Rhododendron* Glenn Dale Hybrid 'Trouper', and *Rhododendron indicum* 'Formosa'. Data will be presented for five species: barberry, Foster holly, euonymus, 'Trouper' azalea, and dwarf gardenia.

RESULTS AND DISCUSSION

Herbicides ranked according to safety—from least injury to greatest injury—were: Ronstar, Prowl 2.45G, OH-2, Prowl 60DF, and Rout (Table 1). Prowl 2.45G and OH-2 suppressed rooting or root formation of 2 species: euonymus and 'Trouper' azalea. These 2 species were also affected by Prowl 60DF; other species sensitive to application of Prowl 60DF included 'Catawba' crapemyrtle, dwarf gardenia, and Foster holly. Rout suppressed rooting of six of the ornamental species tested: Foster holly, 'Rose Glow' barberry, 'Compacta' Japanese holly, euonymus, 'Trouper' azalea, and dwarf gardenia. Root ratings and root length of dwarf gardenia were also suppressed with Rout; Prowl 2.45G resulted in lower root ratings for gardenia compared to nontreated control.

Species affected by Ronstar were dwarf gardenia and 'Trouper' azalea. Dwarf gardenia had suppressed root length and primary root numbers when compared to the nontreated cuttings. Ronstar also suppressed 'Trouper' azalea rooting percentages (75% vs 91.7%) and root length compared to the nontreated cuttings. Results from Ronstar suppression concur with those of Johnson (4), which also demonstrated a reduction in the root density of *Cotoneaster*. These two species (gardenia and 'Trouper' azalea) were adversely affected by all herbicides in at least one of the four root parameters measured.

Several key factors are evident when using preemergence-applied herbicides in the propagation process. No one herbicide is safe on all woody plants. Ronstar, generally thought to be one of the safer herbicides, affected rooting or root growth of 'Trouper' azalea. Secondly, herbicide use may not affect the rooting percentage, but can still negatively affect subsequent development of the root system.

These data show that several herbicides were non-injurious to the rooting and subsequent root development of the majority of the ornamentals tested. This suggests that a potential exists for safe use of herbicides in propagation of direct stuck cuttings. Growers

should experiment on a small scale with a given herbicide before using any herbicide on their cuttings.

Table 1. Effects of selected herbicides on rooting of woody ornamentals.

	Herbicides					
	Ronstar (2G) 4 lbs	OH-2 (3G) 3 lbs	Rout (3G) 3 lbs	Prowl (60DF) 3 lbs	Prowl (2.45G) 3 lbs	Nontreated —
	'Rose Glow' barberry[z]					
Rooted, %	95.2a[y]	95.9a	73.3b	100.0a	94.7a	90.0a
Root length (cm)	9.3a	9.3a	4.9b	6.8ab	7.3ab	7.4ab
No. primary roots	15.1a	17.2a	11.2a	14.8a	14.3a	18.6a
Root rating[x]	3.7a	3.7a	2.6b	3.3a	3.3a	3.4a
	Foster holly					
Rooted, %	77.3a	83.3a	50.0b	83.3a	79.2a	86.4a
Root length (cm)	5.4a	6.5a	1.9bc	1.4c	3.9ab	5.3a
No. primary roots	6.4a	6.4a	2.2b	4.9a	5.9a	6.0a
Root rating	3.0a	3.2a	1.9b	1.9b	2.5ab	3.0a
	Euonymus					
Rooted, %	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a
Root length (cm)	10.1a	9.7ab	9.1ab	8.6b	9.3ab	8.8b
No. primary roots	26.5ab	21.1c	21.0c	24.8bc	24.1bc	30.3a
Root rating	4.0a	3.7b	3.4b	3.6b	3.6b	4.0a
	'Trouper' azalea[w]					
Rooted, %	75.0b	87.5a	91.7a	91.7a	87.5a	91.7a
Root length (cm)	1.5c	2.6bc	2.7bc	3.0b	3.1b	4.4a
Root rating	2.1c	2.5bc	3.0b	3.0ab	2.9b	3.6a
	Dwarf gardenia					
Rooted, %	100.0a	100.0a	98.5b	100.0a	100.0a	100.0a
Root length (cm)	8.4a	7.9a	1.1b	7.9a	7.7a	8.1a
No. primary roots	14.1a	15.7a	9.7b	14.5a	13.5ab	12.4ab
Root rating	3.6a	3.6a	2.0c	3.3b	3.2b	3.6a

[z]Auburn, Ala.—Expt. 1, 'Rosey Glow' barberry, Foster holly, and euonymus.
[y]Mean separation within rows by Duncan's multiple range test (5% level).
[x]Root rating scale: 1 = no roots, 2 = few short, clubby, distorted roots, 3 = light rooting, 4 = medium rooting, 5 = heavy rooting.
[w]Mobile, Ala.—Expt. 2, 'Trouper' azalea and dwarf gardenia.

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QUESTION BOX

Ted Goreau and Charlie Parkerson, Moderators

TED BILDERBACK: I have been asked to go into more detail about the Klip-Kleen technique. The question was whether or not the shear could be used for more than simply sanitation. We wanted to see if it could be used to apply quick-dip hormone solutions. Could it overcome the possibility of xylem plugging? *Cyrilla* responded but with *Ilex* 'Nellie Stevens', and others, the quick-dip is about as good as you can do. The manufacturers have adjusted the flow rate from that on the original product. I think it is worth more study. I believe, whether or not it works, has something to do with large xylem tissues. The idea of getting into the xylem is simply that it is through this tissue that the solution moves up into the plant.

BRUCE BRIGGS: What is a disinfectant that can be used on shears?

TED BILDERBACK: We use a 9:1 bleach solution.

GRADY HOLT: TecTrol is also good.

GARY HOLT: Would it be overdoing it to make cuttings with the Klip-Kleen shear in the field, then do a quick-dip just before sticking them?

BRYSON JAMES: I've been asked if I can say anything positive about the "root-control bags." I think the idea is good, but there needs to be work done before we can draw conclusions.

CHRIS THREADGILL: I have encouraged using milk cartons for liner production of trees. Several people have asked about the availability of other sizes. Usually quarts are not hard to find. We need to let companies know we want other sizes.

TOM LETT: Milk cartons are available in my area for 1/5 of a cent a piece, so they are certainly cost-effective. One of the tricks is keeping the medium in the container until it gets wet and plant roots form a root mass. As a temporary bottom, we use two layers of paper, which soon disintegrates. We incorporate 9 pounds 18-6-12 per cu. yd. of mix.

DON COVAN: I've been asked about our losses in cutting propagation as compared with seedling production. We have found this to be highly species-dependent.

FORREST KEELING: Pregermination sometimes can help. Often the first seeds that germinate are the best.

JIM BERRY: There have been questions about using Ronstar in propagation. We do use Ronstar. We put on the herbicide after the flats are filled before the cuttings are stuck. Ronstar should probably not be used on 'Coral Bells' and some other sensitive azalea cultivars.

TIM GWALTNEY: We've seen no problem but are careful to water after applying the Ronstar. We try to wait three days to stick

cuttings in order to protect workers. We use the recommended rates and make applications in the open; that is, in a house with both ends open.

CARL WHITCOMB: Ronstar seems safe because it is insoluble. Apparently Goal, Treflan and Surflan do damage because they are soluble.

BRUCE BRIGGS: What about putting Ronstar on later?

TIM GWALTNEY: We do use the material later and have seen no problem.

BRAD MAY: The question of needle-drop and yellowing on *Juniperus procumbens* 'Nana' cuttings has come up. We have found that if we stop *Alternaria* with Kocide the problem stops.

CHARLIE PARKERSON: One of our Question Box questions is: "What is the purpose for crossing the western dogwood, *Cornus nuttallii,* with *Cornus florida* dogwood"? The object has been to get the larger western dogwood flower and the eastern (Florida) dogwood flowering habit plus resistance to bark splitting. Reports from nurseries on some of the new cultivars that are a result of this cross have varied widely.

Another question that has been asked is whether or not anyone has had problems with Aliette causing small leaves. Gary Taylor, Ben Davis, and Doug Ryan say they have been using the product successfully.

TED GOREAU: We used Aliette as a top spray for some juniper cuttings, including shore juniper, that were showing root rot. We did notice uneven growth later, which we felt could have been caused by the fungicide.

DEREK BURCH: I was asked about the gray slime that sometimes develops under mist. The cause is one of the basidiomycete group of fungi.

BRUCE BRIGGS: We have found that a wetting agent we buy from Amway has gotten rid of the mycelium of the fungus, which is really what the slime is.

TED BILDERBACK: Our biggest problem is in a pile of mix. The mycelium develops and cuts off oxygen below. This causes fermentation in the pile and the development of acetic acid since the fungus extracts most of the salts. The salts then become available and can be toxic to some types of plants if concentrations are high due to their rapid release; pH goes down also. The only solution is to turn the pile and turn on water to leach out the salts. The time required for one pound of CaO, in the form of 180 dolomite, to give 8 ppm calcium is about six months.

CHARLIE PARKERSON: Does the age of the mix have anything to do with it?

TED BILDERBACK: Material that is six to nine months old may be going through this fermentation.

BRYSON JAMES: The problem is that 180 mesh dolomite often

contains as much as 40 to 50 percent 100 mesh material. Some nurserymen use materials other than CaO for quicker results. Any lime with 6 or more percent MgO can be called dolomite. Most are 6 to 8 percent. Look at magnesium content as well as particle size when you buy lime. Try to find a product with at least 10 percent magnesium and at least 50 percent of the particles 100 mesh or finer.

CARL WHITCOMB: Nurserymen have reported yellowing in blue rug junipers (*Juniperus horizontalis* 'Wiltonii') that could very well be caused by the magnesium running out. It could be expected to last about two years or less. Even if it doesn't run out, the ratio of calcium to magnesium will get bigger if the irrigation water contains lime. Sometimes applying magnesium oxide helps.

BRUCE BRIGGS: What about using Epsom salts, which is about 10 percent magnesium?

CARL WHITCOMB: Epsom salts is okay, but it's expensive and hard to dissolve. There is a pelletized material, but it still seems not to give satisfactory results. Gypsum would add calcium but not magnesium.

BRYSON JAMES: Particle size is the key to the effectiveness of any of these materials. That is why pelletizing helps.

KEITH GUTHRIE: Pelletizing also adds water, so the rate of application must be increased.

GARY TAYLOR: What is the best time to prune viburnums? We have a problem with leggy plants.

MIKE DIRR: They should be cut back right after flowering.

CATHY COX: What are the sources for the materials you use in rooting?

MIKE DIRR: Research Organics, 4353 East 49th Street, Cleveland, OH 44125-1083 is an excellent supplier.

DAVID ELLIS: Would increasing the dip time make a difference?

MIKE DIRR: Usually the five-second dip, using high concentrations is long enough.

JUDSON GERMANY: I would like to ask Jim Berry why they no longer use superphosphate. This was a standard recommendation for many years.

JIM BERRY: Today's fertilizers contain enough phosphorus without that special addition.

TED BILDERBACK: Not only that, but the superphosphate washes out.

GARY ADAMS: I was asked about herbicides to control prostrate spurge. We have found Goal, Prowl and Southern Weed Grass Control to be effective.

CHARLES GILLIAM: Rout and OH2 are also effective but require 90 days to act.

CARL WHITCOMB: Treflan also works.

GARY ADAMS: Sedge control is also a problem. We have had the best control using Pennant.

BILL DAUGHTRY: Basagran and Classic also help.

TED GOREAU: Sometimes I feel it is important that we stop and decide just what our goal is in plant propagation and production. What is it we want?

CHARLES COX: Florida has set up grades and standards for nurserymen's use. However, there is probably no such thing as a #1 plant. Aftercare, which we cannot control, is extremely important.

RANDY SETTLE: The standards for "quality" vary from region to region also. For example, up the East Coast the demand is for sheared plants while in other areas buyers do not want that formal look.

DAVID ELLIS: Would rooting percentage for chionanthus improve if cuttings were taken from a seedling?

BRUCE BRIGGS: We have been able to root the plants by taking a dormant cutting, then slitting the stem before treating with hormone, then sticking.

JIM BERRY: Azalea dieback seems to be a constant problem. There have been several questions about it at this meeting. We have established a good spray program that we follow routinely and have found that it helps considerably.

TED GOREAU: Another possible reason that we may have continuing problems is that new strains of *Phytophthora* are developing.

MARTEEN VAN DER GIESSEN: We believe that what we were seeing was winter damage. In fact, we held some of our plants to sell later to be sure they would survive.

JIM BERRY: Avoiding damage seems related to not keeping the tissue too soft.

WARREN FLETCHER: Could the organism present be *Rhizoctonia* instead of *Phytophthora*?

HUGH GRAMLING: We use Aliette followed by Subdue in about a two months' rotation.

I have a question for Bill Daughtry. Have you noticed any buildup of chlorides or chlorates in your system using chlorine gas injection? Foliage growers in Florida have reported that they did.

BILL DAUGHTRY: We have not.

BRUCE BRIGGS: Actually the chlorine breaks down rapidly, certainly before it ever hits the plants.

PRACTICING BASIC PROPAGATION

CLAYTON W. FULLER AND PENNY L. DIGIOIA

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Cut-em stick-em root-em, we did it! We are now successful plant propagators. But wait a minute, why were we successful and what basic propagating principles did we practice? Many people in the world of plant propagation ask this question. We will present a very brief overview of our methods of achieving success. Planning ahead is our key to success.

Propagating facility. We no longer use solid benches with media. We prefer flats as they allow us to move the rooted cuttings to a hardening-off house as soon as they are rooted. Flats also allow for a more efficient use of our propagation structures.

Provisions for media heating, either hot water pipes under the bench or bio-therms on the bench, are necessary to maintain the 74°F medium temperature we use. We use hot water pipes.

Water quality should be checked. In addition to pH, chemicals added by the water supplier or naturally occurring chemicals in the water supply can cause failure.

The mist or fog system used must be reliable, so that it does not quit on a hot sunny day and allow the cuttings to dry out, and they must be easy to operate. We use an electronic leaf. We feel this mist controller is the easiest and most reliable for our operation, and does not require resetting during nights or cloudy days.

Provisions for air movement in the propagating facility must be provided as high humidity and stagnant air favors fungal diseases. We no longer use the fan set convection tube for air movement as this method moved too much air and interfered with the distribution of the mist. At Bigelow Nurseries we now use horizontal air flow fans that give us the air movement we need without interference with the mist systems. We think this method would also work well with a fog system.

Sanitary conditions in the propagating facility must be maintained. Clean floors and benches, removal of weeds and trash, hoses hung up, no feet on benches, and discarding cuttings that failed to root are just a few sanitary steps we follow.

When the above criteria have been met, we are ready to think about the cuttings.

Planning ahead in the stock blocks. Planning ahead ensures collecting only top quality cuttings because we have done the following: The stock blocks have been fertilized, irrigated, weeded, and visually observed and sprayed if necessary for any diseases or insect pest problems. Plants under stress from any of the preceding will not produce the best cuttings for propagation. This may sound

like a lot of extra work but it pays huge dividends in percentage of rooted cuttings.

Fungicide dip of cuttings. We do no fungicide dipping of cuttings because of our disease preventative program with stock plants in the nursery and greenhouse and a "spray only as needed" program. We feel that it would not be economical with clean stock.

To "hormone" or not to "hormone." Realizing that without the hormones available to us many plant species would be too costly to root, hormones are used on most of our cuttings. We are currently using Hormodin 1, 2, or 3, mixed with carbamate at a 10:1, v/v, ratio. We are also using Dip-N-Grow this year. There are some plants species that our experience indicates do not require a hormone treatment, as the percentage of rooting is the same with or without them. The following is a list of species, and cultivars on which we use no hormone:

Acanthopanax sieboldianus; Clethra alnifolia and *C. alnifolia* 'Rosea'; *Cornus alba* 'Argenteo-marginata', 'Sibirica', and Spaethii; *Euonymus alata* and *E. alata* 'Compacta'; *E. fortunei* 'Minima', 'Vegetus', 'Emerald and Gold', 'Emerald Gaiety', 'Kewensis', 'Emerald Cushion', var. *radicans,* 'Sarcoxie', and 'Colorata'; *Hedera helix* 'Baltica'; *Hydrangea arborescens* and *H. arborescens* 'Annabelle'; *H. macrophylla* 'Lacecap', 'Nikko Blue', and 'Domotoi'; *H. paniculata* 'Grandiflora'; *Pachysandra terminalis* and *P. terminalis* 'Silver Edge'; and many of the perennials we propagate.

Propagation flats. The use of flats permits easy movement of rooted cuttings to the potting area or removal of single flats from the propagating house if a cultural problem develops. When we made the decision to abandon bench propagation we looked for a flat that was easy to clean and handle, had good drainage, and was rugged and reusable. Wood and galvanized flats did not meet these criteria. Plastic flats were easy to wash but not rugged enough. We currently use Kadon flats that are 20 in. long, 15 in. wide and 2¾ in. deep. Although they are expensive, the cost is justified by their longevity—8 years and still going strong. The only problem we see is that they warp if not properly stacked. However, you need only restack them properly and they straighten out. They are easily cleaned with high pressure water.

Propagation media. Perlite is our best medium with the species we propagate and the mist controller we use. After the cuttings are removed, the perlite is mixed into the growing medium for our containerized hardy mums.

Cleanliness of people, tools, flats, and work area. We require all personnel to wash when leaving and returning to the propagating area. Tools are dipped in an Amphyl solution, and flats are washed and stacked. Perlite is used only from the bag, any that spills goes to the used perlite bin. The work bench is washed and the floor is swept daily. Cuttings are transported only in clean flats.

Collection of cuttings. All collected cuttings are transported in moist, clean burlap or flats. All our softwood and 85% of the hardwood cuttings are cut in the field with side cutting shears, and tied in bundles of 25 with an elastic which eliminates any further cutting or counting at the workbench. Preparation at the work bench includes removal of excess leaves and flower buds, wounding if required, cutting off the tail of heel cuttings, and application of hormones if required. Prepared cuttings are then sent to the propagating house to be stuck. The same procedure is used with our herbaceous perennials.

Sticking cuttings. Sometimes not enough attention is paid to this job. Insertion of the cutting should only be deep enough to keep the cutting upright. If inserted too deeply failure will likely result from basal rotting.

Timing and types of cuttings. With softwood cuttings we feel that the wood is ready for cutting when visual observations indicate that current growth is 75% completed. The onset of winter weather dictates the ripeness of hardwoods. Cuttings of broadleaves, such as rhododendron and leucothoe, can be taken either between growth cycles in summer or after fall growth. Almost all of our cuttings are made from current year's growth with the length of the cutting determined by the plant size, i.e. *Euonymous fortunei* 'Emerald Gaiety' 1½ to 2 in., *E. alata* 6 to 7 in.

Table 1. Schedule for rooting cuttings.

Species/Cultivar	Date	Hormone[1]	Cut Type[2]	Wound	Length (in.)	WTR[3]
Cotinus coggygria 'Purpureus'	6/3	#3	B		5	7
Cotoneaster salicifolia	7/6	#2	S		3	4
Cytisus × *praecox*	7/22	#2	S		6	4
Euonymus alata	6/25	—	S		7	5
Ilex crenata 'Greenluster'	8/15	#2	S		3	4
Leucothoe fontanesiana	1/15	#1	S		5	8
Myrica pensylvanica	7/6	#1	B		4	5
Pachistima canbyi	7/25	#2	S		2	4
Rhododendron (semi-evergreen azalea types)	7/25	#2	H		3–4	5
Rosa rugosa	7/28	#1	A		1–2	4
Sciadopitys verticillata	1/15	#2	B	2 sides	10	12
Taxus cultivars	11/15	#3	S		8	8

[1]Hormodin
[2]A = directly above node; B = ¼in. below node; H = heel cutting
[3]Weeks to root

Care of cuttings after rooting. Rooted cuttings are moved to a shaded greenhouse for acclimation. Care must be taken to ensure that they remain turgid by handmisting during acclimation. We pot most of our rooted softwood cuttings the same season (ground covers year-round), except types such as *Cornus kousa* and

Hydrangea anomala subsp. *petiolaris*, that are potted the following spring after bud break. Potting of softwoods continues until October 1st; after that date they are overwintered in the propagation flat. Fertilizer, Osmocote 17-6-10, is applied only to cuttings that have started growth. All rooted softwood cuttings are overwintered in polyhouses at a minimum temperature of 30°F. Our winter hardwoods are potted the following spring.

CONCLUSIONS

We plant propagators should always keep excellent records of our work, our curiosity should never wane. If we experience failure, and all of us do, check the records for timing, weather conditions, health of the stock plant, disease and pest problems, hormone, or type of cutting. Do not let failure turn to defeat; rather, let it challenge us to strive harder for success.

RAY HESER: Have you noticed any problems with rooting cuttings after herbicide treatment of stock blocks?

CLAYTON FULLER: No.

TOM McCLOUD: What is your herbicide program?

CLAYTON FULLER: As I presented in my paper last year we use a program in which the herbicide and fertilizer are applied together. The herbicide combinations used include Goal/Dual and Goal/Simazine. We apply one application per year and alternate between the two combinations.

THE IMPORTANCE OF PRODUCING DISEASE AND DROUGHT RESISTANT PLANTS

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As I begin I do not wish to offend the producers of many popular plants. What I am about to say is only a reflection of what this small and inexperienced producer sees as problems not only for himself but also for our industry as a whole.

The subject of this paper is the importance of producing disease and drought resistant plants. We constantly produce plant material because it is an old favorite our customers always buy, because it has a spectacular flower or fragrance, or maybe just because for a variety of personal and sentimental reasons, we just like it. I mention this last because I know I frequently fall prey to my own sentiments.

At Quansett Nurseries we produce several hundred *Syringa vulgaris* plants each year and never have trouble selling them and yet each year we consistently spend time and energy and sprays trying, usually unsuccessfully, to keep them free of powdery mildew. There is a magnificent block of deciduous azaleas at the Arnold Arboretum that, when in bloom, has a range of color from pure white to bright red, including pinks, oranges, and delicate shades of all of the above. Truly outstanding when in bloom but very difficult to maintain as saleable plants after they finish blooming. How many times have we had to spray rhododendrons for phytophthera, or at least those few cultivars whose beautiful blossoms are just what we want to produce? For many years new roses have been produced with incredible color and fragrance. But how resistant are some of these to leaf spot and how much time will the end user spend in trying to keep black spot off them. Producers of turf have produced some of the most spectacular looking lawns of blue grass and yet how many home owners are capable of maintaining blue grass lawns without multitudes of chemicals, water, and care?

We are rapidly entering a period when the public will be requiring plant material that can stand its environment without lots of care; when disease and drought resistant plants will not be just desirable, but required.

We know how impatient most of our customers are, especially those in the southern half of this continent. They want a finished landscape immediately but also want it to take care of itself. We must remember our ultimate customers are often not horticulturists. They mostly want something they do not have to spend a lot

of time caring for.

When we started Quansett Nurseries eight years ago we realized with our limited resources we had to produce plant material that obviously was in demand and that could be produced in a short time without major capital outlay. As a result we grew several seashore plants such as *Rosa rugosa, Prunus maritime, Elaeagnus umbellata,* and *Cytisus.* We also produced old favorites of *Syringa, Spiraea,* and old-fashioned roses. As we grew we added perennials and ornamental grasses to our list. We probably should have started with the perennials and grasses as they were certainly the easiest to produce. Unfortunately we did not know this at the time.

We produce perennials and grasses from seeds, cuttings, and division, with the majority from seed and division. Perennial seedlings germinated in January and February are transplanted from plug trays into one and two gallon containers in March. The one gallon containers are saleable in May and the two gallon in June and July. Several crops are planted throughout the year with the last planting completed in October. These are saleable in late April after being stored in unheated polyhouses or under microfoam.

The grasses are produced from divisions taken in December and January. These divisions are grown in plug trays or quart containers until they are planted into two, three and even seven gallon containers in June. And, yes, even the seven gallon containers planted with the larger growing types such as *Miscanthus* and *Erianthus,* are saleable in September.

The demand for this material has grown a lot faster than our ability to produce it. Those garden centers we sell to tell us perennials are becoming a larger and larger part of what they sell. The landscapers are leaping at the ornamental grasses as they represent a relatively new set of plants for our area and require very low maintenance. When the gypsy moth scourge was upon us the grass and perennial areas in the nursery were the ones that required practically no spraying.

Thus we have plant material that takes, in some cases, less than one year to produce and generally two as a maximum. We have a rapidly increasing demand and fewer pests and diseases, as well as less required maintenance, but that is only part of the reason to produce this type of plant material.

I am from Massachusetts which, I realize is not considered a major agricultural producer. Partially because of this, government agencies and environmental groups do not consider our industry important. Frequently laws and regulations are proposed without sufficient study as to their impact on agriculture. Large users of water have had to register the specific amount of water they use in order to be allowed to continue to use that same amount of water in future years. Provision is given for increasing that use but only through a lengthy permit process. Agriculture has no special access

to water. Industrial and agricultural users are lumped together. This registration is only the first step in what promises to be a long and difficult battle.

In Massachusetts the drought was obviously nothing like what occurred in other parts of the country. But even in parts of Massachusetts we had a dry year. This dryness combined with fast paced building development has placed considerable pressure on existing water supplies. This caused several municipalities to put water bans into effect. This essentially shut down landscaping in those areas, and this was in an area that would be considered wet by standards across the country this past summer.

In addition to water use, Massachusetts is in the process of enacting strict ground water regulations. These regulations promise to have a significant impact on pesticide use. Already we have felt pressure from the State Pesticide Board to ban the use, handling, or storage of a wide variety of chemicals in a significant distance from water recharge areas. Again, these regulations were drawn up without any study on agricultural impact.

This pressure has increased so dramatically in recent years the Massachusetts Nurseryman's Association has had to hire a lobbyist to ensure a decent climate for the nursery industry. This has not only been at significant cost but also requires a sacrifice of substantial time from the membership.

But why am I telling you these problems in Massachusetts? Because they are basically the same ones each of you are facing or soon will face. In fact, I am sure some of you have heavier regulations than I have mentioned. I am tired of being labeled as an environmental polluter by environmental groups. I always believed our industry was an improver of the environment. If we are to continue to be, we must be more responsive to this public pressure. We are always advertising how effective our products are in increasing the value of land. How about advertising how we improve the environment and are dedicated to a reduction in water use.

We can reduce pesticide and water use by improving integrated pest management for our industry and designing more efficient irrigation systems, but we can also develop and produce more disease and drought-resistant material.

In the September 1, 1988, issue of the *American Nurseryman* we learned that a city ordinance passed in Los Angeles requires landscaping for all commercial, industrial, and multi-family housing to meet "xeriscape" requirements. A point system drawn up by the city planning department awards points for plants capable of flourishing on natural rainfall after two years of irrigation. Those without sufficient points will be denied building permits.

How long before other areas require similar or even stricter regulations, especially with such chronic water shortages?

In conclusion, I believe it behooves all of us to pay more atten-

tion to the reasons we produce individual plant material. The production of disease resistant and drought tolerant material not only represents great selling opportunities but may also be a requirement before we are ready for it if we do not pay attention now.

MT. CUBA CENTER AND THE UNEXPLOITED WEALTH *OF THE PIEDMONT*

RICHARD W. LIGHTY

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Since World War II we have had a resurgence of interest in new plants from faraway places rivaling that of the Golden Age of Plant Exploration (1840 through 1920). Both eras focused on faraway places—particularly the Orient, and ignored the places easily reached.

But during the 18th century, prior to the opening of the Far East, there had been a frenzy of exploration centered on the eastern coast of North America, involving men like John and William Bartram, Andre Michaux, John Mitchell, and Peter Kalm. These people had friends and patrons in Europe who were avid collectors of minerals, artifacts, animals and plants. The cabinets of curiosity which they assembled served as study collections for these wealthy savants and later as nuclei around which museums, arboretums and zoological gardens were formed. They served also as introduction gardens from which new and useful plants were distributed. Indeed, many of our most useful and widely grown ornamentals came into gardens via this route. Plants like *Phlox paniculata,* the common garden phlox, which exists in hundreds of cultivars, were grown and selected first by amateurs and ultimately by the seed firms and nurseries that were arising to serve the leisure needs of an educated middle class.

But with the opening of Asia by commercial trading companies, such as the Dutch East India Company and the British East India Company, the attention of plantsmen turned from eastern North America, so that our flora was left to the botanists to study. American gardeners regarded European gardens as the source of quality plants, and the incompletely exploited wealth of native American ornamentals was ignored.

We are now seeing renewed interest in our own plants; those of the Coastal Plain, the Piedmont[1], and the mountains. Mt. Cuba

[1] Hilly upland region of the eastern U.S. between the Atlantic coastal plain and the Appalachians, stretching from southeast New York to central Alabama.

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Center for the Study of Piedmont Flora is one manifestation of this interest. There are roughly 3000 species of plants occurring naturally in the Piedmont physiographic province, and of these about 1500 have some ornamental potential. Probably fewer than 500 have had any significant use in gardens.

To illustrate this potential I would like to focus on two native plants—one herbaceous and one woody, which have been widely used and whose potential for horticultural variation has been exploited to some degree.

Phlox paniculata occurs over most of the eastern half of the U.S. where it inhabits moist stream valleys in sun or light shade. Its 1-in. flowers are typically lavender or magenta, but white forms and other variants occur occasionally. Its multiple, stout stems rise 3 to 6 ft. from a semiwoody crown. It was among the earliest American plants to reach Europe, having been introduced by 1730, and was quickly and widely distributed as seed. Such a practice, based on a small sample of seed originally introduced, leads to inbreeding and the appearance of many variants. Those that appealed to gardeners were selected and propagated asexually to produce an array of types with different colors, with darker or lighter "eyes", shorter or taller habits, and larger flowers in fuller inflorescences. This selection process was quickened by the advent of nurseries with plant selection programs, and by the demands of gardeners as they vied with one another for more colorful gardens. England was the focus for most of the early efforts, but the Dutch, French, and Germans later got into the act, followed much later by the Americans as our own nursery industry flourished in the service of the estates of our wealthy industrialists. Ironically, most eastern Americans looked on the tall garden phlox as a European plant, although its humble progenitors still flowered just outside their garden gates.

A second native species, exemplifying another stage in the process of the making of a good garden plant, is *Kalmia latifolia*, the mountain laurel. It was introduced to Europe in 1734 and was well-received, although problems of asexual propagation slowed the spread and selection of improved ornamental variants. Over two centuries, a number of natural variants were selected, named and grown in a limited number of collections. In addition, some outstanding types have been produced as selected seedlings of parents with known potential, but these show more variation than is usually acceptable in woody plant cultivars.

Today there are more than forty cultivars of mountain laurel, some of them are dramatically beautiful and, thanks to the technology of tissue culture, these are now becoming available at local retail outlets as well as through mail order houses. I need not dwell on the marketing potential that has been thus released; this group has a good grasp of that. I do want to emphasize that these cultivars represent but the tip of an iceberg of useful variation that can now be

tapped for use by gardeners. Exciting things are happening and I'm sure we will ultimately see in *Kalmia* the same wide range of ornamentally useful variation that we have in *Phlox paniculata*. The point of both these examples is that the variation is out there in the wild and in gardens and has only to be unlocked by vigorous introduction and selection programs, research on cultural and production problems, or by improving our ability to propagate a wealth of known superior forms.

Mt. Cuba Center is being established to systematically explore the Piedmont for variants for use in gardens and in the general landscape. Once found, these variants will be evaluated, not only for their ornamental worth or freedom from pests, but for attributes such as enhanced propagation and production ability, which will make them better nursery items, or to introduce greater garden adaptability, giving them lower maintenance requirements.

For several years we have been looking at *Trillium erectum* as it occurs on the Piedmont and adjacent areas. We have not only found the centers of variability for a number of ornamental characteristics such as flower color, size, and position, but have also isolated clones which propagate rapidly by division. One such clone has a doubling time of one year under our conditions. We are also running preliminary trials on seedling production of trilliums and believe that it may eventually be possible for nurseries to be competitive with those who are wild collecting plants thus decimating our natural stands.

A selection we plan to name and release in the near future is a clone of *Solidago sphacelata* found in Rockingham County, N.C. It has proved to be a tough, reliable, easy-to-propagate deciduous groundcover for sunny, dry sites. Like *Rudbeckia* 'Goldsturm' and *Sedum telephium* 'Autumn Joy', this plant is a candidate for public and commercial landscapes where high visual impact and low maintenance are necessary.

On the woody plant side we are looking at eight *Leucothoe axillaris* selections for a variety of ornamental qualities as well as qualities like easy propagation and reliable production. It occurred to us that most of the named cultivars are strangely colored or variegated forms and that the market could use an elegant green type. Our selection is one with elegantly arching stems, sharp-pointed leaves with an undulate edge, and large quantities of flowers in short racemes.

In addition to selecting superior sorts of new or familiar native ornamentals from the wild, we are looking at American plants that are being offered by small or specialty nurseries. Among those we feel merit much wider use are *Chionanthus pygmaeus*, an endangered species from Florida which is perfectly hardy in Wilmington, Delaware; *Stewartia ovata* forma *grandiflora*, which is available from only a few retail nurseries; and *Ilex verticillata*

'Maryland Beauty', a registered cultivar selected for and presently limited to the Christmas cut-stem trade. Sometimes we discover an outstanding form that is grown only locally and for which we cannot find a cultivar name. One such plant is a compact *Aster novae-angliae* clone with large purple flowers that is seen in many gardens within an area of only a few square miles in one part of Pennsylvania. No doubt it was a local selection passed from hand to hand by gardeners.

Still another aspect of our work is to sort through the available cultivars and selections of specific plant groups such as *Cornus sericea, Juniperus virginiana, Cornus florida,* and *Ilex verticillata,* so as to be able to publish on the horticultural variation in these groups, introduce in a broad way the outstanding but neglected sorts, and identify areas for further work.

Underlying all of our goals is the belief that our native plants are as garden-worthy as those of any region of the world and that the rising interest in naturalistic gardening will put demands on our native flora that should not be met by wild collecting. A public that comes to appreciate native plants will be more inclined to protect them than one which is oblivious to their beauty. In pursuing these ends we believe that nurseries, gardeners, and Mt. Cuba alike can all profit from the enlightened appreciation, production, and use of an enlarged array of ornamental plants.

RALPH SHUGERT: How do you propagate your *Ilex verticillata*?

FRANK GUOIN: Cuttings taken in June-July, no hormone, under mist root in 3 to 4 weeks. They can be potted up immediately after rooting.

EVALUATION OF WOODY ORNAMENTALS FOR KANSAS[1]

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Evaluations of new, different, and superior plants are meaningful to nurserymen, arborists, landscape architects and designers, and to consumers. This project attempts to identify and evaluate worthy landscape plants for use in Kansas. Specific problems in plant selection for Kansas vary widely because of large differences in climate, soils, and urbanization. A special need for increased selections of shade trees for western Kansas has been expressed by the nursery industry. New, different, and superior cultivars or woody species also are needed in the more populous eastern and central regions.

MATERIALS AND METHODS

Planting sites are on Kansas Agricultural Experiment Station fields in Manhattan, Hays, Colby, Tribune, Garden City, and Wichita. Each spring since 1984, five species or cultivars (Table 1) have been planted at each site in a randomized block design (five replications per site). Height and diameter (at 30.5 cm) of new and existing plantings are measured at the same time. All plantings are subjectively rated for foliage quality and overall quality during the summer. Survival also is recorded in late summer.

After the initial planting, care of the plants, except fertilization, is the responsibility of personnel located at each site. Each plant was fertilized with 75 g of a low nitrogen, complete fertilizer during the spring of the first season after planting and annually in subsequent years.

RESULTS AND DISCUSSION

1984 Planting. Survival varied with species and site (Table 2). Some sites (especially Colby, Tribune, and Garden City) were quite dry, and plants have suffered. Although differences in survival, growth, and quality were partly due to environmental factors, some were obviously due to variations in care. Survival, growth, and quality were better at sites where periodic irrigation was provided and weeds were controlled.

The only plant established during 1984 that survived at all sites

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[1] Contribution no. 89-200-A of the Kansas Agricultural Experiment Station, Manhattan, Kansas.

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Table 1. Species planted to date.

Botanical name	Common name
	1984
Crataegus crus-galli var. *inermis*	Thornless cockspur hawthorn
Fraxinus excelsior 'Kimberly'	'Kimberly' European ash
Pistacia chinensis	Chinese pistachio
Pyrus calleryana 'Aristocrat'	'Aristocrat' Callery pear
Quercus shumardii	Shumard oak
	1985
Acer platanoides 'Greenlace'	*'Greenlace' Norway maple*
A. rubrum	red maple
Cercocarpus montanus	mountain mahogany
Phellodendron amurense	Amur corktree
Q. acutissima	sawtooth oak
	1986
A. saccharum	sugar maple (Caddo selection)
A. saccharum 'Legacy'	*'Legacy' sugar maple*
Celtis laevigata 'All Seasons'	'All Seasons' sugar hackberry
Evodia hupehensis	Hupeh evodia
Q. imbricaria	shingle oak
	1987
A. rubrum × *A. saccharinum 'Autumn Blaze'*	*'Autumn Blaze' maple*
A. truncatum	*purpleblow maple*
F. americana 'Champaign County'	'Champaign County' white ash
Pinus strobiformus[P. (flexilis var. *reflexia)]*	*southwestern white pine*
Q. robur 'Westminster Globe'	'Westminster Globe' English oak
	1988
Corylus colurna	Turkish filbert
F. mandshurica 'Mancana'	'Mancana' Manchurian ash
Platanus × *acerifolia* 'Bloodgood'	'Bloodgood' London planetree
Q. frainetto 'Schmidt'	'Schmidt' Hungarian oak
Sapindus drummondii	western soapberry

two years after planting was thornless cockspur hawthorn (Table 2). This plant seemed to be reasonably well adapted to all sites, although it was chlorotic at Garden City, where only one plant survived. Chlorosis was not a problem at the other locations. 'Kimberly' European ash had problems at all sites. The original planting did not leaf out well for unknown reasons. Additionally, several of these plants were killed during the 1985 winter in Manhattan; some deer damage also occurred. Borer damage to 'Kimberly' ash in Wichita resulted in eventual tree mortality. All plants had died by mid-summer 1988 at Manhattan because of borer attack.

Some of the problems associated with Shumard oak and 'Aristocrat' pear were due to oversized and poor-quality stock from

the nursery. Both plants did reasonably well at sites where the original planting survived, except at Garden City. There 'Aristocrat' pear was quite chlorotic; the soil pH was 8.3. The majority of the Chinese pistache did not survive, except at Garden City and Wichita.

Average height growth of the 1984 species for each site is presented in Table 2. Data were analyzed as a repeated-measures

Table 2. Survival, average height, and diameter growth per year, and summer and overall quality ratings (1–5) for trees planted at 6 locations in Kansas in 1984.

Location	Survival (%)			Average growth (%/year)		Quality ratings (1987)	
	1984	1986	1987	Height	Diameter	Summer	Overall
				thornless cockspur hawthorn			
Manhattan	80	80	80	8.3 ab[z]	26.4	5.0	5.0
Hays	100	100	100	6.7 ab	20.2	3.8	4.5
Colby	100	100	100	3.4 a	22.6	4.4	4.4
Tribune	80	80	80	6.4 ab	25.5	4.3	4.5
Garden City	20	20	0	—	—	—	—
Wichita	100	100	100	9.5 b	22.4	5.0	5.0
				'Kimberly' European ash			
Manhattan	100	40	40	24.0	47.0	5.0	4.0
Hays	20	0	0	—	—	—	—
Colby	0	0	0	—	—	—	—
Tribune	20	20	20	14.8	42.8	5.0	5.0
Garden City	0	0	0	—	—	—	—
Wichita	100	40	40	24.1	30.8	5.0	1.8
				Shumard oak			
Manhattan	80	80	80	11.9	35.5 b	4.9	4.3
Hays	60	40	40	0.8	15.6 a	3.5	3.8
Colby	0	0	0	—	—	—	—
Tribune	40	40	40	3.6	8.8 a	3.5	3.3
Garden City	20	20	20	4.3	9.0 a	2.5	3.0
Wichita	40	40	40	16.3	23.1 ab	5.0	3.5
				'Aristocrat' callery pear			
Manhattan	60	40	40	26.0 c	39.9 b	5.0	5.0
Hays	60	60	60	13.3 b	27.7 b	5.0	5.0
Colby	0	0	0	—	—	—	—
Tribune	20	20	0	—	—	—	—
Garden City	40	40	40	1.0 a	12.13 a	1.3	1.3
Witchita	100	100	100	22.3 c	35.9 b	5.0	4.8
				Chinese pistache			
Manhattan	0	0	0	—	—	—	—
Hays	80	20	20	14.8 a	45.5	5.0	5.0
Colby	100	0	0	—	—	—	—
Tribune	20	0	0	—	—	—	—
Garden City	100	80	80	12.1 a	27.6	4.2	3.8
Wichita	100	100	100	26.0 a	37.9	5.0	4.6

[z]Within species and columns, mean separation by Tukey's HSD (.05). Means not followed by a letter did not have significant F ratios (p = .05).

ANOVA. Only plants surviving through 1988 were considered, and missing data were ignored.

Height growth was generally greater at sites with a more moderate environment (Manhattan and Wichita). Stem diameter growth also followed this trend (Table 2).

Foliage and overall quality of the plants during 1987 is presented in Table 2. The appearance and quality of 'Aristocrat' pear was excellent at Manhattan, Hays, and Wichita. The quality of Shumard oak and Chinese pistache was good where they survived.

From the results collected thus far, we can conclude that thornless cockspur hawthorn is a desirable plant for consideration in most Kansas landscapes. It would be approprate for use as a single specimen, in groups or masses, and as a screen. The flower and fruit displays are good, and we have seen only minimal incidence of rust on the foliage. This cultivar will likely be somewhat shorter at maturity than the species. The only problem we have encountered is some, but not extensive, suckering from the base. This can be handled easily by periodic pruning.

'Kimberly' European ash grew well but was subject to winter injury and borers. It would be a questionable plant for widespread planting.

Shumard oak is similar in habit to pin and scarlet oak but does not exhibit the iron chlorosis problem that plagues pin oak. From its performance in these trials, we would conditionally recommend this plant as a possible alternative to pin oak.

'Aristocrat' flowering pear grew well in Manhattan, Wichita, and Hays. It suffered greatly in Garden City, where chlorosis was a severe problem. We did not find the clustering of major branches, a problem with 'Bradford' pear, on the 'Aristocrat' pear trees in our trials.

Chinese pistache was reliably hardy only at the more southerly sites (Wichita and Garden City). In these areas, however, it certainly deserves wider consideration and planting as a specimen, street, or small ornamental tree. It was tolerant of alkaline soil conditons (pH 8.3).

1985 Planting. Survival of the 1985 planting was somewhat better than that of the 1984 study (data not shown). Sawtooth oak survived reasonably well at all sites. 'Greenlace' Norway maple survived poorly at all locations except Wichita; this may have been related to the quality of nursery stock received. Mountain mahogany survived better at drier sites than in Manhattan or Wichita. The only plant with any substantial loss during the 1986 winter was Amur corktree. Some of the losses can undoubtedly be correlated with environmental conditions and supplemental care.

1986 Planting. Survival was again variable. Both sugar maple selections and shingle oak established well at all locations. Performance of 'All Seasons' sugar hackberry was disappointing, because the plant failed to break dormancy in several locations.

Shingle oak established well except at Colby. Evodia did well, but some loss was experienced during late summer, 1986, or during the 1986–87 winter.

'Legacy' sugar maple had not grown notably at any location, wheras the 'Caddo' selection had grown at all sites. The most dramatic growth was by Evodia.

1987 and 1988 Plantings. The 1987 and 1988 evaluations showed that Amur cork did not perform well at most locations. Sawtooth oak did well at all locations except Garden City, where it suffered from chlorosis. Red maple performed better than expected at locations where it survived. Foliage quality of the 'Greenlace' Norway maple scorched at the more westerly locations.

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A CRISIS IN CULTIVAR NOMENCLATURE

RICHARD H. MUNSON

The Botanic Garden of Smith College
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Northampton, Massachusetts 01063

The ability of our nursery industry to function smoothly and fairly is dependent upon, among others, the use of correct and consistent names to our plants. The rules of nomenclature for cultivated plants have for many years controlled, rather successfully, the proper use of cultivar names. This resulted in a system that assured relatively uniform names throughout the industry, avoided most improper cultivar names, and gave everyone an opportunity to sell cultivars under their correct names. The only exception to this situation concerned the sale of patented cultivars where royalty agreements protected patent owners against unauthorized propagation and sale of their plants. Trademarking, a relatively new practice, however, threatens the availability of horticultural cultivars beyond the constraints of the plant patent law.

In order to understand more fully how the practice of trademarking has affected our industry several examples are given below. It should be understood, however, that there are no clear solutions to the problems and that the examples are meant to illustrate the problems and not to condemn, necessarily, those individuals and organizations which follow these practices. Our

Shingle oak established well except at Colby. Evodia did well, but some loss was experienced during late summer, 1986, or during the 1986–87 winter.

'Legacy' sugar maple had not grown notably at any location, wheras the 'Caddo' selection had grown at all sites. The most dramatic growth was by Evodia.

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opinions, whether pro or con, should be tempered by the realization that anyone who has spent a great deal of time and money developing a new plant ought to be able to reap the benefits of his or her work. The major point of contention is how long someone should have exclusive rights to an introduction.

Davis and Luby (3) give several reasons why trademarks are being used by some commercial firms as a way to protect a brand or generic name under which cultivars will be sold. The most important is that nurserymen may protect the fancy name applied to a plant by trademarking it and patenting the cultivar name. Since trademarks are good for 20 years and can be renewed indefinitely, this results in a perpetual lock on the name that most consumers recognize, even after the patent for the cultivar has expired. In many cases this gives the trademark owner exclusive perpetual control over a particular clone.

Some of the problems with cultivar names, code names, and trademarked names lie within the International Code of Nomenclature for Cultivated Plants-1980 (2) itself. Adherence to the Code (I.C.N.C.P.) is a strictly voluntary "gentlemen's agreement" and has no force of law behind it. Consequently there is a great deal of non-adherence to the rules of the Code. The Code addresses not only the correct or incorrect form of cultivar names but also the official registration of cultivar names. Unfortunately the I.C.N.C.P. is somewhat ambiguous about the subject of trademarked cultivar names. Articles 3, 4, 53, and 56 refer to trademarks but *do not expressly prohibit the practice of trademarking cultivar* names.

The Code does, nevertheless, recommend (Recommendation 31 Aa) avoiding names composed of an arbitrary sequence of letters. This presumably means the use of code names. However, the use of code names, a practice becoming widespread, is not expressly forbidden. When a code name, used as a cultivar name, is coupled with a "fancy" trademarked name, a grower other than the trademark owner may have a great deal of difficulty selling the plant under the cultivar name. Article 27 states, in essence, that a cultivar name published after 1 January 1959 must be a fancy name not in Latin form. To many this implies a real word in common usage, not a code name. The pamphlet published by the American Association of Nurserymen entitled "Naming and Registering New Cultivars" (1) also states in Rule #5 "The name [cv] must be in common language." This also implies the prohibition of code names as cultivar names. However, the use of code names as cultivar names was invented and put into practice by an organization of plant breeders for the purpose of protecting their introductions. C.I.O.P.O.R.A. (*Communauté Internationale des Obtenteurs de Plantes Ornamentales et Fruitières Réproduction Asexuée*, or The International Community of Breeders of Asexually Reproduced Fruit Tree and

Ornamental Varieties) introduced this practice which has been followed by some American nurserymen. The code names originally had the first letter (designating the breeder) in upper case letters followed by several more in lower case. For example, introductions by the fictitious Wombat Nursery would look like this: WOMgen, WOMetl, and WOMzeg. Because code names are now being used and advertised as actual cultivar names, albeit unregistered cultivar names, along with a fancy sounding trademarked name it is unlikely that a non-trademark holder will be able to sell many plants with the rather unattractive cultivar name of 'Womzeg', for example. Since this code name could not have been officially registered as a legitimate cultivar name (a registrar would reject it as a code name), another nurseryman could register the clone with an acceptable cultivar name and sell it with greater ease. Now there are at least three names under which one clone is sold, two of which have attractive sounding names: the trademark name and the legitimate cultivar name.

Another very serious problem is the blanket trademarking of a name which applies to cultivars of several genera and species. For example, an American nursery has trademarked the name, MAJESTIC BEAUTY™. This name is applied to cultivars in the following genera: *Araucaria, Chorisia, Cinnamomum, Cupaniopsis, Fraxinus, Liriodendron, Magnolia, Olea, Pinus,* and *Raphiolepis*. Each of these clones has either a "code name", cultivar name, or a cultivar name in long-standing use in the trade. If the cultivar name is not patented or the patent has expired, a grower other than the trademark owner must sell the plant under the cultivar name and not the trademarked name. In a few cases this does not affect sales negatively but in most other cases sales would be difficult. Again, if the cultivar name is not registered, a grower could select another name, register it, and sell his plants under the third name. This results in the use of many different names for the same clone. Also in contention here is whether or not code names can be used as legitimate cultivar names. If viewed as legitimate by some registration authorities then a second grower has no other ethical choice than to use the code name cultivar name if he wants to sell the plant.

To further illustrate this problem the following real example should suffice. The University of British Columbia Botanic Garden selected and registered with the Canadian Ornamental Plant Foundation the cultivar of *Rubus calycinoides* named 'Emerald Carpet'. Since Monrovia Nursery in California owns the trademarked name EMERALD CARPET™ for all plants by that name, the U.B.C. Botanic Garden, or its cooperators, cannot sell the plant in the United States by its legitimate cultivar name. Although the trademark is not valid in Canada, most of its potential market is effectively shut out by the trademarked name. This case points out

the futility of following proper cultivar registration procedures only to be beaten by a previously unknown or subsequent trademark.

Another problem that has surfaced recently is the real fact that many nurseries have used several names over time for the same clone. Eventually, one of the names gained widespread use and popularity. A nursery decides to trademark this successful name and reverts to a former, less desirable, name for its official cultivar name. Although cultivar names are governed by rules of priority of publication most names are never officially registered so there is little or no barrier to this practice. Again, the result is having several names for the same clone with the most desirable name now the property of a single nurseryman.

A similar example is the practice of giving a new trademarked name to a clone for which another valid cultivar name already exists, resulting in two names for the same clone. For example, *Liriodendron tulipifera* 'Aureo-marginatum' has been a correct cultivar name since 1903. It now has the trademark name MAJESTIC BEAUTY™ attached to it, giving two names for the same clone (4). Although most nursery professionals would recognize that the two names identify the same clone, consumers would most likely be drawn to the more attractive trademarked name giving the trademark owner an unfair advantage.

An equally serious problem is the trademarking of legitimate cultivar names. Although it is reportedly not possible to trademark cultivar names legally it seems to be happening with alarming frequency. Many patented cultivars have had their cultivar names trademarked as the patents neared expiration. The problem exists because most trademark commissioners do not understand plant nomenclature and registration and because there is a dual trademarking system in the United States. There are federal trademarks which apply to all states and there are trademarks issued by states and are valid only in that state. There seems to be no system for coordination of the granting of federal and state trademarks although the states are supposed to follow federal laws. Thus, a trademark can be obtained for a plant name in one or several states without the federal trademarking authority knowing about it. It is also possible for the same clone to have received several different trademarks in several different states. The ramifications of this possibility are truly frightening.

In summary, the crisis facing cultivar nomenclature is multi-faceted. There is no legal weight forcing adherence to the I.C.N.C.P. Names of patented cultivars are being trademarked as they near the patent expiration. Non-patented cultivar names are being trademarked as well as cultivar names that have been long present in the public domain. Some cultivar names are being changed and trademarked retroactively. There are both state and federal trademarks but there seems to be no communication

between authorities. At least one court has ruled that cultivar names cannot be trademarked but the practice seems to be continuing. It appears that aside from voluntary restraint, there is little that can be done to stop the trademarking of cultivars and/or the assignment of nonsensical code names to cultivars. Real hope for a solution that will restore order to our system of cultivar nomenclature can only come from a compromise worked out by a joint conference of international registration authorities (I.R.A.s), American and Canadian nursery organizations, the commissioners for patents and trademarks for both countries, plant patent owners, and representatives of the International Commission for the Nomenclature of Cultivated Plants, to name a few. Members of the legal profession must also be present since our nomenclatural problems extend into the legal realm as well. Whatever can be done to solve these problems needs to be done soon.

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BRUCE BRIGGS: Plants brought into this country from many foreign countries, such as Japan and Germany, have names that are difficult to pronounce. Is it permissible to translate the foreign name into what it means in English?

RICHARD MUNSON: The names should stay in the foreign language. However, there is nothing stopping you from giving it a common name that would make it easier to sell.

PETER DEL TREDICI: How widespread is the giving of another cultivar name to a plant that already has a legitimate cultivar name? One that comes to mind is *Liriodendron tulipifera* 'Aureo-marginatum' and 'Majestic Beauty'.

RICHARD MUNSON: Not very widespread.

DICK LIGHTY: I have a comment on trademarking a plant name. You could take a plant with a trademarked name and give it another trademarked name after the patent expires. This could be done by many different individuals. You would then have a number of different named plants all the same plant with different trademarked names.

PETER ORUM: I would like to make a comment. We commercial people have to sell the product and make some money.

Strange names make selling a plant difficult and I have a story to tell you that points that out. Some time back we obtained one plant of a small sedum from Bailey's Nursery. We did not and they did not know the name of the plant. We propagated it, sold it as 'Bailey's, and sold 20,000 to 30,000 per year. Someone came along and told us what it was. It came from Germany and had a name nobody knew and no one could pronounce in our catalogue. For the next few years we sold only a few thousand plants with the new name. We then changed it back to the original name and again sold 20,000 to 30,000 plants.

ACER × *FREEMANII*—A SOURCE FOR NEW SHADE TREE SELECTIONS

KRIS R. BACHTELL

The Morton Arboretum
Lisle, Illinois 60532

Two commonly planted maples in the U.S. Midwestern landscape are the red maple, Acer rubrum, and the silver maple, *A. saccharinum*. Many selections have been made from each species (1). A large number of red maple selections exhibit consistent, attractive fall coloration and predictable growth form. Most silver maple selections feature a narrow growth form and deeply dissected leaves. Despite selection efforts, both maples encounter problems in certain Chicago landscape situations.

Red maple grows best in locations with good quality soil and adequate moisture. When transplanted into highly disturbed soils typical of new construction sites in the Chicago area, red maple usually performs poorly. These soils are alkaline, with pH levels often above 7.4, and they also possess a high bulk density because of their clay content. Planted in these conditions, red maple is slow to establish and often succumbs to stress-related problems. Plants which survive long enough to become established often exhibit alkaline soil-induced chlorosis.

Silver maple is more tolerant of adverse soil conditions associated with recent construction. Unfortunately, it can be an unkempt and weedy tree, with weak branches prone to ice-breakage. Large numbers of seeds and seedlings are often produced, requiring additional maintenance. Aesthetically it lacks the colorful flowers, fruits, autumn foliage, and bark of the red maple.

The attributes and problems characteristic of each of these species should be a guide for future plant selection. Hybrids of the red and silver maple could combine the desirable aesthetic features

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The attributes and problems characteristic of each of these species should be a guide for future plant selection. Hybrids of the red and silver maple could combine the desirable aesthetic features

of the red maple with the broader environmental adaptability and fast growth rate of the silver maple. Hybrids might exhibit, for example:

1) greater tolerance of alkaline soils than that of red maple
2) greater drought tolerance than that of red maple
3) stronger branch attachment and wood than that of silver maple
4) better fall color than that of silver maple
5) faster rate of growth than red maple and slower rate of growth than silver maple
6) no seed production on staminate (male) plants
7) a commercially feasible propagation method through cuttings or tissue culture, thus avoiding the potential problem of delayed graft failure.

A hybrid between these two species has been taxonomically recognized and is called Freeman maple, *Acer* × *freemanii* (5). The hybrid is named after Oliver M. Freeman, a plant breeder with the United States Department of Agriculture in Washington, D.C., who successfully crossed the species in 1933 (3).

Spontaneous hybrid plants have been identified by researchers and horticulturists in several areas of the United States. William Ellis, while conducting research for his Ph.D. dissertation in 1963, cited 29 specimens of apparent hybrid material collected from New Brunswick, Canada, to southwestern Wisconsin, and southward to southern Indiana near the Ohio River (2). The native ranges of both parent species overlap appreciably east of the Mississippi River. Based on Ellis' work, the southern limit of the hybrid is southern Indiana. Dr. George Ware, Dendrologist, Morton Arboretum, Lisle, Illinois, thinks the southern limit of the hybrid is the result of different flowering periods of the two parents in the southern portion of their range (personal communication).

Because the Freeman maple is of hybrid origin, the potential for variation among individual trees is great. Since the hybrid trees and the two parent species could grow together in the same area, the opportunity for backcrossing is also increased. This is known as introgression, and can lead to a hybrid population with considerable variation (4).

IDENTIFYING HYBRID TREES

Dr. Edward Hasselkus, Professor of Horticulture, University of Wisconsin—Madison, notes the following characteristics in hybrid trees he has observed: the form is taller than broad; the leaves are five-lobed; the bark on young trees is light gray; and the rate of growth is slower than silver maple but several times faster than red maple (personal communication). Fall coloration can vary greatly

on individual trees, ranging from an attractive crimson to a poor yellow-green.

Outlined below are different characteristics useful in identifying hybrid trees (Table 1). Because the Freeman maple is so

Table 1. Comparison of different identification characteristics among red, freeman, and silver maples.

RED MAPLE	FREEMAN MAPLE	SILVER MAPLE
BARK-young tree light gray long persistent	light gray short to long persistent	light gray short persistent
BARK-mature tree black or dark brown small plates	black to brown exfoliating on the trunks of some older trees	dark brown exfoliating on the trunks and larger branches of older trees
BRANCHING—young trees ascending	ascending	ascending to horizontal
BRANCHING—mature trees horizontal	ascending	becoming decurrent and pendulous
FORM: conical to oval, occasionally columnar	narrow to broad-oval	broad-oval to globose
LEAVES—# of lobes usually 3, sometimes 5 with basal pair much smaller than middle lobe	5, the middle lobe occasionally 3-lobed	5, the middle lobe usually 3-lobed
LEAVES—sinuses straight or slightly convex irregularly toothed to base of sinus	sides concave, rarely straight, irregularly toothed, may or may not be toothed to base of sinus	concave, entire, no serration in sinuses
FRUIT—samara size small, ¾ in. long	intermediate	large, 1⅓ to 2⅓ in.
FRUIT—length of pedicel long, 2 to 3 in.	intermediate	short, 1½ in. or less
FALL COLORATION yellow to brilliant red	variable yellow to crimson, sometimes mixed with yellow and green	yellow-green
ODOR OF SCRATCHED TWIG no odor	intermediate; odor absent on some; present on others, usually not as strong as silver maple	strong pungent odor
SUSCEPTIBILITY TO POTATO LEAF HOPPER (stunting of mid-summer terminal growth: data from Lisle, Illinois) Susceptible	intermediate	not susceptible

variable, it is difficult to give precise measurements for the identifying characteristics, but most are generally intermediate between that of red and silver maple.

CULTIVARS

The usefulness of Freeman maple selections has already been recognized by some nurserymen. Several cultivars are currently being grown by nurseries, although only a few of these are formally recognized as being hybrids. According to Hasselkus, several cultivars currently being grown as selections of red or silver maple are really hybrids.

Outlined below are cultivars currently being included under Freeman maple and those selections Hasselkus (personal communication) also attributes to this hybrid. Along with the cultivar name, a brief description is included describing the plant's origin and growth characteristics. Note that the characteristics are similar to those described earlier for the Freeman maple.

1) *Acer* × *freemanii* cultivars:

'Autumn Blaze'. Original tree believed to be from Ohio. Selected by Glenn Jeffers, Fostoria, OH. Upright-narrow form, with rate of growth medium to fast. Leaves 5-lobed, more closely resembling silver than red maple. Fall color in Madison, WI orange-red. Rated by Hasselkus as the best fall color of available *A.* × *freemanii* selections. Flowers believed to be staminate.

'Autumn Fantasy'. Original tree from central Illinois. Selected by Willett Wandell of Discov-tree Research and Development, Inc., Oquawka, IL. Upright-oval form, with leaves 5-lobed, more closely resembling silver than red maple. Fall color in central Illinois an attractive crimson. Not known if flowers are staminate or pistillate.

'Celebration'. Original tree from Lake County, OH. Selected by Lake County Nursery, Perry, OH. Upright-oval form, noted for its uniform, compact branching habit. Mature tree 45 ft. high by 20 to 25 ft. wide. Leaves similar to silver maple. Fall color in Madison, WI typically yellowish-green. Flowers staminate.

'Marmo'. The original tree is located at the Morton Arboretum, Lisle, IL and was released by the Morton Arboretum. Although the exact history is not known, it is believed the Arboretum received the tree from a Wisconsin nursery in the late 1920's. The original 60-year specimen has an upright-narrow oval form and is 70 ft. high by 35 to 40 ft. wide. Leaves are 5-lobed, sinuses toothed ⅔ the depth of the sinuses, and more closely resembles silver than red maple. Fall color in Lisle, IL, crimson mixed with yellow and/or green. Flowers are staminate.

2) *Acer rubrum* cultivars (all believed to be of hybrid origin):

'Armstrong'. This plant has been generally believed by the

nursery industry to be a hybrid. Selected by Newton Armstrong, Windsor, OH in 1947 and promoted by E. H. Scanlon and Associates, Olmsted Falls, OH. The original tree is from Ohio. A strongly fastigiate form with 5-lobed leaves that resemble silver maple more than red maple. Fall color in Lisle, IL is typically poor, being yellow-green with some green tinged with red. Flowers mostly pistillate, but also bears staminate flowers.

'Armstrong Two'. This cultivar originated from a planting of 'Armstrong' in Windsor, OH and was selected by E. H. Scanlon and Associates, Olmsted Falls, OH. Described in Scanlon catalog as selected from a planting of 'Armstrong' for superior autumn leaf color. The form is narrower and more tightly ascending branches than 'Armstrong'.

'Morgan' (Canadian Name) = 'Indian Summer' (U.S. name). As described in catalog of Sheridan Nursery, Oakville, Ontario, Canada. Selected by the Morgan Arboretum, MacDonald College, Quebec. This cultivar is noted for its consistent, brilliant scarlet fall color, even on young plants. Flowers are pistillate.

'Scarlet Sentinel'. The original tree is located near Interstate 90, in Ashtabula, OH. It was found by George Schichtel of Schichtel Nursery, Orchard Park, NY and released by J. Frank Schmidt, Boring, OR in 1972. Form is upright-oval. Leaves are 5-lobed, more closely resembling silver than red maple. Fall color in Madison, WI typically poor, yellow-green. Flowers are pistillate.

3) *Acer saccharinum* cultivars (believed to be of hybrid origin):

'Lee's Red'. Selected in southern Ontario, Canada and as described in the catalog of Sheridan Nursery, Oakville, Ontario, of note for its brilliant red fall color. Foliage not as deeply divided as that of silver maple.

The Freeman maple selections being tested in several Midwestern locations are performing well. They are proving to be more tolerant of adverse soil conditions than red maple and are also more ornamental than silver maple. Selection efforts need to continue with this group of plants. A tree that produces consistent fall coloration equal to most red maple cultivars needs yet to be developed.

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PETER DEL TREDICI: *Acer saccharinum* has two times the number of chromosomes as *A. rubrum*. Do the hybrids therefore favor the *A. saccharum* parent?

KRIS BACHTELL: Not necessarily from what we have seen. They are quite variable as to which parent is favored.

IT'S A PLANT INTRODUCTION PROGRAMME (P.I.P.) PLANT

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Botanic gardens are cultural, scientific, and educational institutions based on the world of plants. Historically, old world botanic gardens were private or university associated places reserved for scholars and the cognoscenté of the day. Fortunately, especially among North American botanic gardens and arboreta, this is no longer the case. Indeed, in most instances, it is quite the opposite. We encourage visitors and public membership through advertising and educational promotion—sometimes to the point where we must remind ourselves that while we may be a "tourist attraction", this is not our primary role. Our plant collections are both living museums and research laboratories where we demonstrate and document the diversity of the plant kingdom. In doing this, we are constantly trialing and evaluating new plants to determine their potential. Unfortunately, many plants which prove to have merit fail to go beyond the boundaries of the botanic garden or arboretum. Most of us at some time or another will have encountered a plant we thought had a great future in horticulture; yet, for some reason, it fell into the position where the trade failed to grow it because of lack of demand and garden designers could not recommend it because it was not available. Both groups regretted the situation but were not able to do much about it: a horticultural "Catch 22."

To help remedy this situation in eastern Canada, Royal Botanical Gardens, in co-operation with the Growers Group of Landscape Ontario initiated the Plant Introduction Programme

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To help remedy this situation in eastern Canada, Royal Botanical Gardens, in co-operation with the Growers Group of Landscape Ontario initiated the Plant Introduction Programme

(P.I.P.) in 1983. It was essential to the project to have input from all aspects of the horticulture industry. Thus, growers, educators, researchers, landscape architects, contractors, and retailers were invited to participate. With the help of these professionals and seed money from the Growers Group, it was possible to establish goals, parameters, and a procedural framework for the project. Once this was in place, it was possible to obtain additional support from the Ontario Ministry of Agriculture as well as Food and Agriculture Canada.

Unlike many similar schemes, it was decided not to limit potential introductions to only new plants. Obviously, this broadens the scope enormously and permits us to consider native plants and older cultivars of merit.

A Steering Committee and three Subcommittees—Financial, Research, and Development and Marketing—were established to administer the programme.

An initial industry-wide call for plants to be considered for the programme yielded over 150 suggestions. Of these, 19 taxa were considered immediately worthy of further evaluation and, in 1984, some 40 professionals representing all sectors of the horticulture industry were invited to the first P.I.P. field day at Royal Botanical Gardens. Participants were asked to rate each plant's visual characteristics and its potential for use by retailers, designers, and contractors. The results of this poll were used to prepare an initial short list of plants for introduction. The selected plants were then planted in evaluation gardens at Royal Botanical Gardens and at several test stations across Canada. Concurrently, production of stock plants and propagation research began.

Once sufficient stock plants of a given selection are available, they are sold to participator nurseries who agree contractually to produce a minimum number of plants by a prescribed date. P.I.P. advertises and promotes the plants to help create a demand and provides the growers with labels and coloured brochures. The limited number of stock plants are distributed only to participator nurseries. However, once the plant is on the market it may be purchased, grown, and sold by anyone. Should the plant happen to be a Royal Botanical Gardens introduction, then the Canadian Ornamental Plant Foundation royalties are returned to the programme as are funds generated by the sale of stock plants.

The first P.I.P. plant to be marketed in 1987 was *Potentilla reptans* 'Pleniflora', a sun-loving, low, creeping, herbaceous ground cover which produces 2 cm diameter double yellow flowers throughout the summer. It has a vigorous growth rate, spreading rapidly to form a dense mat. It is hardy to Canadian Plant Hardiness Zone 3b and was selected in response to designers' and contractors' needs for hardy, vigorous, fast-growing utility ground covers. It propagates very easily from runners or divisions and is well suited

to container growing.

The 1988 P.I.P. plant is *Viburnum farreri* 'Nanum'. Particularly suited to small gardens, it is a dwarf, rounded shrub with upright branching to height of 1 m and a spread of 1.5 m. The fragrant, blush-pink flowers open in mid to late May in Hamilton. The emerging leaves are wine-purple, turning to a summer dark green and back to purple in the autumn. It is hardy through Canadian Plant Hardiness Zone 6 and will grow in sun or partial shade. It propagates very easily from softwood cuttings.

Future introductions may include *Syringa vulgaris* 'Sensation', a French hybrid lilac in which each deep purple floret is edged with white; *Syringa vulgaris* 'McMaster Centennial', a double white lilac, originating from breeding programmes at Royal Botanical Gardens; some flower bud hardy selections of *Cornus florida* from native Ontario populations; a selection of *Cephalanthus occidentalis* with superior flowering and fall colour; and a selection of *Cercidiphyllum japonicum* with very interesting branching.

All of these plants and more are undergoing extensive testing and evaluation to determine their hardiness, adaptability, and best methods of propagation and production.

P.I.P. is neither a grand nor costly project. It is not designed to replace or compete with private, public, or commercial plant breeders and promoters. It does, however, provide another avenue through which good plants can reach our gardens and demonstrates how, with a little encouragement, all sectors of the horticultural community can work co-operatively and productively toward a common mutually beneficial goal.

DALE HENDRICKS: How do we get plants that are in the program?

DAVID SCHMIDT: Once a plant is introduced to our nurseries they will produce stock, then introduce it to the landscape trade. You can write us to find out who the participating nurseries are.

WAYNE MEZITT: We have been growing the lilac 'Sensation' for 20 years. Is your program also a reintroduction program.

CHRIS GRAHAM: The P.I.P. program does not deal with strictly new and unique plants. It is a recognition program (popularization program) for plants that have merit but are not being grown.

BILL FLEMER: Was that *Cercidiphyllum* a selected cultivar?

DAVID SCHMIDT: Just a seedling form of the plant with a distinctive growth habit that is growing in the garden.

Tuesday afternoon, December 6, 1988

The Tuesday Afternoon session convened at 1:45 p.m. with Anna Knuttel serving as Moderator.

THE USE OF GLYCOLS AS SOLVENTS FOR ROOTING HORMONES

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Abstract: Cuttings of *Malus* 'Snowdrift', *Prunus subhirtella* 'Pendula Plena Rosea', and *P. serrulata* 'Kwanzan' were subjected to various concentrations of indole-3-butyric acid (IBA) and 1-naphthleneacetic acid (NAA) dissolved in propylene and ethylene glycols; IBA/NAA combinations obtained from Woods Rooting Compound and from Chloromone (indole-naphthylacetamide). Cuttings were rooted in a mist supplied greenhouse with bottom heat during the summer of 1988. Rooting percentage and rooting time indicated no significant differences between glycol preparations and Wood's Rooting Compound. In all cases, auxin-glycol solutions and Wood's Rooting Compound proved to be superior to Chloromone. It is clear that auxin preparations using glycols as solvents are acceptable as liquid quick-dips.

INTRODUCTION

There is a need for a liquid quick-dip auxin preparation that can be readily prepared by the average nurseryman from easily obtained materials. Commercial liquid rooting hormone formulations utilize very toxic solvents and auxin combinations which have led to hormone overdose, excessive callus, and extensive basal burning of some cuttings (1,2,6,8,9). Solvents such as ethyl alcohol, dimethyl sulfoxide (DMSO), and acetone have been shown to be toxic to plant tissue (1,7,9,11,12). The wounding of cuttings is a common practice and this further exposes unprotected plant tissues to harsh solvents (8).

Glycols are polyhydric alcohols that are closely related to glycerol and behave in many ways like water (5). These two characteristics make them ideal candidates as solvents for auxins. There have been reports of polyethylene glycol being used as a solvent for auxins (6), but the author could find no references in the *Proceedings International Plant Propagators' Society* on the use of ethylene glycol or propylene glycol for this purpose.

MATERIALS AND METHODS

Three to four node cuttings of *Malus* 'Snowdrift', *P. subhirtella* 'Pendula Plena Rosea' and *P. serrulata* 'Kwanzan' were collected between June and August of 1988 (Figure 1, Tables 1,2). Cuttings were wounded basally, treated with the respective hormone and

stuck in 2¼ in. Nu-Pots with a peat:sand:perlite medium (1:3:1,v/v/v). Cuttings were placed in a greenhouse under mist (10 sec/10 min) with supplemental bottom heat set at 25°C.

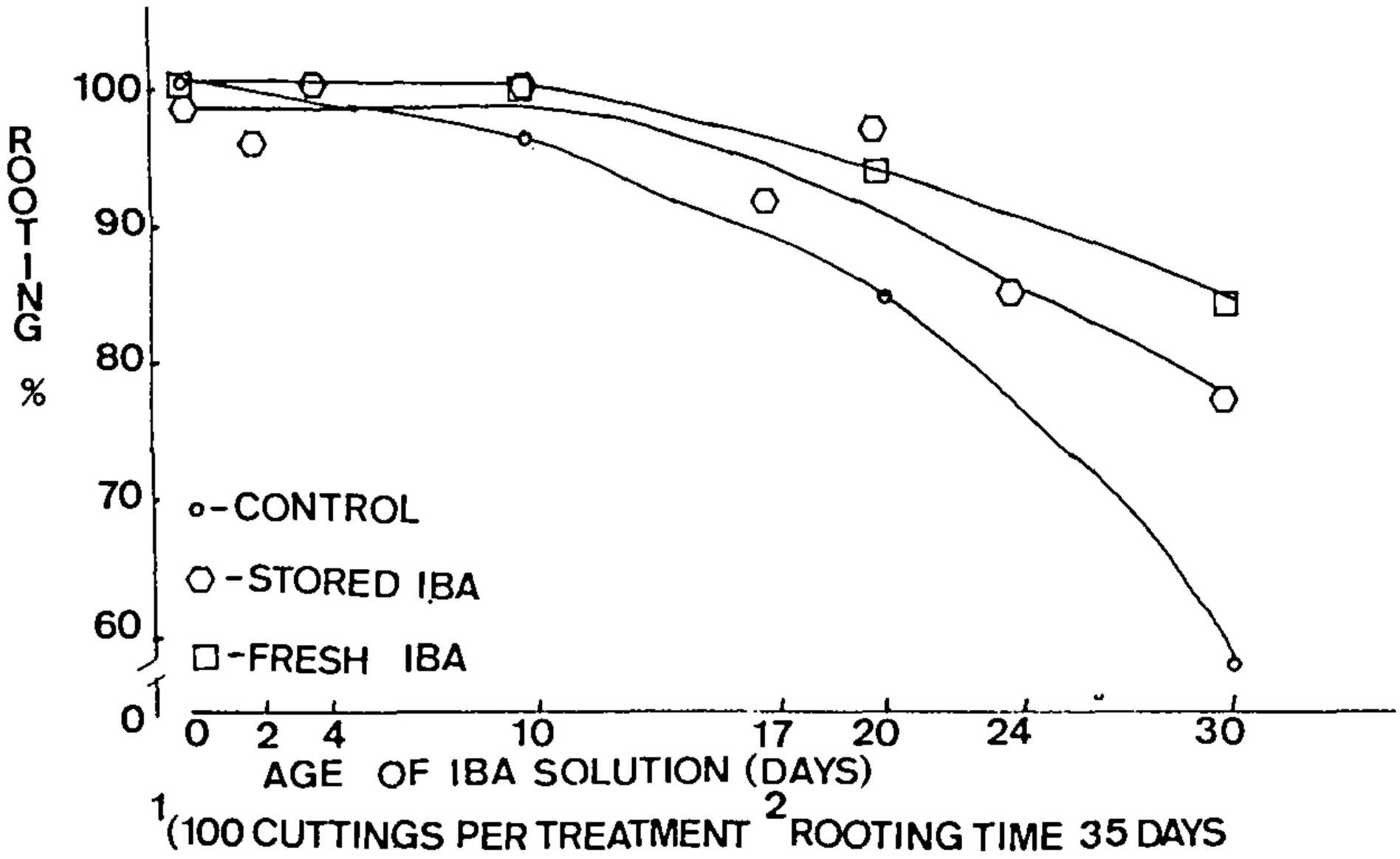

Figure 1. Response of *Prunus serrulata* 'Kwanzan' to an 800 ppm IBA-glycol solution[1,2]

Auxin-glycol preparations were made by combining 1 part auxin-talc (Hormo Root series), 8 parts water at 60°C., and 1 part glycol in a kitchen blender, and mixing thoroughly for 45 to 60 sec. The auxin-talc concentration was selected to provide specific ppm of auxin in the final solution. Benomyl, boron, and rutin (quercetin −3,5 rhamnoglucoside) were also added in some cases to the auxin glycol solution. Benomyl was added in excess of desired ppm to insure saturation. Although the solubility of benomyl is around 4 ppm in the preparation, 14 g of Benlate was added to 250 ml of solution (Figure 1, Table 1,2 give specific amounts of auxins and additives used).

Table 1. Response of *Malus* 'Snowdrift' cuttings to various auxin solutions.[1,2]

Auxin solution	Rooting Percentage[3]
1000 ppm IBA ethylene glycol	98[a]
1000 ppm IBA propylene glycol	98[a]
1000 ppm IBA/NAA Woods	100[a]
1000 ppm indole-naphthyl acetamide	76[b]

[1]100 cuttings per treatment
[2]Rooting time, 36 days
[3]Significant difference, 5% level; Yates Chi Square.

Groups of *Prunus serrulata* 'Kwanzan' cuttings were each treated with an 800 ppm IBA-glycol solution over a 30 day period to test for loss of hormone activity with time. The solution for each trial was prepared as outlined but the original solution was made up and stored in a clear glass bottle at room temperature. Samples of the solution were withdrawn at intervals and used to treat cuttings. Control tests were made every 10 days with freshly prepared hormone solution and with 20% propylene glycol without hormones. Wood's Rooting Compound was diluted with tap water to yield the respective ppm strength of IBA/NAA, and Chloromone was used full strength (1000 ppm indole-naphthylacetamide).

Cuttings of *Malus* 'Snowdrift' were collected in June, treated with hormone as described, then examined after 36 days in the bench. Cuttings of *P. serrulata* 'Kwanzan' were collected from July 9th to August 9th and each sample was evaluated 35 days from the time of sticking. *Prunus subhirtella* 'Pendula Plena Rosea' cuttings were examined 56 days from the time of sticking. All cuttings were collected in samples of 100 per specific treatment and were considered to be adequately rooted when 2 to 5 roots emerged from the bottom of the pot. The times selected for evaluation of each species corresponds to this criteria. Statistical evaluations of rooting percentage was based upon Yates modified chi square test, ($p>0.05$).

Table 2. *Effect of additives to IBA-propylene glycol solution on Prunus subhirtella* 'Pendula Plena Rosea'.[1,2]

Auxin solution	Rooting percentage[3]
2000 ppm IBA	25[c]
2000 ppm IBA, 4 ppm Benlate, 50 ppm boron	72[a]
2000 ppm IBA, 4 ppm Benlate, 50 ppm boron, 1000 ppm rutin	62[b]

[1]100 cuttings per treatment
[2]Rooting time 56 days
[3]Significant difference, 5% level; Yates Chi Square

RESULTS

No significant difference between IBA-glycol solutions and IBA/NAA solutions obtained from Wood's Rooting Compound for *Malus* 'Snowdrift' occurred (Table 1). Full strength Chloromone solution was significantly different from the others. In addition, cuttings treated with Chloromone took 24 days longer to achieve adequate rooting.

When samples of *P. serrulata* 'Kwanzan' cuttings were subjected to the same hormone solution (IBA,800ppm) over a period of 30 days, there was a gradual reduction in rooting percentage when the hormone solution was 21 days old (Figure 1), and this was particularly evident with the rooting percentage of the sample taken at 30 days. It was observed that the root quality of control cuttings was lower in comparison to the hormone-treated cuttings. There-

fore in this experiment, control cuttings were considered rooted if only 1 to 2 roots were visible.

The response of *P. subhirtella* 'Pendula Plena Rosea' to additives in the IBA-glycol solution was dramatic (Table 2). Highly significant promotion occurred with the addition of benomyl and boron at 4ppm and 50ppm, respectively. The use of the phenolic compound, rutin, appeared to be inhibitory at 1000ppm.

DISCUSSION

The effectiveness of glycols as solvents in IBA root promoting solutions is clearly demonstrated by the results presented. *Malus* 'Snowdrift' cuttings are very responsive to such solutions and it appears that the solubility of IBA obtained from talc preparation presents no difficulties. Hence, if no other source of IBA were available to the propagator except for talc formulations, they could be used to formulate an effective liquid quick-dip.

When an IBA-glycol solution is prepared as outlined, there is the possibility that some reduction in effectiveness will occur over time if stored for more than 21 days. This may be due to the precipitation of IBA from the solution. This phenomenon is not unusual and it has been encountered in IBA-ethanol solutions as well (4,8,10). Root appearance of *P. serrulata* 'Kwanzan' cuttings did not suggest any toxic effects of the solution nor was there any basal burning at the hormone concentration used (IBA,800 ppm).

The use of auxin co-factors is not new (3,13), and their promotive effect on *P. subhirtella* 'Pendula Plena Rosea' suggests that they should be added. There are a number of rooting co-factors and their use in rooting compounds has been limited mainly to talc preparations. However, since many of these compounds are not water soluble, their effectiveness in talc preparations is limited and in some cases, concentrations high enough to be effective, approach toxicity. By including co-factors as outlined here, some of these problems can be overcome. In general, the data presented here indicate that the use of glycols as solvents for root promoting chemicals is effective and should be investigated further.

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HYDROGELS AS AUXIN CARRIERS FOR ROOT REGENERATION

BONNIE LEE APPLETON

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Starch-based polymers, commonly referred to as hydrogels (hydrophilic gels), water-absorbing polymers, transplant gels, or super-absorbents, are being used in a variety of ways in the production of numerous horticultural crops. These products, under such trade names as Terra-Sorb, Agrosoke, Water Grabber, Hydra-Soil, Viterra Gelscape, Aqua Lox, Stasorb, Liqua-Gel, StaWet, Moisture Mizer, and others, are purported to hold up to several hundred times their weight in water, and then to subsequently release water under drying conditions, thereby decreasing the need for irrigation. Gels are also reported to improve field soil and container media aeration, to reduce fertilizer leaching, and to promote ion exchange.

HYDROGEL USES

Hydrogels, not to be confused with wetting agents which are designed to improve water penetration (not retention) into potting media and field soils (16), are advertised by their manufacturers for many uses. These uses range from dipping transplant roots, coating seeds and fluid drilling pregerminated seeds to incorporation into potting media, and landscape planting holes and beds. Other water retaining/extending recommended uses include hydroseeding and sodding, and cut flower holding.

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Research using hydrogels has yielded mixed results, sometimes showing considerable benefit (5), and other times showing no benefit from their use (4,9). Most negative reports have centered around a decrease in medium aeration when hydrogels are incorporated (8).

Under my test conditions I have seen no benefit from their use when incorporated into greenhouse pot plant media for reducing water use or watering frequency, and have found no benefit using them as a root dip when transplanting bareroot Christmas tree seedlings, or as a slurry added to the planting hole when transplanting container-grown nursery stock. I have also used them both as an incorporated dry powder and as a slurry in the soil within the in-ground fabric containers in hopes of reducing the need for field irrigation, and even under severe drought conditions have again seen no benefit that justifies the cost of their use, at least in the conditions under which I tested them.

AUXIN CARRIERS AND APPLICATION METHODS

The auxins or rooting hormones used in plant propagation are applied in a number of ways depending in great part upon the inert carriers used. Auxins in solvents such as water, acetone, glycerol, DMF, DMSO and various alcohols may be used directly as concentrated quick-dips, dilute long soaks, drenches, sprays, and injections, and indirectly when toothpicks, string, and other physical carriers are soaked in them. Powders such as talc and pastes such as lanolin and wheat flour are also used as carriers and application methods.

It has been reported that hydrogels can be used not only for water retention, but also as carriers for numerous horticultural chemicals including fertilizers, herbicides, fungicides, insecticides and nematicides (11). At least one hydrogel/fertilizer product is now being marketed (SoilMoist Plus, JRM Holdings, Inc., Hudson, Ohio 44236), and reports exist of others that are forthcoming (2,11).

Several researchers have and are investigating the use of hydrogels as carriers for auxins or rooting hormones, both for root development on cuttings, and for root regeneration on larger bareroot transplant stock (1, 13, 14, 17, 18). Increased root regeneration on bareroot trees has been obtained using spray applications, and on balled and burlap trees using a soil drench. Trees successfully tested include magnolia (15), oaks (6, 13), Colorado spruce (7), linden (20), and crabapple (20). Successes with other means of application have also been reported (19).

Regarding auxin incorporation into hydrogels, again, as with their general use, mixed results have been obtained. I reported encouraging results after an initial year's testing, with significant increased root regeneration on 2-0 white pine seedlings and 2 to 3 ft. dogwood (3). In two subsequent years' experiments, however, one

using plants for which root regeneration is easy (silver maple), moderate (dogwood), and difficult (sourgum), and one using dogwood under low and high volumes of applied irrigation (data unpublished to date), results were very inconsistent.

Having obtained mixed results, the only conclusion I have reached relative to the use of hydrogels for use as auxin carriers appears to be the fact that, as with the other uses, their efficacy varies greatly depending on media (or field soil) moisture levels. In addition, there exists the possibility of a negative chemical interaction between the hydrogel and the potassium of the K-IBA auxin used in this work. Dissolved salts in tap water and fertilizer have been reported to adversely effect gel hydration significantly (12), which conflicts with reports of effective incorporation of fertilizer into gels (11).

Aitken (1) reported no significant improvement in root development on rooted cuttings of 'Coral Bell' azalea when either hydrogel/IBA or hydrogel/IBA/nutrient combinations were used. Root development was significantly improved only when using just a hydrogel/nutrient combination. Starbuck and Preczewski reported statistically significant increases in the number of new roots on bareroot 1-year old dwarf peach trees treated with a hydrogel/IBA combination (18), but later Starbuck reported that a hydrogel/IBA combination did not significantly increase the number of new roots on bareroot, potted roses, and may have caused a reduction in shoot growth, although the gel did not counteract the root promoting effect of an alternative IBA source, K-IBA (17).

One important characteristic of auxins that should be kept in mind when evaluating rooting experiments is the fact that while auxins promote root initiation, they can inhibit root elongation (10), and also shoot growth (17). With rootless cuttings, root initiation may be considered most important, while with nursery stock being transplanted with a portion of its root system already existing, root elongation may be as much or more important than additional root initiation or regeneration, depending upon the percent of the plant's root system that is harvested. A clear advantage to universally using hydrogels as carriers for auxins for root regeneration has yet to be satisfactorily demonstrated.

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BASAMID—UPDATE

RALPH SHUGERT

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This paper is an update of the paper (1) presented at the IPPS Southern Region during their 1987 meeting in Tampa, Florida. The soil sterilant, Basamid, is labeled for use in the U.S.

Basamid-granular (active ingredient: Dazomet) is a product from BASF in the Federal Republic of Germany, and when incorporated into the soil has nematicidal, fungicidal, and herbicidal effects. It therefore is classed as a chemical soil sterilant.

The first testing at Zelenka Nursery was conducted by our Research and Development Department in October, 1985, in the hope of finding a substitute for methyl bromide. The latter product had not given us satisfactory weed control and the per acre price, in western Michigan, had steadily increased each year. The Basamid R&D tests have proven satisfactory and this product is now an accepted production practice of Zelenka Nursery. One of our most serious weed problems, particularly in seed/transplant beds, is yellow nutsedge (*Cyperus esculentus*) which escapes methyl bromide treatment.

From October, 1985, through our most recent application on October 3, 1988, we have made very few changes and I will share them with you. In our area of western Michigan, we feel the ideal time of application is from September 15th to 30th. The calendar dates are secondary to the soil temperatures, but this allows the placement of soil fumigant on our extensive "Calendar of Events" for that nursery department. From our experience, soil temperature (54 to 60°F) is the key for effective herbicidal results at our rate of 310 lb/A. At that rate we have observed no soil pH change.

In September, 1988, we treated 10 acres and completed a second 10 acres on October 3, 1988. Seed beds comprise 8 acres and transplant beds the balance.

We prepare the sites by rototilling 8 to 10 in. deep, applying the Basamid with an Orbit-Air Gandy Spreader (Model #6224), and then sealing with ¼ in. of irrigation water. If there is no rainfall, we re-apply water every 2 days to assure moisture in the top soil area. The water seal completely eliminates the need for a plastic seal. Seven to 10 days after application, with the soil temperature about 50°F, we re-till to a depth of 4 to 6 in. We then take soil samples from the re-tilled areas and sow lettuce seed to observe germination and check for inhibition. The label suggests cress seed (*Lepidium sativum*), but lettuce works just as well.

I alluded earlier to our nursery's yellow nutsedge problems. Our

experience to date has been favorable, certainly not 100%, but satisfactory. In fallowed areas, prior to tillage, we have had in some areas almost a yellow nut sedge meadow. After fumigation with Basamid, we see definite partial eradication and some suppression. To date, we have not found a herbicide we can safely apply over the top of a wide range of woody ornamentals, without the danger of potential plant injury and still eliminate yellow nut sedge. I believe we have tried them all!

I mentioned our use of the Orbit-Air Gandy Spreader earlier. We are deeply indebted to Wayne Lovelace who *shared* his input into our *seeking*. Since Basamid is a micro-granular formulation, the spreader equipment is vitally important. I also acknowledge my dear friend, Margaret Scott (GB&I Region), for sending me data relative to the product's use in Europe and the Far East. The advice and counsel from these two Society members is deeply appreciated.

In conclusion, as I mentioned last year at the Southern Region conference, this product has given us longer weed control, after application, than methyl bromide. We are seeing some suppression to yellow nut sedge nutlet germination and it is definitely cost effective. Not only is the per acre cost attractive ($930 versus $1,100), but there is the added labor cost saving in not disposing of the methyl bromide poly tarps. When the above costs are added to hand weeding, and reduced labor costs due to longer weed control, this product is cost effective.

I would urge any of you interested in this topic to do some testing at your nursery. If I can be of assistance, please call on me. Let all of us truly live the Society's motto: "To Seek and To Share".

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BRUCE BRIGGS: Is the gas heavier or lighter than air? Because of possible ground water contamination problems, you want to make sure that it goes up and not down.

RALPH SHUGERT: I have two papers from overseas that address its use and ground water contamination was not a problem.

VOICE: Is there a difference between heavy and light soils on effectiveness, and what is a safe distance for planted beds.

RALPH SHUGERT: I have only used it on sandy soil and do not know its success on heavy soils. We let some get into a *Thuja occidentalis* 'Pyramidalis' windbreak and it did not affect the growth of that hedge.

FRANK GOUIN: We incorporated it 2 in. and got no killing below 2½ in. It tends to be light and come up. Basamid works best on light soils. We also observed that it gives excellent control of nutsedge. After application, drag it, roll it, and give it a water seal.

PINE AND MEADOW VOLE CONTROL IN ORCHARDS

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Pine and meadow voles (small rodents) cause serious economic losses in orchards each year. Large productive orchards that have taken many years and a sizeable investment to establish can be destroyed in a single season if effective control measures are not taken. Population carry-over from the previous year is probably the most important factor influencing the current season's vole population. Populations may be very high or very low among individual trees or sections of an orchard. Proper vole management requires close observation and monitoring of the populations regardless of control methods.

The *optimum time* for rodenticide treatment to reduce vole damage to trees is in late fall (October, November, December). Snow gives the animals a great deal of cover and may prevent the grower from treating during this period. Since reproduction rates are high in the late summer and early fall, the optimal time for vole control is after harvest and just prior to the damaging period. In addition, early spring applications (February) of rodenticides can greatly reduce vole populations for the following season. February is also a time when pine vole runways can be easily seen and treated.

POPULATION MONITORING

The potential for damage should be determined prior to and after treatment. To evaluate an orchard treatment, growers may place a whole apple (with a one-inch slice off the side) in an active vole run or tunnel at 20 to 40 tree intervals in each block prior to treatment. Twenty-four hours after placement, the apple can be checked for vole teeth marks. The percent of apples with gnawing provides an estimate of the percentage of trees that could be damaged. After the orchard is treated, a second 24-hour check for activity (after a 20-day interval and using new apples) can reflect the degree of control achieved. The maximum effect from baiting will be about 20 days after treatment. To mark the original location of the apple placement site, sites may be covered with split rubber tires, sections of straw, wood slabs, shingles, tar paper, etc. If a herbicide strip exists, vole monitoring must be done in adjacent cover because voles will seldom range on bare ground.

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[1] Professor of Horticulture

CONTROL MEASURES

Anticoagulant vs Acute Baits. Recent studies have shown that rodent baits usually kill more meadow voles than pine voles, and anticoagulants (chlorophacinone) kill more pine than meadow voles. For this reason, if only one application is to be made, the toxicant choice should be made so that chlorophacinone is used against pine voles and ZP rodent bait is used against meadow voles. If two applications are made against heavy populations of meadow voles, the zinc phosphide should be used first and followed 2 to 6 weeks later with chlorophacinone. For pine voles, two chlorophacinone applications may be used. Multiple applications of zinc phosphides (even different formulations) is not recommended because voles will become bait shy after the first application and survivors will remain bait shy for 2 to 4 months.

Hand Baiting. Hand placement of bait will only be effective if placed directly in active vole runway systems. No site cover is necessary, but they have many obvious advantages. Site covers (made of split tires, rubber mats, wood slabs, tar paper, odd lots of shingles, or large metal shipping container lids) can greatly increase contact with the vole population, decrease baiting time, and increase or prolong effectiveness of the rodenticide. Split tires are convex and work very well in keeping bait in good condition. To further prevent absorption of soil moisture by bait, proper quantities of the rodenticide may be placed in open plastic cups or containers under split tires. Site covers should be placed under the trees (at least one per tree) 2 to 3 months ahead of baiting. Random placement of covers prior to baiting may result in 50 to 80% of the covers with good activity. If no runway exists under the cover at the time of baiting, it should be moved to an active run or hole since voles will not be attracted under covers before the bait spoils. Place site covers in under tree grassy areas, not in the herbicide strip.

A) Chlorophacinone (Rozol or Parapel) bait has achieved excellent control of pine voles if applied in two applications at 10 lb/A (¼ lb/tree on a 40 tree per acre base) each spaced about 20 to 40 days apart. This program has given the most reliable control of the animal if done properly. Do not cut the rate per acre. If populations are not high, one application should be sufficient.

B) New pelleted zinc phosphide formulations are now available to the apple industry. One of these formulations made by Bell Laboratories is much superior to grain baits for control of pine and meadow voles. Label rates for hand placement of 1 to 3 lb/A are adequate for control. Do not follow with a second application for at least 3 months since voles will likely be "bait shy".

C) Diphacinone (Ramik-Brown) bait has achieved good control if applied in two applications at 10 lb/A each, but additional toxi-

cant in the bait would provide better control since this rodenticide is not as toxic as chlorophacinone.

D) Zinc phosphide grain baits applied by hand have not given adequate control of pine voles, and for meadow voles is not as good as ZP Rodent Bait AG from Bell Labs. Zinc phosphide coated apple slices are more effective than grain baits but neither are adequate in a single baiting per year. Since zinc phosphide is not a good repeat bait, another toxicant must be chosen for a second application.

Broadcast Baiting. Broadcast baiting may not work if heavy thatch or bluegrass cover prevents bait from reaching pine and meadow vole runways and surface feeding areas. Under these conditions, hand baiting is recommended. However, in clump grass cover, good control has been achieved for both pine and meadow voles with broadcast baiting. At least 3 days of good weather should follow the treatment, but good kills have been achieved when only 24 hours has lapsed before a rain. Broadcasting bait requires distribution over the area where trails and runways are found, thus close examination of the orchard floor for runs is necessary. Commercially-made feed, seed, or fertilizer spreaders may be used for broadcasting bait uniformly. In case of spilled pellets while loading equipment, pick up and reload pellets or dispose of properly. Caution should be taken to use spreaders which dispense bait at a uniform spreading rate. Many spreader hoppers should contain at least 75 lb or more to obtain a uniform rate per acre. Voles will not pick up bait in herbicide strips. Apply to ground cover adjacent to the herbicide strip. Rates per acre are based on orchard acres and not just on acreage spread.

A) Chlorophacinone (Rozol or Parapel) baits broadcast evenly by ground equipment at the rate of at least 15 lb/A will generally control pine voles. When populations are extremely high, a second application should be made one month after the first treatment.

B) New zinc phosphide pellets (⅛ in. diameter) will give adequate control at labelled rates of 6–10 lb/A. The Bell Laboratory formulation is much superior to grain baits and most other pelleted baits. Do not apply within 3 months of a previous application. If a second treatment is required, select one of the anticoagulants (chlorophacinone or diphacinone).

C) Diphacinone (Ramik-Brown) has also achieved good control if applied in two applications 20 to 40 days apart at 20 lb/A, but this bait would perform better if additional toxicant were added to the formulation.

D) Zinc phosphide grain baits have not given good control of pine or meadow voles, particularly where populations are high. Taste aversion caused by this treatment will reduce the effectiveness of ZP rodent bait.

Cultural Control. The use of cultivation equipment such as the Smitty Tree Hoe three times a year has reduced pine vole popula-

tions to control levels in some orchards but has not in others. These differences are probably due to soil factors, invasion potential, frequency of cultivation, middle row mowing, and other activities. The use of residual herbicides in combination with the Tree Hoe will further reduce populations; however, residual herbicides alone have had almost no effect on reducing *existing* populations. The use of cultural control has been most successful where it has been started prior to the establishment of a pine vole population. In addition, bare ground herbicide strips have been effective in preventing *initial infestations* as long as the strip is wide, kept bare, and frequent middle row mowing is practiced. Wide band cultivation and herbicide strips may interfere with the application of broadcast baits or with stations used for hand placement of bait, and will cause more soil erosion.

Meadow vole populations are more easily affected by changes in cultural practices and thus are more economical. But, chemical methods have been found to be less expensive for control of pine voles in orchards than the practice of clean culture (combinations of herbicides, mowing and cultivation). Broadcast baiting, while less labor intensive than hand baiting, was found to be just as expensive since larger quantities of bait are needed for treatment. The costs of broadcast or hand placed baiting were found to be less for acute toxicants, since the quantity of bait required for a lethal dose is less.

The use of tree planters has aggravated vole control since the slit in the soil allows voles an underground trail of loosened soil from tree to tree down the row. This slit may be in the soil for years and voles may tunnel deeper making control more difficult.

FRED HESER: How long can the baits stand water?

ROSS BYERS: Not long. Each one is quite different but none stand more than one week. They must be protected from direct contact with water or snow.

JIM CROSS: Do you see cycles in population?

ROSS BYERS: Yes, but most cyles in commercial orchards are not related to natural cycling but related to whether the owner got good control or not.

PETER VERMEULEN: Given the high value of ornamental crops would it be better to go with both types at the same time?

ROSS BYERS: No, it would be better to kill off the major part of the population with an effective zinc phosphide first, then follow up with an anticoagulant. If you are going to cover the plants it is possible to use both types at the same time. However, separate the two rodenticides into different places.

Thursday Morning, December 8, 1988

The Thursday morning session convened at 8:00 a.m. with Len Savella serving as Moderator.

PIECE ROOT GRAFTING OF OAKS: AN UPDATE

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In 1984 I reported on using root pieces of *Quercus robur* for grafting *Q. robur* 'Fastigiata'. The results were better, more uniform plants, absence of suckering, and an excellent root system. One of the key factors was a relatively high temperature, both for the precallusing of the root pieces and to heal the grafts. In the years following 1984 further trials were conducted using *Q. palustris* 'Sovereign' grafted on *Q. palustris* root-pieces and a selected *Q. rubra* grafted on *Q. rubra* roots. The results of these trials were encouraging.

In regard to *Q. palustris* 'Sovereign', Dirr (1) reports that the originator, Coles Nursery, abandoned the growing of this plant due to graft incompatability. I can not speak on this phenomenon, but would suggest that successful graft unions could be perpetuated by using piece roots of the original plant or from successful unions.

Today I would like to speak to you about a trial that involves the grafting of *Q. robur* root pieces and *Q. macrocarpa,* burr oak scions.

Well-branched, 10 cm long and 5 to 10 mm thick, root pieces were cut from one-year-old seedlings of *Q. robur.* The seedlings had been stored for 10 weeks at a temperature of 0°C. The root pieces were bundled and heeled into peat in a grafting bench at a temperature of 12 to 15°C for 25 days. This procedure was different from the original in the following: 1) roots were stored for 10 weeks instead of 3 weeks; 2) roots were not potted immediately; and 3) temperatures were lower by 10°C. The vigorous callus and root formation that had occurred at 20 to 25°C was nearly absent.

As the season was getting late I decided to graft nevertheless. On March 7, 1988, 290 *Q. robur* 'Fastigiata' scions from two selections, and 10 *Q. macrocarpa* scions were grafted on root pieces of *Q. robur.*

The grafting procedure, as in other years, was a side graft into the top of the root. Scions were bound to the root with rubber grafting strips. The finished grafts, since there were no visible new roots, were pushed into 2¼ × 3 in. deep rosepots. The medium was a loose soilless peat mix. Pots and grafts were then placed into a

plastic covered grafting bench. Pot, union, and part of the scion were covered with moist peat.

Normal grafting after-care, such as venting and shading, was carried out on a daily basis. Watering was done when needed. Grafting case temperature varied between 15 and 18°C. On May 15, 1988 the grafts, after having been hardened off for two weeks, were removed from the grafting bench and planted out.

RESULTS

Of the 290 *Q. robur* 'Fastigiata' grafts, 152 had successfully knitted. Five of the 10 *Q. macrocarpa* were growing. Root action and callusing are much less pronounced than under the original high temperature regimen. The main reason for the majority of the failures was roots that had decayed.

CONCLUSION

Temperatures of 20 to 25°C, and preparation of roots with a short storage period (3 to 4 weeks) gives excellent results. Roots of various *Quercus* species can successfully be used for grafting scions of selected plants of the same species. More importantly, interspecific grafting can also be carried out. It should be pointed out, however, that both *Q.robur* and *Q. macrocarpa* belong to the white oak group.

LITERATURE CITED

1. Dirr, Michael A. 1983. *Manual of Woody Landscape Plants. 3rd ed.* Stipes Publishing Co., Champaign, IL.

PROPAGATION AND CULTURE OF CYCLAMEN SPECIES

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I am concerned about the precarious position of cyclamen in the wild. I also find them fascinating plants to grow and study—each plant is different, even within a single species.

There are no cyclamen species indigenous to North America. They occur around the Mediterranean basin, throughout southern and central Europe, western Asia, and north Africa; however, they are easily naturalized in many parts of this country.

As I gradually began to build a collection of almost all of the 19 species of cyclamen, I was frustrated to find that most of them were not available in this country. I ordered tubers from every source I could locate and was extremely disappointed to discover that most of what I received were wild collected plants and fewer than half of them grew. I then discovered that they were on Appendix II of the Endangered Species List which means that they are considered plants in peril, and that a CITES permit is required for exporting or importing them. In 1976, 256,000 tubers were exported from Turkey, and in 1979, 1,099,725 were exported. By 1985, the number had increased to 6,632,000, according to Christopher Grey-Wilson in his excellent book, *The Genus Cyclamen*. Turkey then agreed to limit their exports to 1,000,000 per year. In 1988 the Natural Resources Defense Council reported that one U.S. dealer imported 86,000 tubers directly from Turkey, and the Netherlands imported 1,600,000. The majority of the tubers imported into this country are funneled through Holland and many come in with spurious names, such as *"Anemone coum"*. Except for a few distinctly shaped tubers, it is extremely difficult to identify cyclamen species when they are in a dried state, and it is just about as difficult to bring them back into growth. It is illegal to sell collected tubers of the species *mirabile, repandum, trochopteranthum, pseudibericum* and *parviflorum* from Turkey, and Greece has banned the exporting of *C. graecum, creticum, balearicum,* and *persicum*.

Cyclamen are members of the Primulaceae family; their cousins are dodecatheons and primulas. What the members of this family have in common are five stamens, one style and a persistent calyx. The plants grow from tubers—not bulbs or corms. The tubers may have roots all over them as in the case of *C. purpurascens,* only from the bottom as with *C. graecum,* or they may come from the top of the tuber, as with *C. hederifolium*. Although they are classified as dicots, only one seedling leaf is usually present; the second one is repressed and appears only if something happens to the first one.

They are very easily cultivated as long as you give them some shade and excellent drainage. In general they grow best near the top of the soil, with the exception of *C. repandum* which needs deep planting. *Cyclamen graecum* and *C. cilicium* both grow and bloom best with some sun. Drainage can be improved by the addition of small pebbles worked into the soil or by making a raised bed incorporating gravel, which will also discourage rodents. My only serious problem is a curious racoon that overturns a thousand or more pots almost every night; this becomes a disaster when the plants have been sorted by color; they have stopped blooming, and the racoon is especially vigorous in tossing the pots about.

I have not been successful in propagating these plants except by seeds, but in working with them have discovered a number of common approaches as well as some important differences. One of the most important requirements for a high germination percentage is fresh seed. When the seed capsule is ripe, the coil which has brought it down to the top of the tuber relaxes and a tiny opening appears in the pod. It is important to collect the seeds at this point or slightly before, for the ubiquitous ants are ready to clean out the pod and carry away every seed within the hour. This is an excellent aid for the dispersal of seeds, but a nuisance when I am trying to collect seeds for nursery propagation. The rarer seeds are planted immediately in small pots with two or three seeds per pot. The seeds in abundant supply are sown spacing them about ⅜ in. apart in small flats and are then covered by about ¼ in. of grit or potting soil, and set in a dark place. Total darkness greatly increases the germination percentage. The effect of temperature on different species is extremely important. In general each species requires the same modulations of temperatures that it would receive in its native land. The species *graecum, persicum, intaminatum,* and *purpurascens* require summer heat for seed germination, while *C. balearicum, repandum,* and *parviflorum* seed will germinate only after a considerable cool period. All of the others require heat and then falling temperatures to stimulate germination.

I will give a brief summary of many of the species with their individual requirements, presenting them in the order in which they bloom for me in central North Carolina. Sporadically throughout the summer, but primarily from late August into November, *C. hederifolium* produces its lovely flowers in shades of pink or white. The appearance of the beautiful and extraordinarily variable leaves signals an end of the flowering period. Also at this time *C. africanum,* one of the most dramatic species, blooms with flowers and leaves similar to but larger than those of *C. hederifolium*. It is difficult to distinguish between these two species unless a chromosome count is done; however, the leaves of this one rise directly from the tuber rather than at an angle as with *C. hederifolium*. In every way *C. africanum* is larger than *C. hederifolium*. The easiest way to

determine whether you have the real thing is to leave it outside during the winter. If it dies when the temperature goes below 20°F, then you know you had *C. africanum.*

Overlapping the blooming period of these species is *C. graecum* with flowers that are similar, but different in that they have streaks of a darker mauve color on the corolla lobes. The interior of the mouth of the corolla is dark, the anthers are purple, and the velvety heartshaped leaves appear with the flowers.

The fourth species to come into flower during late summer is *C. rohlfsianum,* a beautiful, rare and tender plant from Libya. The resemblance to dodecatheon is striking when you notice the exertion of the stigma and anthers in a cone beyond the mouth of the corolla lobes of the flowers, many of which are fragrant. This is one of the few species which requires complete drying off during the summer. Water is withheld from the time the leaves begin to yellow in May until sometime in July when a good soaking will bring them back into growth.

Often during the summer in the greenhouse, *C. intaminatum,* the miniature of the genus begins to produce its beautiful white or palest pink flowers. It has quite rounded leaves, which are green or green with patterns of silver dots around the edge. Some forms even have beautifully variegated leaves. This is hardy with us and grows well in a scree pot in shade or in the garden given a well-drained site.

Cyclamen cilicium bridges the gap between the fall flowering and winter flowering species. I was delighted to see them blooming in the Chicago Botanic Garden last December. The leaves, which are spoon-shaped, are produced at the same time as the flowers, which may be anything from deep mauve through pale pink to pure white without any color at the base of the corolla. I finally have seeds from such an albino, but have yet to see it bloom. This is a remarkably hardy species, but is relatively short-lived and is more susceptible than most to death from too much moisture. It needs to be high and dry during the summer.

Cyclamen mirabile, the species which led to the protection of many cyclamen, blooms also at this time. In many ways it is most similar to *C. cilicium;* however there are important distinctions. The petal tips are fimbriated in *C. mirabile,* while they are entire in *C. cilicium.* Often, but not always, the new leaves have a rosy overcast on the part of the leaf which will be silver at maturity. I have also noticed a pinching in at the base of the corolla lobes.

Beginning sometime in October and blooming well into December is *C. cyprium,* a tender species, with wonderfully fragrant white flowers with a distinctive "bird-in-flight" mauve marking and often beautifully variegated leaves.

In December the main winter flowering species begin to make a show which will last into March. *Cyclamen coum,* with all of its

diversity of leaf shapes and flower colors is the best of the winter species and the easiest to grow. It is generally agreed that there are two distinct subspecies of *C. coum*. *Cyclamen coum* subsp. *caucasicum*, occurs in the Caucasus and has larger flowers and heart-shaped leaves. *Cyclamen coum* subsp. *coum* occurs in the West and has more rounded leaves and smaller flowers. There are wonderful forms with completely silvered leaves (pewter leaf), or with only a tiny bit of green (silver leaf), with many degrees of variegation, and even a green leaf one. The flowers may vary from pure white, through pink to magenta.

Cyclamen libanoticum from Lebanon also blooms in winter with lovely, relatively-large flowers of an unusual shade of pink. The beautiful leaves are dull pewter-green sometimes with bright white markings. Hardiness is being tested this winter in central North Carolina.

Cyclamen persicum is the species from which the florists' cyclamen was developed. It is a tender, fragrant, elegant plant which can stand only 26°F. Breeders worked for years to develop larger flowers with brighter colors and in so doing lost much of the fragrance which is present in the wild plant. Now they are working to make them smaller and to recapture its natural fragrance. I think it is hard to improve on the wild form.

Cyclamen trochopteranthum is a delightful, hardy species which has leaves reminiscent of *C. cilicium* and fragrant flowers similar to those of *C. coum*. The difference is that the petals are not completely reflexed and stand out from the flower like propellers.

The diminutive *C. parviflorum* has been described as not garden worthy; however, I disagree. It is like a small version of *C. coum* but is wonderfully fragrant. The flowers are produced on short stems, so it is one which is best viewed on hands and knees, in a pot on a greenhouse bench, or on a hillside.

Cyclamen pseudibericum is considered by many to be the most spectacular species in the genus. There are many forms, and certainly the one with large purple flowers and well marked leaves cannot be beat. It is extremely hardy, surviving −12°F in North Carolina and can bloom anytime from November through March.

In spring we look forward to three more species to cheer our souls on cold, gray days. *Cyclamen balearicum* has proven hardy in U.S.D.A. Zone 7. It has white, fragrant flowers, often with pink veins and beautiful gray leaves often overlaid with silver.

Cyclamen repandum is a wonderful, fragrant, spring flowering plant, which has elongated and twisted petals of a medium shade of pink. This is the only species that requires full shade and deep planting. It is remarkably hardy and survives the winters possibly because it has the ability to wait to surface until the worst of the winter weather has passed. There are two additional forms of *C. repandum* worth growing. *Cyclamen repandum* var. *rhodense* has

white flowers with a darker pink area at the base of the corolla, and leaves heavily speckled with white. *Cyclamen repandum* var. *peloponnese* has similar splashes of white on the leaves, but flowers which are pink or even a deep magenta-pink. These two varieties of *C. repandum* as well as the pure white form are not hardy.

The beautiful, white-flowered *C. creticum* is one of the rarest of all of the cyclamen. It produces its leaves in the fall, but blooms only in mid-spring. To my surprise it has proven hardy, coming through the Eastern U.S. terrible winter of 1986.

The hardiest species of all is *C. purpurascens,* which blooms throughout the summer and fall and is hardy in Minnesota. It has the shortest dormancy requirement producing new leaves just as the old ones fade in late spring. The fragrant flowers are various shades of rose, and the leaves may be solid green or with varying degrees of variegation; some are even completely silvered. There has been some confusion over the status of a form with solid green leaves from the Fatrense mountains of Czechoslovakia, but botanists agree that there is no basis for giving it either separate species status or a varietal name. The 19th species, *C. somalense,* was discovered in 1986, and I have not yet seen it.

I urge you to get to know this group of plants by growing them from seed yourself or by purchasing nursery propagated, rather than wild-collected specimens.

PROPAGATING AND GROWING CRABAPPLES BY BUDDING

THOMAS R. SIMPSON
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Vincennes, Indiana 47591

INTRODUCTION

One thing I have learned in the nursery industry is that there is seldom only one correct way to perform a nursery task. As sure as you think you have perfected a method, someone else will come along with a new technique, an improved product, or a totally different way of thinking that produces equal or even better results.

When I returned in 1978 to the family homestead and business of which I had been a part for 10 years as a school boy, I soon attended my first series of nursery seminars and meetings. At one of them I was amazed to see a friendly but heated debate between two nationally respected propagators on the subject of rooting cuttings. One fought tooth-and-nail for the practice of "wounding the cutting within an inch of its' life"; and the other was equally adamant about *not* wounding. Both men were highly respected experts in the field.

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Each truly believed his method was the best, and each proved his points with excellent yet comparable results. The reason I mention this is because our methods of budding may be totally different from yours. I am not suggesting that ours are the only, or even the best methods, but simply that these are the budding techniques that have proven to work best for us in our location through years of trial and error.

Simpson Nursery Company has been around for 137 years, being started by my great-great grandfather in 1851 when he contracted to grow 12,000 grafts of apples, pears, and grape vines. Through the years the name has changed a few times, and the emphasis has gone from nursery to orchard and back to nursery again, but it has always been owned and operated by the same Simpson family. If my son, Mathew, or daughter, Ann, should choose to continue in the same tradition, they would be the sixth generation. So, you see, we have been propagating trees for a long time.

SCION TREES

In a business where 95% of the products sold are produced by bud grafting, it is extremely important that the scions be of the very best quality, and that they be true to name. To insure this quality and accuracy, we grow and carefully maintain our own blocks of scion trees containing each cultivar of tree we propagate. We try to locate these blocks in areas that are visible, and easily accessible for pruning, spraying, mowing, and for performing other maintenance practices. Each scion tree is paint-coded to match our system of product identification to further insure against any accidental mixture of cultivars. The ideal practice is to keep scion trees of various ages growing in different locations near the rotating budding operations to insure against weather-related damage and old age deterioration of scion quality. Our scion trees are carefully monitored all year for disease, insect and weather damage. Pruning is done in winter or early spring in order to develop vigorous and healthy bud sticks.

UNDERSTOCK

A very important part of growing top quality ornamental trees is to use the best available understock. We do not grow our own, but purchase seedlings each year from nurseries which have consistently provided us with the best quality in past years. From time to time we have tested other special understocks for one reason or another, but now we use only domestic apple seedlings for crabapples, calleryana pear seedlings for ornamental pears and Washington hawthorn seedlings for hawthorn cultivars.

We prefer single-stemmed seedlings of ¼ in. caliper. Each seedling is carefully inspected and pruned for producing a good

straight understock in a length to fit our mechanical transplanter. The tops of apple seedlings are dipped in a liquid lime-sulphur mixture of 1 part to 10 parts water for added protection against scab. All seedlings are tied in small bundles and stacked in ricks with good air circulation in controlled refrigerated storage until planting time. They are hand-watered as necessary to maintain proper moisture.

As soon as weather and soil conditions permit in early spring, the seedlings are planted with a 2 row planter in rows spaced 50 in. o.c., and seedlings spaced 12 in. apart in the rows. The seedlings are then packed firmly into the ground by using the same packer my grandfather used years ago. It consists of two large cast iron wheels probably weighing 200 pounds each. Finally, any leaning trees are straightened by foot and all fields are cultivated. It is important at budding time that the seedlings are growing perpendicular to the ground and with a caliper equal to or greater than that of the mature bud sticks.

BUDDING

Prior to 1986, all of our propagation was done by shield budding, or T-budding. On specific cultivars of apples, pears, and hawthorns, which consistently result in poor bud take, we have double-budded to increase the percentage stand. This is done by budding a second time at a later date on the opposite side of the tree just above the height of the first bud.

In 1986 we chip-budded our pears after researching other nurseries that claimed better results by that method. The results for us were substantially better than double T-budding, and so we are now chip budding all of our pears and hawthorns. With crabapples, we are continuing experiments with the two techniques on approximately 50 cultivars. We have found results to be surprisingly varied as some cultivars respond quite differently to one method or the other, while other cultivars seem to show little difference in response. Additional factors, such as budding dates, weather conditions, and maturity of scions and understocks have a great deal to do with the final results.

Our budding season usually begins the first week of August, depending upon maturity of scions and size of rootstocks. The process takes approximately 6 to 8 weeks to complete. Certain cultivars respond well to early season budding and other do not. Every year we keep records of budding dates by cultivar and their results in percentages of successful takes. This gives us a sequential trend over the years to help determine our budding schedule. We use only our own "home-trained" permanent employees for actual budding, and these men have developed a healthy pride in their work.

Fresh scion sticks are collected daily as the budding operation progresses; 50 to 100 sticks are collected at a time and held in 30 gal. plastic containers of fresh water in shaded locations near the areas

being budded. Immediately after collecting scions, the leaves are removed with a knife leaving approximately ⅛ in. of the petiole remaining. The stipules are then removed.

Meanwhile, the rows of seedlings are being prepared for budding. We use three-men crews composed of the budder, the tyer and a cleaner. The cleaner works ahead of the budder and tyer, and prepares the seedlings by removing any weeds and lower branches of the rootstock that may interfere with budding. The soil is leveled to expose the base of the seedling, and the trunk is wiped clean with a soft cloth. Finally, the soil is lightly raked to provide a smooth path for the budder. The cleaner needs to work at a pace which keeps him well ahead of the budder, but not more than about 100 trees. Cleaned trunks exposed to the sun for very long can cause the bark to tighten, making it more difficult to get a perfect bud union. Each budder carries several budsticks with him in a 2½ gal. bucket with about 6 to 8 in. of water.

In T-budding, the budder holds the scion stick upside down and carefully cuts into the wood below the bud, slicing toward him under the bud with a level cut. He then makes a shallow cross cut into the cambium only, and "shucks" the budshield from the wood. He then uses the end of his knife blade to make a vertical incision in the rootstock trunk and a crosscut at the top of the first cut. While making the crosscut he uses the straight part of his knife in a twisting motion to open the bark as he inserts the bud into the T-pocket between the bark and the wood. Any part of the shield that protrudes above the crosscut is removed.

The tyer then wraps the bud with a ¼ × 7in. budding rubber from bottom to top with a firm pressure allowing 2 or 3 wraps below the handle and 3 or 4 above, leaving the petiole and bud exposed, but tightly in place. These bands are never removed, as eventually the sun rots them and they fall off on their own. After a couple of weeks, the petiole of a healed bud will drop off at a touch. If it is rigidly anchored to the shield, the bud is dead.

In chip budding, the budder holds his scion stick right side up, making an angled crosscut below the base of the bud which will form a wedge at the bottom of the shield. He then inserts his knife above the bud and slices level with firm pressure down to his first cut and removes the bud shield. He then makes a matching cut in the trunk of the rootstock and removes the wood which forms a "pocket" at the bottom of the cut. The wedge shaped end of the bud shield is then inserted into the "pocket" of the rootstock cut which holds it in place for the tyer. Ideally, the bud shield and corresponding wood removed from the rootstock will match exactly. However, if the bud shield is narrower than the corresponding cut in the rootstock, it must be positioned to one side or another so that at least one side of the two cambium edges are aligned.

The tyer then seals the bud with a ½ in. strip of white plastic

budwrap at a length convenient for him. He begins at the top and firmly wraps the tape until all of the shield and incisions are completely covered, tying it off at the bottom. These ties must be removed after the incision begins to callus and the buds are firmly anchored by the healing process. Spot-checking determines the proper timing for removal which could be from two weeks to two months depending upon cultivar and growing conditions. Waiting too long can result in the rootstock callusing completely over the bud, smothering it to death.

After budding is completed, we cultivate between the rows, pulling the soil up around the trees, but not covering the buds. Then a 12 in. band of Surflan is applied to the rows for spring weed control. In past springs, we have had problems with chickweed forming dense mats around the buds, causing them to rot. Surflan controls this problem very well.

The fields are then winterized by sowing winter wheat between the rows for erosion control, since our land is not perfectly level. Finally, we install rabbit fencing around each bud field with 2 ft. chicken wire.

In early spring as the buds begin to push, we cut off the seedling tops about ¼ in. above the buds. These cuts are made with hand loppers at a 45° angle, with the bud on the high side. As the buds begin to grow, steel stakes are positioned to the side of each trunk and the newly formed shoots are carefully trained as they develop during the growing season. Summer cultural practices include continual inspection, tying, pruning, suckering, and spraying for insects and diseases. Most cultivars are tipped to promote branching.

All of our budded trees are grown and sold as one-year bareroot liners, developing vigorous growth in height, caliper, and branching, depending upon cultivar characteristics. In 1988, in spite of one of our worst droughts ever, our trees made excellent growth. Some one-year hawthorns and a few crabapples reached a height of 8 ft. without the benefit of irrigation.

In conclusion, I mentioned earlier that there is a great variance in the results of T-budding versus chip budding on crabapples, depending on specific cultivar. We have detailed information on results of one year only, and feel that it is inconclusive at this time. However, when we are able to share the results over a period of two or three years, we will be happy to do so.

PROPAGATION AND PRODUCTION OF CRABAPPLES ON THEIR OWN ROOTS

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Traditionally, crabapples have been commercially propagated by two methods: field budding in July or August, or bench grafting during the winter. Other methods of propagation used are seed, top working, and root grafting. All of these methods, except for seed, pose three common problems; understock suckering, graft incompatibility, and crooks in the trunk.

Producing crabapples on their own roots can eliminate these problems with some advantages over budding and grafting. Multistem crabapples can be easily grown from own-root crabapples. Other advantages of own-root are lower costs in the making of cuttings, and the production of a more fibrous and massive root system. With a better root system, transplanting of balled and burlapped stock will be more successful.

When propagating by cuttings, good vigorous stock plants are needed to promote softwood growth. Stock plants should be fertilized and pruned in late winter or early spring, and should be irrigated to increase the amount of cutting material. The drought in 1988 caused an early hardening of cutting wood where irrigation was not used.

Softwood cuttings are made from the current season's growth in mid-May to mid-June. Timing of the cuttings may vary from year to year depending on the season. Cuttings that have been taken in July and early August have lower rooting percentages. At this time, cutting wood is hard, and although callus is formed, roots may not be initiated.

Cutting material from 6 to 24 in. in length is taken from field or stock plants. After collection, the cutting material is sprayed with water and refrigerated at 40°F. until they are prepared for sticking. Two node cuttings are then made with the basal portions being 1 to 1½ in. long. Wounding the cuttings does not seem to benefit rooting so is not practiced. The cuttings are then bundled and tied with a rubber band.

Rooting hormone is prepared in liquid forms. Concentrations of 1200, 2500, 5000, and 10,000 ppm IBA have all been used. A concentration of 2500 ppm IBA encourages the best rooting when cutting wood is taken at the proper time. If cuttings are taken later in the season, a higher concentration of IBA may be needed to promote rooting. The bundles of cuttings are given a 5 sec dip in the IBA solution.

Cuttings are taken to a 50 to 60% shaded polyhouse and stuck in 2⅜ in. band pots. The potting medium is 50% peat and 50% perlite. The depth of the band pot is 5 in. which allows for good drainage. Eddy-mist nozzles provide adequate mist until the cuttings are well-rooted.

The rooting time varies with cultivars and rooting conditions. Generally, roots are initiated in 3 to 4 weeks. When the majority of cuttings show roots, mist should be decreased, as excess moisture may cause root decay.

Cuttings that are taken early in the season should continue to grow. At the end of the growing season 8 to 12 in. of growth can be obtained. If a rooted cutting does not put out any new growth, it will stay dormant until the following spring. Cuttings taken in July and August usually will not produce new growth.

Some of the red- and pink-flowered types ('Adams', 'Indian Magic', Indian Summer', 'Robinson', and 'Profusion') have consistently rooted 90 to 100%. Table 1 shows the rooting ease among different crabapple taxa.

The rooted cuttings are stored in a minimally heated polyhouse for the first winter. Heat is provided so that temperatures do not fall below 30°F. In the winter and early spring the young plants are potted into 3⅝ in. square band pots. Band pots encourage roots to go deep, which will help in the anchorage of the tree.

Polyhouses promote an earlier than normal flush of growth in the spring. This growth can be used as a source of cutting wood. When the danger of frost is past, the potted crabapples are placed outside under irrigation. Liquid fertilizer is applied twice a week and is gradually decreased in September. Aphids can be a constant

Table 1. Rooting ease among different crabapple cultivars and species.

Best rooting	
Adams	Robinson
Donald Wyman	Snowdrift
Indian Summer	Snow Magic P.P. 4815
Indian Magic	*M.* × *zumi* 'Calocarpa'
Profusion	
Good rooting	
M. × *atrosanguinea*	Ralph Shay
Beverly	Red Baron
David	Red Jade
M. floribunda	Red Jewel P.P. 3267
Mary Potter	*M. sargentii*
Prairifire	
Difficult-to-root	
Burgandy	
Royalty	
Selkirk	

problem on the succulent growth of young plants if control measures are not applied.

Many cultivars can reach 6 to 8 ft in height by the end of the first year. The growth is comparable to that of a one-year budded plant, but without understock suckering. A one-year budded plant has a three-year root system, while the own-root crab has only a two-year.

There are many crabapples that do well on their own roots. The growth is the same or better than a budded type. With different propagation and cultural techniques, production of crabapples on their own roots can be commercially practiced with many taxa.

GROWTH COMPARISON OF CRABAPPLES: OWN ROOTS VS. APPLE ROOTSTOCK

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INTRODUCTION

The merits of propagation methods of a particular plant should be based not only on the ease with which a plant can be propagated by a particular method but also on how well that plant does in its eventual planting site. Crabapples historically have been propagated by T-budding on apple rootstock and, more recently, by chip budding on apple roots. Tom Simpson described these methods in detail in a paper preceding this one. In recent years some nurserymen have used rooted cuttings as a means of propagating crabapples. The two main reasons for shifting to cuttings are: 1) cuttings require less skill to take than budding, and 2) crabapples on their own roots should have less root suckers when the plants are grown on to maturity (1). It is fairly easy to train a person to take cuttings, but T-budding or chip budding requires a longer training period and the chances of a successful take, coupled with some degree of speed, is not too great for the novice propagator. Brian Bunge described his method of cutting propagation in his paper.

Since there has been some debate as to which method produces the best landscape crabapple, our research project compares growth characteristics of crabapples propagated by budding onto apple rootstock vs. crabapples grown on their own roots.

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Since there has been some debate as to which method produces the best landscape crabapple, our research project compares growth characteristics of crabapples propagated by budding onto apple rootstock vs. crabapples grown on their own roots.

METHODS

The crabapples used in this experiment were obtained from the two cooperating nurseries, Simpson Nursery Co., Vincennes, IN and LaPorte County Nursery, LaPorte, IN.

Simpson supplied the budded material and LaPorte County furnished the plants on their own roots. The cultivars used were 'Indian Magic', 'Profusion', and 'Carmen'. The individual plants selected were graded so that the top growth of the plants was as nearly equal in size for both methods of propagation. Twenty trees of each cultivar for each propagation method were lined out in the field at three sites in Indiana. One site was at Purdue University, West Lafayette, IN, and the other two were at the cooperating nurseries in Vincennes and LaPorte, IN. Plants were randomized within cultivar in pairs and spacing was 4 ft in the rows with 6 ft between rows. Planting was done in May, 1987 at LaPorte and Purdue, and in July, 1987 at Vincennes. Irrigation was available and used through the season at Purdue. Each trunk was marked with paint at a height of 25 cm and a trunk diameter was determined at that height.

At the end of the first growing season every other plant was dug after leaf-drop. Prior to digging the trunk diameters were measured at the predetermined height and each tree was tagged so that it could be identified at the time of replanting in the spring. The dug plants from all three sites were placed in common storage at Hilltop Orchard Co., Hartford, MI.

In the spring of 1988 the plants were removed from storage and replanted at the different sites, though not back in the original planting holes. Spacing was the same as in 1987. The summer of 1988 in Indiana was extremely dry and irrigation was used at the Purdue and LaPorte sites during the season. The plants were thoroughly watered in at Vincennes, but irrigation was not available during the season. On November 10, 1988 all 2 year (left in-ground and transplanted) plants at Purdue were dug using a machine-mounted U-blade. The following growth measurements were taken: trunk diameter, maximum root spread, root spread along axis perpendicular to axis of maximum spread, tree height, maximum top canopy circumference, number of root suckers, and number of stem water spouts.

RESULTS

The trunk diameters of trees left in the ground for two growing seasons were significantly greater on all cultivars for trees grown on their own roots (36.8 mm) compared to those that were budded (33.4 mm). This compares with the initial trunk diameters that were smaller (16.1 mm) for own-rooted trees, versus (17.4 mm) for the budded stock. Thus, increase in trunk diameter was significantly

greater across cultivars for the own-rooted trees (Figure 1).

The same pattern was observed in the trees that were dug, stored, and replanted (Figure 2). However, the increase in trunk caliper was substantially reduced in the second season following replanting. This resulted in smaller trunk diameters, 28.6 mm for own rooted versus 27.8 mm for budded trees, at the conclusion of the experiment (Figure 3).

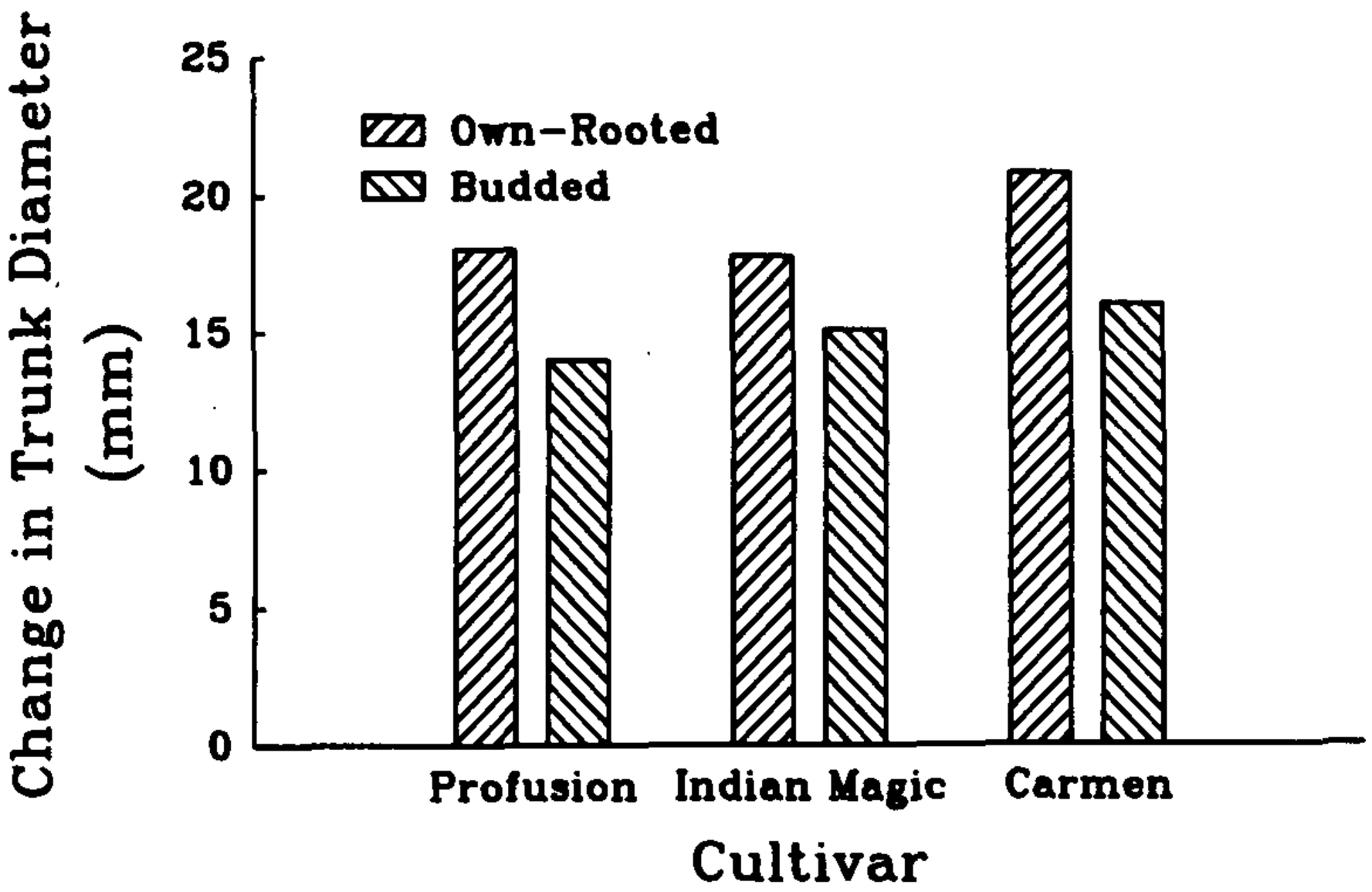

Figure 1. Change in trunk diameter for trees left in-ground two seasons.

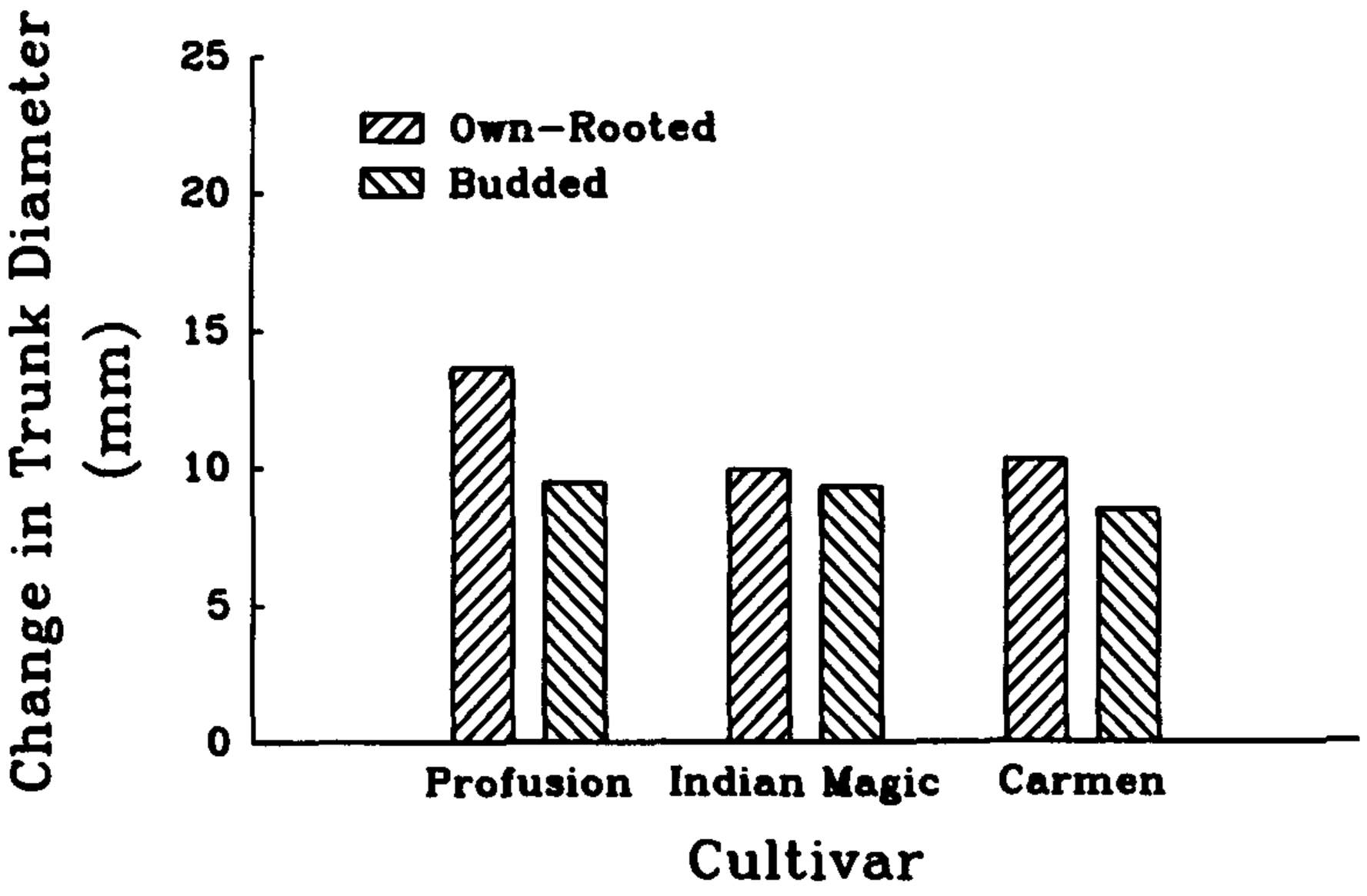

Figure 2. Change in trunk diameter for trees dug, stored, and replanted for second season.

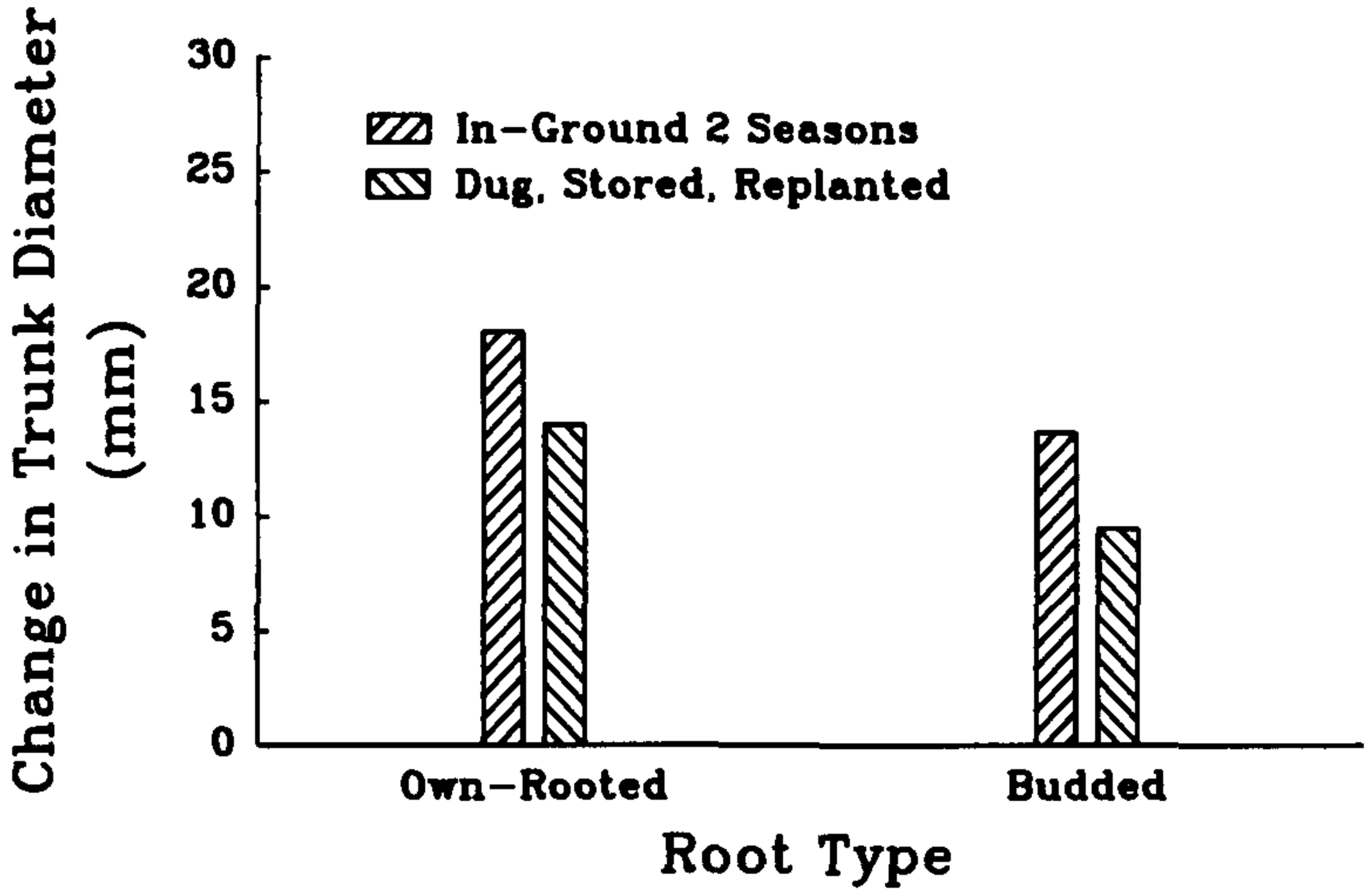

Figure 3. Change in trunk diameter for 'Profusion' comparing in-ground vs. dug, stored, replanted.

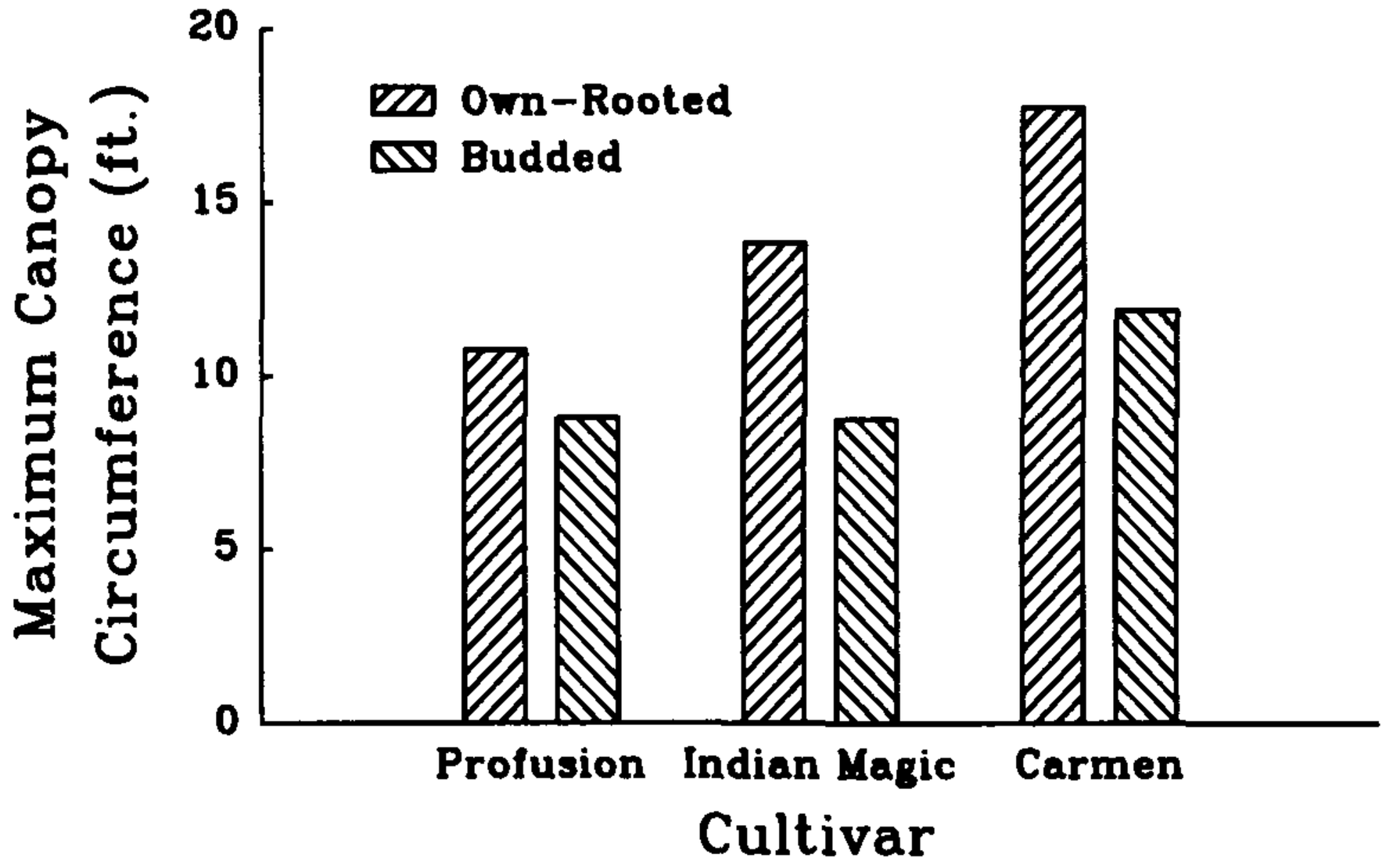

Figure 4. Maximum canopy circumference of trees left in-ground two seasons.

Maximum canopy circumference of trees left in the ground for two growing seasons was significantly greater on the own-rooted trees compared to those that were budded. 'Carmen' developed the broadest heads (Figure 4), but the greatest branch density, as indicated by total shoot weight, was observed in 'Indian Magic'. Trees that were dug and replanted showed such reduced top growth due to transplanting that no consistent differences were observed.

Root system size among trees left in the ground two growing seasons, expressed in area defined by the maximum root spread, times the root spread measured on the axis perpendicular to the maximum, was greater for own-rooted trees than for budded. 'Indian Magic' developed the largest root area coverage, with 'Profusion' and 'Carmen' being substantially smaller. Own-root 'Indian Magic' trees had a root area of 35.7 sq ft while budded trees averaged only 20.5 sq ft (Figure 5).

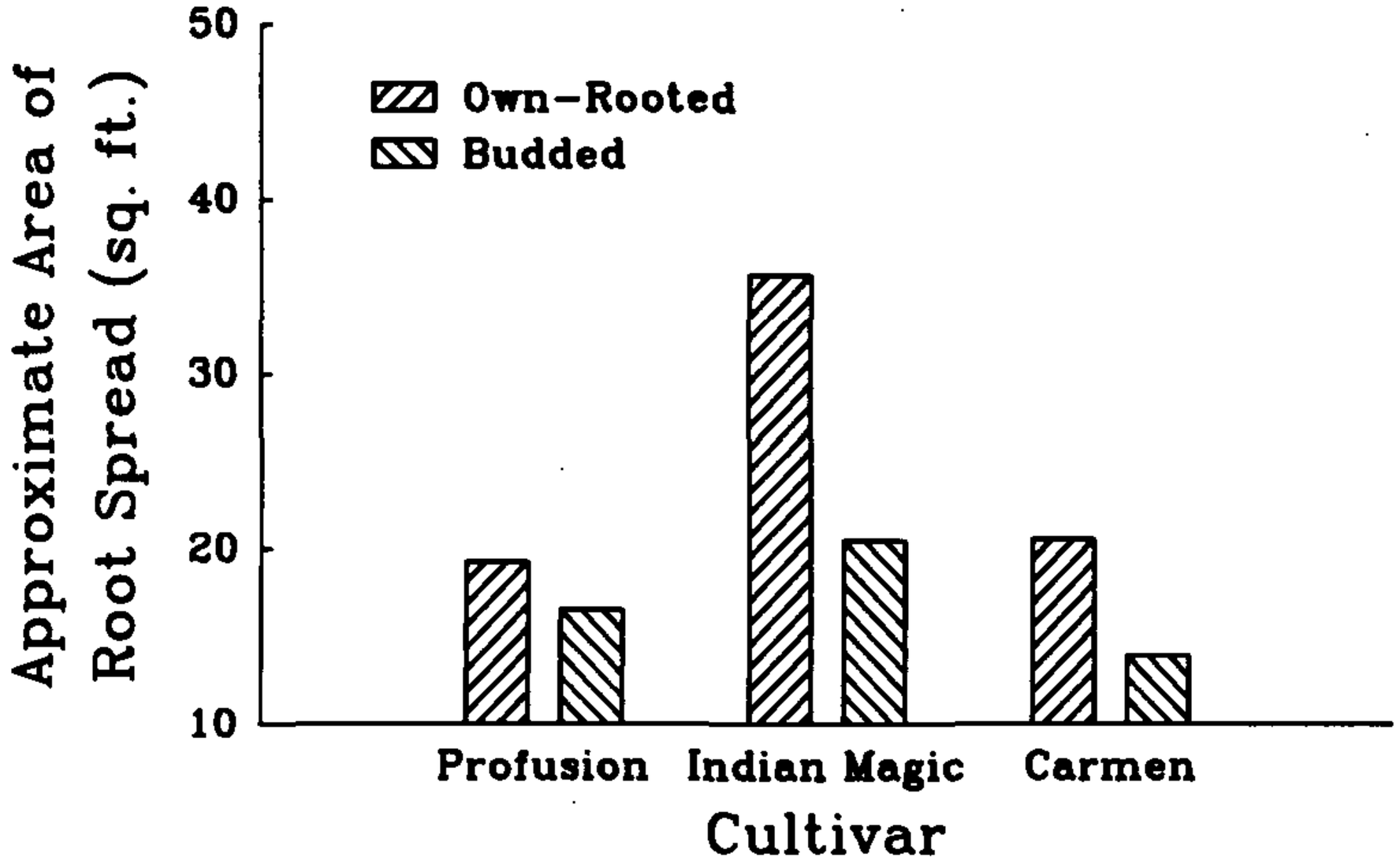

Figure 5. Approximate area of root spread of trees left in-ground two seasons.

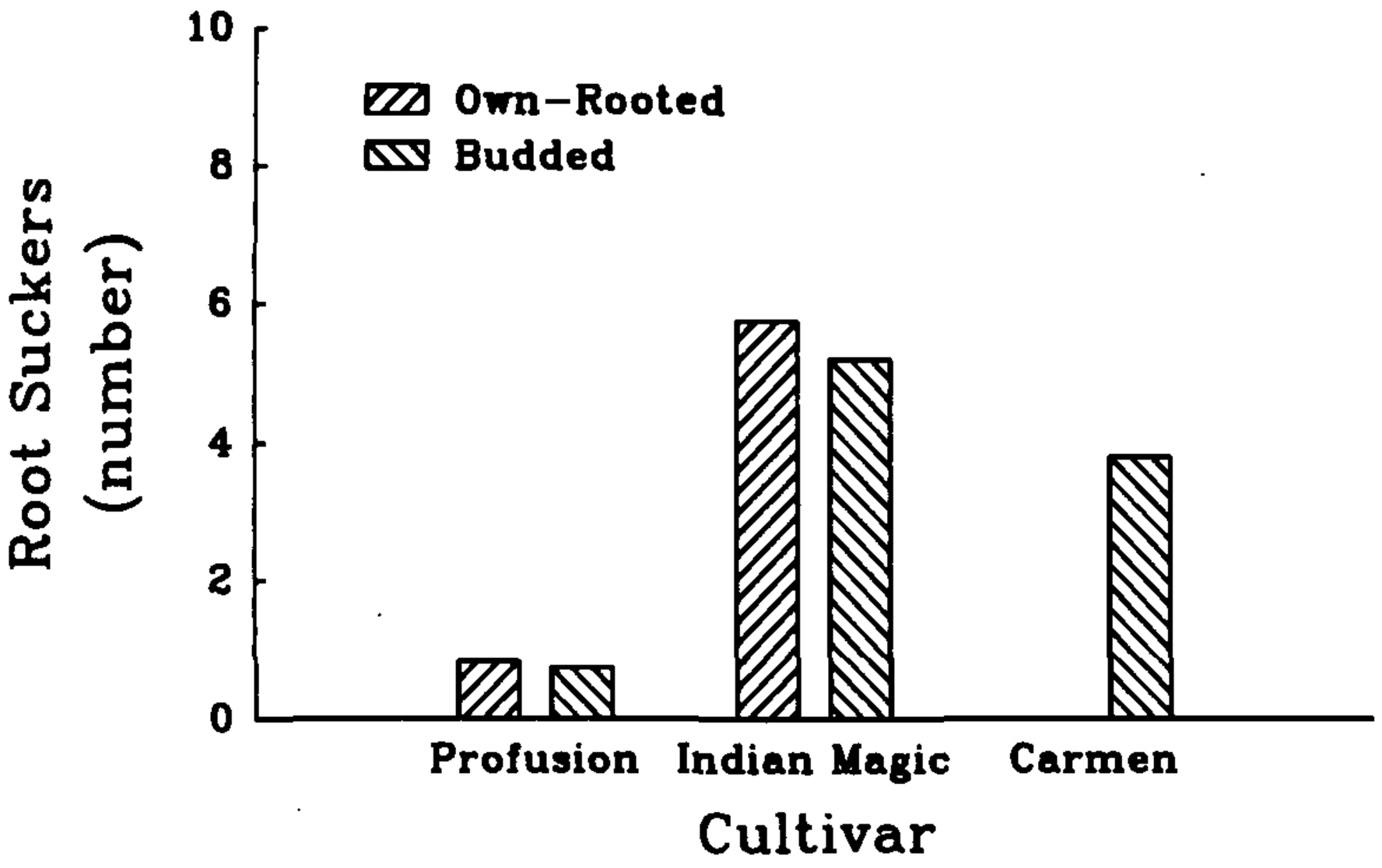

Figure 6. Root sucker number on trees left in-ground two seasons.

Root suckers occurred on both own root and budded trees, but there was a marked cultivar difference between 'Indian Magic' and 'Carmen'. Own root 'Carmen' had no suckers while own root 'Indian Magic' had as many as the budded trees (Figure 6).

OBSERVATIONS

Sometimes field observations are as important as data taken and analyzed statistically. At planting time it was observed that the root systems of crabapples propagated by cuttings had a horizontal growth habit and were relatively shallow, but the roots on the apple rootstocks had a deeper, more vertical growth habit. At the Vincennes site the own-root plant of the 'Carmen' suffered greater plant loss than the deeper-rooted plants on apple rootstock. This appeared to be the result of dry weather. Where early planting and irrigation was available this did not occur.

During a period of high winds in the spring of 1988 at the Purdue site, own root 'Carmen' leaned several degrees from the vertical. This occurred on plants that were established for one year.

The top structure of own-root crabapple was superior in all three cultivars to that observed for budded trees.

SUMMARY

1) Crabapples on their own roots develop faster and into better *shaped, larger trees.*
2) Differences in root suckering was not observed between own-root crabapple and budded trees.
3) Root mass development was greater on own-root crabapples.
4) The shallow, horizontal root development on own-root crabapples could cause problems of tipping in the wind or plant loss after transplanting if the season is dry.
5) Transplanting and storing crabapple trees reduces drastically the amount of growth achieved in the next growing season.

LITERATURE CITED

1. Burd, Susan M. and Michael Dirr. 1977. Propagation of selected *Malus* taxa from softwood cuttings. *Proc. Inter. Plant Prop. Soc.* 27:427–432.

DON SHADDOW: For several years we have been growing rooted crabapple cuttings as multistem plants. That is an advantage of using rooted cuttings.

PROPAGATION METHODS AFFECT TAXUS CUTTINGS AND LINER QUALITY

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INTRODUCTION

Recently, the work of Gouveia (1) and McGuire (2) have shown that *Taxus* species can be rooted with bottom heat in early spring and planted in late spring or fall the same year. In addition, McGuire (2) found that the spring-rooted taxus were equal to or superior to taxus cuttings taken in the fall, rooted on bottom heat, and spring-planted. Cuttings propagated on bottom heat are ready to plant sooner (6) than those without bottom heat (4). In addition, the utilization of bottom heat has eliminated the need to strip needles from the basal end of the cuttings thus saving time and physical injury to propagators (5,3). However, for us—propagating taxus in the spring—does not fit in time-wise with other nursery operations during the busy spring season.

MATERIALS AND METHODS

Five years ago we started a comparison of the rooting and subsequent bed performance of taxus cuttings produced under two different propagation systems.

Our original system involved sticking taxus cuttings in late fall in wooden flats, rooting them on electric heating cables, and then bed planting in May the following year by hand. An 8-row mechanical bed planter was soon purchased. Plants were shaded with sash or snowfence the first year in beds.

In 1977, we initiated the second taxus production system. This is an 18-month production cycle without the use of bottom heat, similar to the procedure outlined by Sabo (4) and seen at Greenleaf Nursery in Oklahoma on an IPPS Eastern Region tour. In November, 6 in. taxus cuttings are stripped and stuck in ground beds filled with 3 in. container medium with 3 in. coarse sand overtop. The air temperature is kept just above freezing with portable 150,000 BTU propane heaters. Cuttings root through the summer in these 13 × 96 ft houses under intermittent mist and 50% saran shade. In January the rooted cuttings are lifted, root-pruned, and heeled back in houses to be bed-planted in April when new root growth is evident. We switched to this system because it provided a less costly method to expand production without the high cost of purchasing and operating bottom heat. We then discontinued shading the newly planted taxus liner beds for the first year. This has worked well with many of the cultivars rooted in this system.

In contrast to these cost savings in the second method we found there were unacceptable bed losses the first winter on some cultivars of the more difficult to produce taxus. These taxus were the slower rooters and were those cultivars found to have less satisfactory root systems produced without bottom heat on the 18-month cycle. Each of the 20 different cultivars of taxus grown at Studebaker's are produced for a certain purpose or market. We therefore designated the problem cultivars for further trials and improvements. In 1984, we reinstated a revised system of bottom heat and conducted rooting trials using both propagation methods to compare rooting percentages and quality of rooted cuttings.

In the revised bottom heat system, cuttings are taken in November, stuck unstripped in groundbeds and rooted at 65 to 70°F on electric heating cables. These are bed-planted in late August the following year for a shortened cycle of 9 months. These cuttings are fall-planted so as to be on the same production cycle for comparisons to the cuttings planted the following spring without bottom heat (which we term an 18-month direct-stick cycle).

The rooted cuttings are planted with an 8 row mechanical transplanter into 5 ft wide beds on a spacing of 7 in. between rows and 5½ in. in the rows. Before planting, the beds are prepared with a sudan grass cover crop for one year, fall plowed and disked, and additional sphagnum peat added at the rate of 215 yd^3/acre. The beds are formed in the fall and fumigated with methyl bromide, then left to settle over the winter before planting in spring. Fall-planted beds are the ones left over from this process. After planting, beds are well watered-in and kept on a weekly watering cycle of 1 in. applied from Rainbird 30 heads on 3 in. aluminum lines. During prolonged periods of extreme heat, such as the summer of 1988, the newly-planted beds were additionally irrigated three to four times daily for short intervals to keep the plants cool. The liners are root-pruned twice in the three growing seasons then undercut and out-planted in the spring of the fourth year.

RESULTS

We made the following observations when comparing the cutting quality, the time of planting, and subsequent liner quality for both production systems over the last five years:

1) The bottom heat system generally produced equal or higher rooting percentages across the board than the non-bottom heat. Ninety to 95% rooting on most cultivars was consistently attainable with bottom heat. An average of 80 to 85% rooting on many cultivars without bottom heat has been attained over the years. The exceptions on the 18-month system are the slower and problem rooters such as: *Taxus* × *media* 'Amherst', 'Brownii', 'Chadwick', 'Everlow', 'Hiti', 'Ohio Globe', 'Slavin', 'Tautoni', and 'Thayerae'. Rooting of

these cultivars was improved 15 to 40 percent overall with the addition of bottom heat.

2) The bottom heat system produced a higher quality, more densely rooted cutting than the non-heated ground bed system. This difference was especially evident with cultivars we listed as problem rooters. With easily-rooted types, such as *T.* × *media'* 'Wardii', 'Runyan', 'Hicksii', 'Densiformis', 'Henry', 'Berryhill', and *T.* × *cuspidata,* the difference was less obvious. This qualitative difference was carried through into the liner stage as a larger top and root mass on 3-year liner types in almost every cultivar tested. Even the easy-to-root cultivars that were virtually similar as rooted cuttings, were comparably better quality 3-years later under the bottom heat system. The distinct advantage of the bottom heat system is greatly augmented by bed planting in the fall vs the spring planting of unheated cuttings. It appears that the fall planting of bottom-heat-rooted cuttings allows root systems to take hold in the fall and begin growing more quickly the following spring. This increased growth the following year was noted by Gouveia (1) in reference to fall planting vs. spring planting.

3) As a result of trials run on bottom heat of many cultivars of unstripped taxus cuttings, we found non-stripping was preferable to stripping. This was not found to be the case in non-heated ground beds and we continue to strip all cuttings done in that method. The obvious benefit was the labor savings realized in non-stripping. In addition, some cultivars were visually more densely rooted non-stripped than stripped (*T.* × *media* 'Tautonii' and 'Amherst') when compared. However, thin stemmed (*T.* × *media* 'Slavin') or a heavily branched cultivar (*T.* × *media* 'Densiformia') require extra care to get them securely into the medium when non-stripped. Cuttings of upright growers, such as *T.* × *cuspidata* 'Columnaris' and *T.* × *media* 'Hicksii', when non-stripped develop branches lower and may produce fatter liners at the base that tend to be a problem in their production.

4) The bottom heat method concentrated the roots more densely around the base of the rooted cutting, while non-bottom heated cuttings exhibited rooting up the stem on many cultivars. These higher roots are troublesome and labor must be spent removing them when liners are dug prior to field planting. If they are not removed, these surface roots are cut off quite severely in field harvest and cause a lower quality balled and burlapped product.

DISCUSSION

Bed survivability from fall planting of bottom heat cuttings has been variable from year to year. Losses have been generally greater than our spring-planted losses of 5 to 15% for unheated cuttings. Previously, we seeded oats in the fall beds as a cover-crop to protect the cuttings the first winter, but the debris and required clearing off of beds in the spring have caused problems. Currently, we are using a Bowie Straw Blower, Model W4-1770, to blow spoiled straw over these beds to a 2-in. depth as a protective mulch and weed inhibitor. We also preferably plant easier-to-root cultivars in the fall which seem to establish better, with lower losses. The first winter in the fall planting system is definitely the greatest challenge to the success of this method. More research needs to be done at this stage of the production system to improve the success of this method.

A promising variation of the bottom heat method is a return to the shortened 6-month production cycle of November sticking, rooting, then out-planting to beds in May. In spring-planted tests of *T.* × *media* 'Hiti', 'Tautonii', 'Chadwick', and 'Everlow', from the first year onward in liner beds, the 6-month bottom heat exhibited equal or larger top and root systems than the 18-month unheated ground bed cuttings. These 6-month trials survived the first winter with normal losses without shading or mulching the first year. The 18-month unheated cuttings planted the same time had higher losses from heaving due to less than sufficient root systems produced without bottom heat. All of these harder-to-root cultivars are now rooted on bottom heat. These 6-month bottom heat cuttings were not as large at any stage in the beds as the fall-planted 9-month bottom-heated cuttings stuck the previous year. However, their comparative quality, high survivability, and simplicity of maintenance may outweigh the benefits of the fall planting method. Larger trials are being conducted on this method for next spring focused on the harder to produce cultivars.

In summary, the overall advantage in quality of the final liner is better with the bottom-heated cuttings, whether planted in spring (6-month) or in fall (9-month), as compared to the non-heated cuttings 18 month liner. However, the quality differential on many cultivars may not warrant or necessitate production on costly bottom heat. Based upon in-house trials in the facilities available at your own nursery, both methods may be used successfully for production of high quality liners.

It is interesting we have come back full circle to re-exploring the original method of taxus propagation we used in the early 60s (7), but with a greater knowledge and improvements to those techniques. Many of these methods and improvements in our propagation system have been due largely to the wonderful sharing of the IPPS whose many members over 27 years helped make our newly-born nursery successful. This Society is indeed a special organization.

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BRUCE BRIGGS: What hormone and what concentrations do you use?

DAN STUDEBAKER: Wood's Rooting Compound at a 1:3 or 1:5 v/v, dilution or 1:2, v/v, for the most difficult types.

BRUCE BRIGGS: Just a comment. Your results show how a hormone does not work without bottom heat.

MICROPROPAGATION OF *OXYDENDRUM ARBOREUM*

THOMAS J. BANKO

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Abstract. Micropropagation and acclimatization of *Oxydendrum arboreum* (L.) DC. (sourwood) is described. Explants were axillary shoots forced from dormant stems of a mature tree, or nodal stem sections obtained from spring growth of the same tree. Optimum shoot growth was obtained with WPM supplemented with 0.4 to 0.8 mg/l zeatin. Shoots could be divided and subcultured after 6 weeks. Microcuttings were rooted on WPM supplemented with 0.5 to 2 mg/l IBA, or in peat/vermiculite after treatment with 0.8% IBA in talc. Mist, plastic bags, and a wet fabric tent were compared for acclimatization and promotion of normal stomatal functioning. The wet tent appeared to promote the most rapid acclimatization.

REVIEW OF LITERATURE

Oxydendrum arboreum (sourwood, sorrel, or lily-of-the-valley tree) is an attractive, slow-growing tree native to the eastern and southeastern United States, that has considerable value for use in the landscape. While *Oxydendrum* can be propagated easily from seed, there are significant variations in growth habit, flowering characteristics, and fall color. Cuttings are difficult to root (3). *Oxydendrum* is a member of the Ericaceae. It was considered to be a

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good candidate for micropropagation, since several other ericaceous plants have been propagated *in vitro,* including rhododendron, blueberry, deciduous azalea, kalmia, and lingonberry (1,4,5,6,7).

MATERIALS AND METHODS

Collection and Preparation of Explants. Explants have been successfully collected for culture in two different ways:

1) Dormant stems of previous season's growth were collected from a mature tree (24 years old) in late February, 1987, and placed in a floral preservative solution (Floralife, Inc., Burr Ridge, IL, 9 g/l) in a greenhouse to force new shoot growth. The forced axillary shoots (1 to 2 cm in length) were used as explants.

2) Actively growing stems were collected after growth started in the spring (late April). Stem sections consisting of 2 nodes each were used as explants.

The explants were washed in distilled water containing 0.1% Tween 20 for 10 min. followed by stirring in 0.5% sodium hypochlorite solution for 5 to 10 min.

The explants were initially placed in culture tubes with 20 ml Woody Plant Medium (WPM) (6) supplemented with 0.8% Difco-Bacto agar, 1 mg/l zeatin, and 2 mg/l indole-3-acetic acid (IAA). Preliminary experiments showed zeatin to be superior to 6-(y y-dimethylallyamino) purine (2iP) and N_6 benzyladenine (BA) for the initiation of shoot growth. The pH of the medium was adjusted to 5.2 prior to the addition of agar and before autoclaving at 121°C for 15 min. The cultures were maintained at 24 to 26°C under a 16-hour photoperiod provided by cool-white fluorescent lamps.

Multiplication. Uniform shoots (10 mm in length) were excised from previously-established cultures and placed individually into 25 × 150 mm culture tubes containing 20 ml WPM with 0.8% Difco-Bacto agar supplemented with 0, 0.9, or 1.8 mg/l IAA, and 0, 0.4, 0.8, 1.6, 3.2, or 6.4 mg/l zeatin. Culture conditions were maintained as previously described.

Rooting. Experiment 1. Shoots longer than 10 mm were excised from an established culture and placed in culture tubes containing WPM supplemented with 0.8% Difco-Bacto agar, and 0, 0.5, 1.0, 1.5, or 2 mg/l indole-3-butyric acid (IBA). Root development was evaluated after 6 weeks.

Experiment 2. Shoots longer than 10 mm were excised and soaked in a 400 ppm IBA solution for 0 (untreated), 5, 10, 20, or 30 min, or the basal ends were dipped in Hormodin No. 1, 2, or 3 (0.1, 0.3, or 0.8% IBA in talc). These treated shoots were then placed in baby food jars containing a sterile medium of peat moss and fine vermiculite (1:1 by volume), moistened with sterile distilled water. The jars were capped with magenta B-Caps and placed under the conditions described for shoot initiation.

Acclimatization. Rooted microcuttings were removed from the culture tubes and potted into ProGro 300S in 2 in. plastic containers. These plants were then placed under 3 different conditions for acclimatization:

1) A wet fabric tent similar to that described by Whitcomb (8). The tent was constructed on a greenhouse bench with a fabric of 85% polyester/15% linen used to wick water down the sides.
2) Intermittent mist, 5 sec. every 5 min, in the same section of the greenhouse as the fabric test.
3) Enclosure within clear plastic bags.

The plants in mist and plastic bags were shaded with the same fabric covering the humid tent, so that light levels would be the same for all three treatments. Each day for 10 days following the start of acclimatization, 8 plants were removed from each of the above treatments and placed under 55% shade cloth in the greenhouse. At that time one leaf from each of three plants per treatment was excised and placed on moist filter paper in a glass petri dish. Comparable leaves from already acclimated plants were also collected in the same way. The excised leaves were then taken to the laboratory where the petri plates were opened and the leaves were allowed to lie abaxial side up for 15 min. prior to obtaining epidermal peels for microscopic determination of stomatal closure. One week after all plants had been removed from their respective acclimatization treatments, they were evaluated for leaf burn and growth.

RESULTS AND DISCUSSION

Collection and Establishment of Explants. Explants obtained either from actively growing stems, or by forcing dormant stems, were successfully established *in vitro*. Although the explants were initially established on WPM containing 1 mg/l zeatin and 2 mg/l IAA, it has since been determined that an auxin is not needed at this stage, and that 0.4 to 0.8 mg/l zeatin is sufficient to promote shoot proliferation.

We have recently established and multiplied cultures from five additional mature trees, including a tree estimated to be 75 to 100 years old, with actively growing stems collected in August.

Multiplication. As the concentration of zeatin was increased, the total number of shoots produced also increased; however, the addition of IAA to the medium reduced shoot numbers. Although the greatest total number of shoots was produced with 1.6 to 3.2 mg/l zeatin, most of these shoots were very short, suggesting excessive amounts of cytokinin. The largest number of shoots longer than 10 mm was produced with 0.4 to 0.8 mg/l zeatin (2).

Rooting. Experiment 1. A preliminary experiment showed IAA and NAA to be ineffective in promoting root development of sourwood *in vitro*. However, in this experiment, the addition of IBA to the medium (0.5 to 2 mg/l) promoted roots on 88 to 95% of the cuttings. Only 5% of the untreated cuttings rooted.

Experiment 2. Rooting in the peat/vermiculite medium was less successful. The most effective treatment was the 0.3% IBA in talc, which resulted in about 50% rooting. Almost all of the microcuttings that were treated with the 400 ppm IBA soak died.

Acclimatization. The three acclimatization treatments provided a range of humidity conditions. Over the 10 day period, the relative humidity (RH) in the plastic bags averaged 96%, while the mean RH of the wet tent was 76%. The air in the vicinity of the intermittent mist had a mean RH of 58%; however, the surfaces of the leaves were wet at all times. The RH for the rest of the greenhouse averaged 40% during this period.

The percentage open stomata data determined for each of the 10 days of acclimatization shows that the stomata of the plants from the wet tent started to close after 3 days (indicating that the stomata were functional and that the plants were successfully acclimating) and, after 8 days, had the same percentage of closed stomata as the fully acclimatized plants (Figure 1). However, the stomata from the plants kept in the plastic bags were only slightly more functional after 10 days than they were at the start of the experiment. The stomata from the mist treatment started to close at 5 days and were at about the same level as the tent treatment at 8 days.

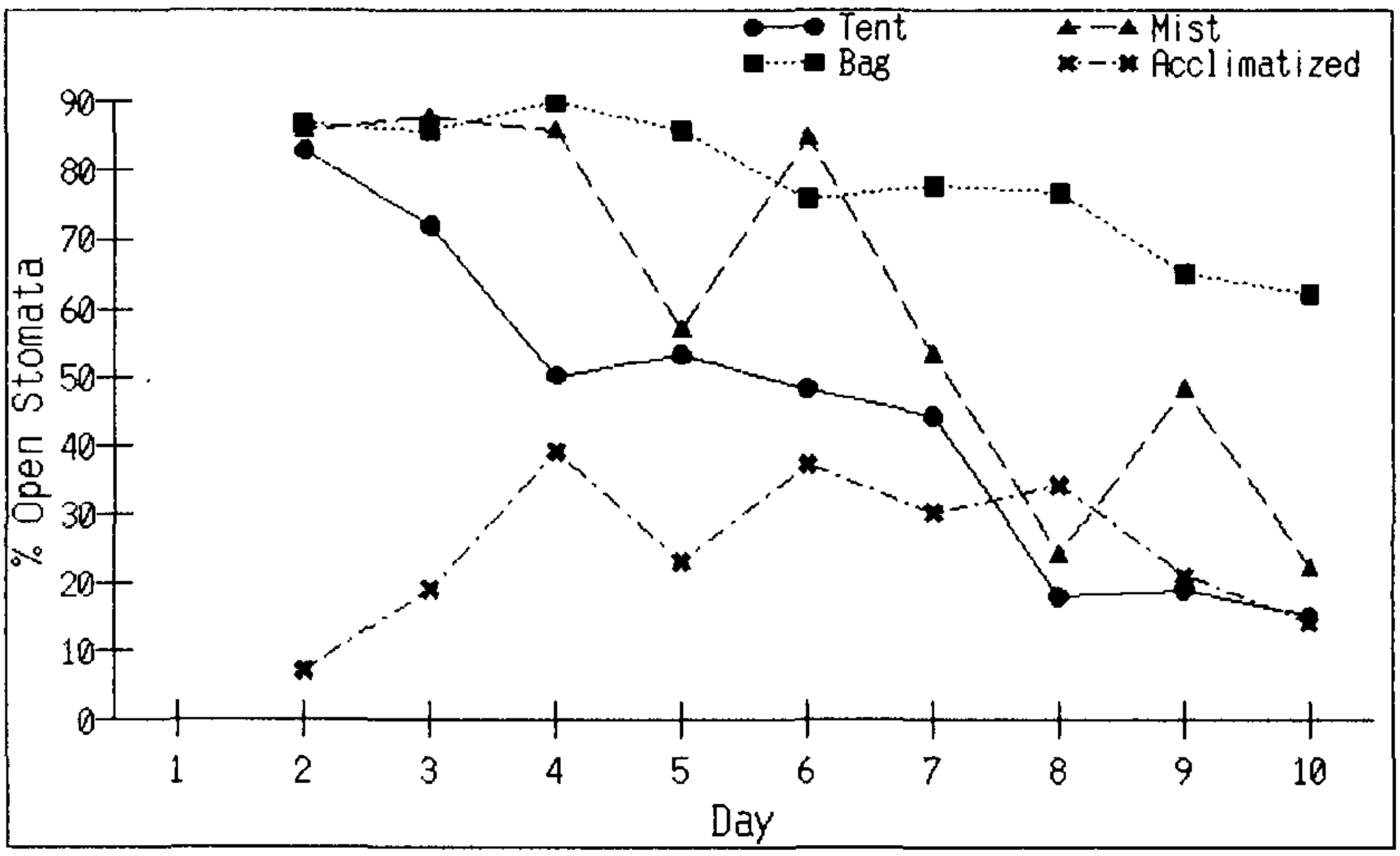

Figure 1. Percent open stomata for excised leaves of tissue-cultured plants after increasing periods of acclimatization in poly bags, intermittent mist, or wet tent.

The leaf-burn ratings showed that the plants from the plastic bags had consistently more leaf burn than the plants from the other two treatments (Figure 2). The growth ratings show that after 7 days, the plants from the tent had the greatest amount of growth and survival, while those from the bags had the lowest ratings (Figure 3). This is consistent with the data on stomate function for the plants from the three different treatments.

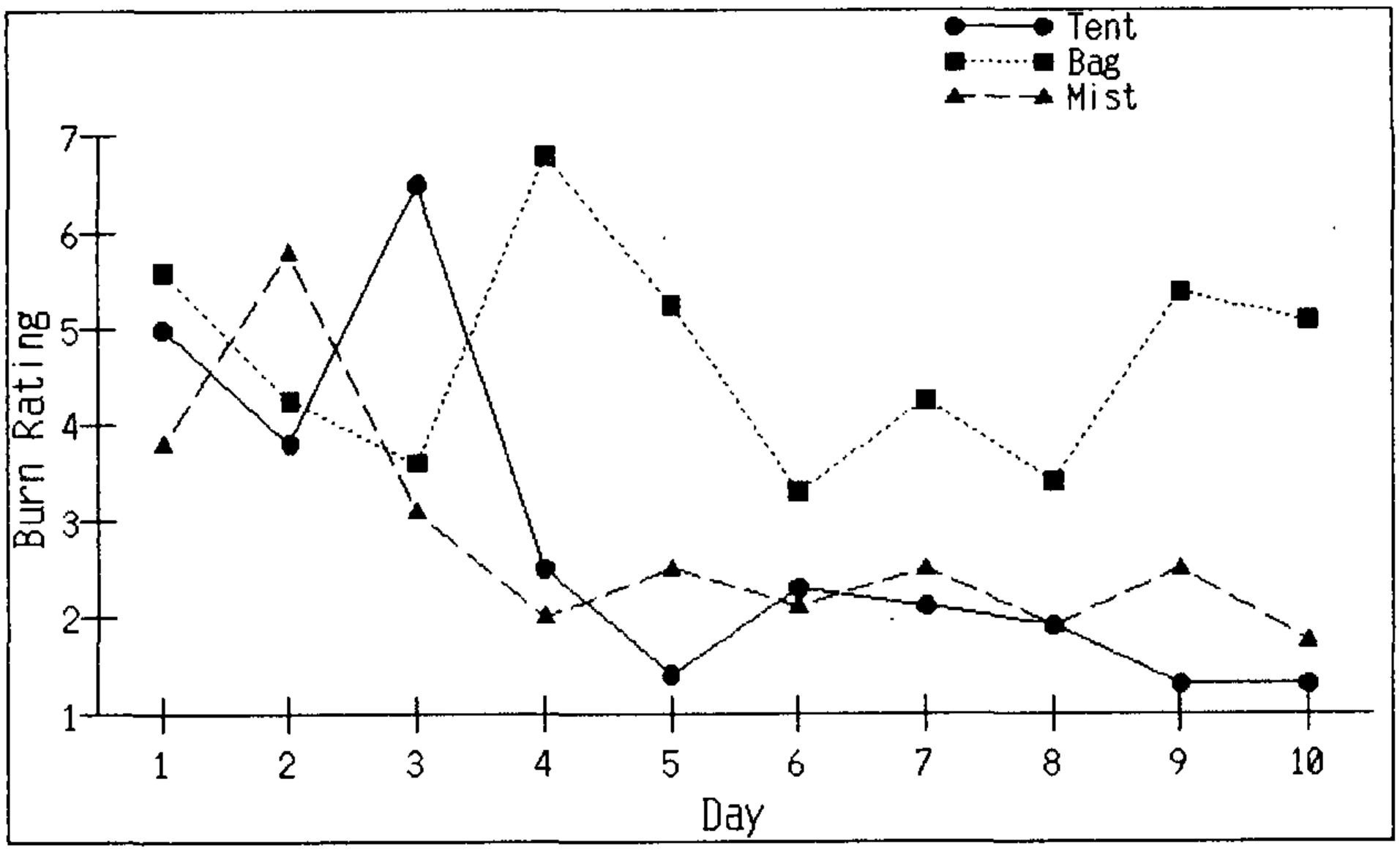

Figure 2. Leaf burn rating for plants removed from three different acclimatization treatments after 1 to 10 days of acclimatization. 1 = no leaf burn; 10 = all leaves burned, plant dead.

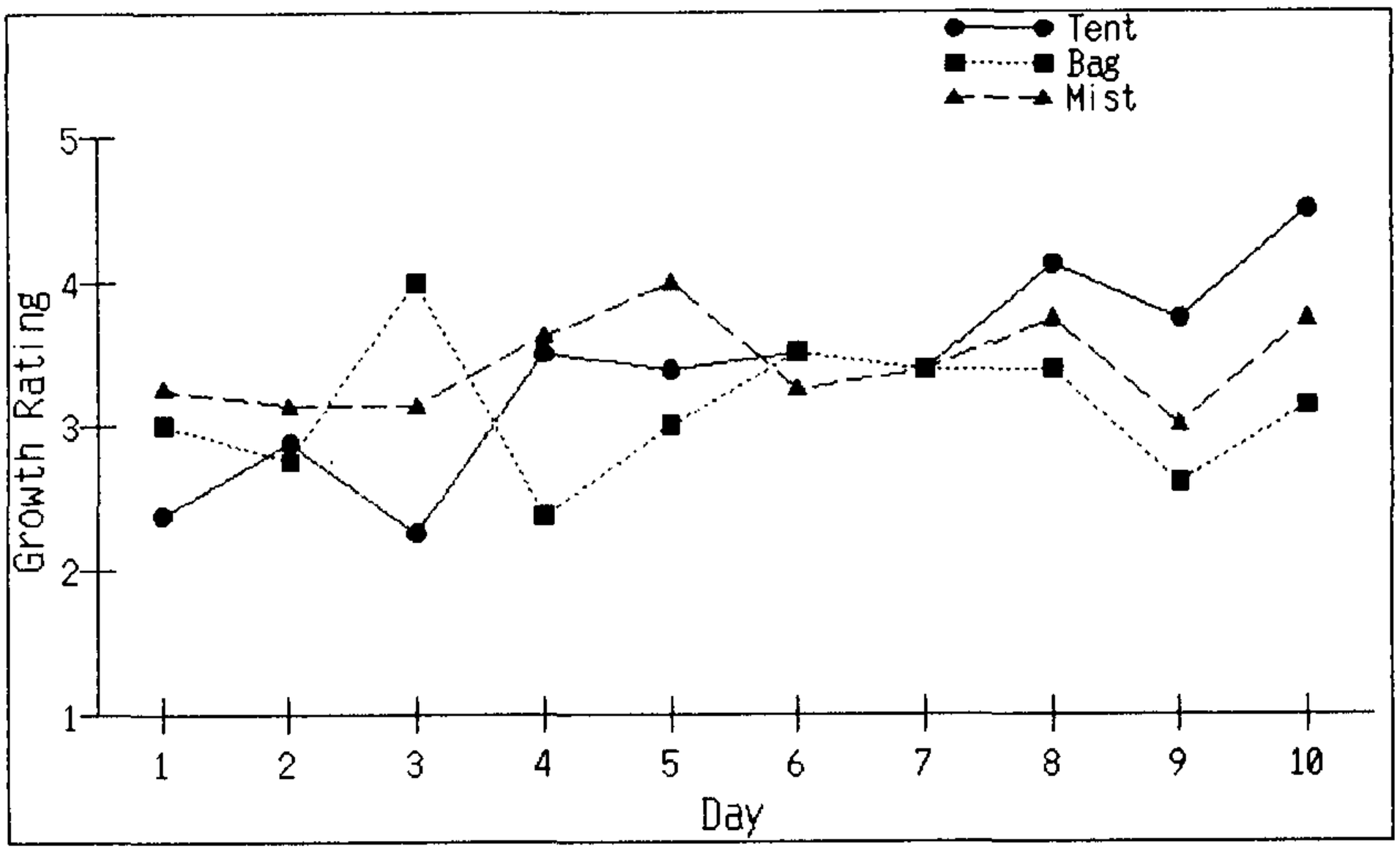

Figure 3. Growth ratings for plants removed from three different acclimatization treatments after 1 to 10 days of acclimatization. 1 = no growth; 5 = vigorous new growth.

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VOICE: What was the growth rate of the shoots after rooting, and did you get multiple shoots?

TOM BANKO: Yes, they do throw multiple shoots and that needs to be worked on. The growth rate can be quite fast. With heavy fertilization, we have obtained 3 ft the first year.

BOXWOOD PRODUCTION IN THE U.S. MIDWEST

KEN ROE AND PHILIP SOMMER

Scarff's Nursery, Inc.
411 N. Dayton-Lakeview Rd.
New Carlisle, Ohio 45344

Gardeners have known the value of *Buxus* species (boxwood) for thousands of years as: specimens, foundation plants, hedges, edging for knot gardens, accent plants, topiary, bonsai, and many other applications limited only by the imagination.

Boxwoods are native to Europe and parts of Asia. *Buxus sempervirens* has been in cultivation since the time of ancient Rome. During the middle ages it was cultivated in castle gardens and monasteries. During the seventeenth and eighteenth centuries it was in general use in Europe. It was during that time that colonists brought boxwood to America.

Along the coast in the states of Virginia, Maryland, and the Carolinas *B. sempervirens* cultivars did beautifully, but as the people moved westward, midwestern nurserymen learned of the limits of its range. Midwestern nurserymen have suffered many

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Along the coast in the states of Virginia, Maryland, and the Carolinas *B. sempervirens* cultivars did beautifully, but as the people moved westward, midwestern nurserymen learned of the limits of its range. Midwestern nurserymen have suffered many

disappointments when trying to grow *B. sempervirens* cultivars in their fields. They have not been able to tolerate midwestern (Zones 4 and 5) winters characterized by temperatures of −10 to −20°F, often without snow cover. These conditions, along with strong drying winds, have made field production of common boxwood economically unfeasible.

Today several cultivars of common boxwood are grown in the midwest with production in containers that can be protected from such severe winters. Once these cultivars are established in a protected garden site they may do well for years. For field production of boxwood, midwestern nurseries turned to Asia as a source of hardier types.

In 1918 E. H. Wilson found *B. microphylla* var. *koreana* and planted it at the Arnold Arboretum. Intrigued by the reported hardiness of the plant, Howard Scarff ordered one pound of seed from Manchuria in 1935. After sowing in flats with a sand medium seeds germinated and grew 100%. Eventually the seedlings grew large enough to line out in the field. The plants did well except that the foliage turned brown over winter. In 1950 Mr. Scarff noticed a few plants held their green color over winter; he selected cuttings from these. The resulting plants did well but lacked uniformity. In 1958 he selected 25 of these plants with the same color, habit, and uniformity, and placed them in a stock block. Progeny of this stock block were the original Wintergreen boxwood that went into the trade. This selection has stood the test of time and is still the most satisfactory boxwood for our area of the midwest and known for its outstanding hardiness and winter color. As beautiful a plant as *B. microphylla* var. *koreana* 'Wintergreen' can be, it is not without problems from a field production standpoint.

'Wintergreen' breaks bud very early in the spring (late March in our area) and the lush new growth is very susceptible to frost damage, which is characterized by a uniform dieback of the twigs. This can render the plants unsalable and necessitate heavy shearing and loss of size. While not killing plants, frost damage can render whole fields unsalable and make a long production cycle of 8 to 10 years even longer. Overcoming the problem of susceptibility to frost damage and the resulting increase in production time is why we are so excited about the hybrid boxwoods introduced by Sheridan Nursery, Canada in the 1970s. These resulted from random crosses of Korean and common box that were growing side by side in the nursery during the early sixties. Of the seedlings resulting from this cross, four were selected and named:

Buxus 'Green Velvet' is a vigorous globe form. It has the large dark green leaves of its common box parent, which it retains through the winter. *Buxus* 'Green Velvet' is a relatively fast grower. Under good cultural conditions one can expect to have a 12 to 15 in. salable shrub from a 3 to 5 in. rooted cutting in 6 years.

Buxus 'Green Gem' (PP #3736) is a slower growing dwarf selection reported to mature at 2 × 2 ft. It has smaller dark green foliage than 'Green Velvet' and a compact habit that would be ideal for low formal hedges. 'Green Gem' has a moderate growth rate. Under good cultural conditions one can expect to have a 10 to 12 in. salable shrub from a 3 to 6 in. rooted cutting in 6 years.

Buxus 'Green Mountain' is a vigorous grower with a very upright habit so that we are trimming it into pyramidal forms. The foliage is much like that of 'Green Velvet'. Under good cultural conditions one can expect to have an 18 to 24 in. pyramidal plant in 8 years from a 3 to 5 in. cutting.

Buxus 'Green Mound' was the fourth cultivar in the green series; however, because of its close resemblance to 'Green Velvet' we have not pursued its production.

'Green Velvet' is not a patented plant but is protected by the Canadian Ornamental Plant Federation (C.O.P.F.) and we pay a voluntary royalty to them. 'Green Mountain' and 'Green Mound' are not protected.

Aside from the ornamental attributes of the green series of boxwoods there are several other reasons why mid-western nurserymen and propagators should be aware of these plants from a production stand point.

1) Late bud break—the Sheridan hybrids break bud 3 to 4 weeks after the Korean cultivars, which is beyond the time when we generally get low enough temperatures to kill new growth.
2) Hardiness—the Sheridan hybrids appear to have inherited the hardiness of its Korean parent. We have not experienced any damage since starting field production but have only had temperatures to −10°F without snow cover. Professor Edward R. Hasselkus from Wisconsin reported that three sister seedlings of *Buxus* 'Green Velvet' have been growing in the University of Wisconsin arboretum for 18 years. (1) They were winter injured once in the 78-79 winter at −28°F. They suffered no injury at −28°F in the 84-85 winter.
3) Drought tolerance—something that the drought of 1988 has taught us is the ability of these plants to tolerate drought.
4) Vigor—the Sheridan hybrids produce salable plants two years earlier than either Korean boxwoods or taxus cultivars.

Propagation of *Buxus* starts with collection of cuttings. The timing of collection does not seem to be a critical factor in propagation of boxwood. We used to wait until a couple of hard frosts, thinking the accumulation of carbohydrates would increase rooting percentage. However, because of the large quantity of cuttings we

now take, we start in September and have seen no decrease in rooting percentage as a result of the early cutting date. If one's objective is quantity of cuttings, then the succulent autumn wood can be pulled off the more mature spring wood with a heel attached. These short 1 to 3 in. cuttings, after a quick-dip into 1000 IBA, root readily at a 95% take. If larger cuttings are desired, take 5 to 7 in. cuttings of spring wood and soak for 2 min in 5,000 K-IBA. One can expect a 90% take using this method. We stick our cuttings in sand that is 30% #9 (almost pea gravel) and 70% concrete sand but any well-drained medium should work. Culturally, we maintain the medium at 70°F. and keep it evenly moist. A Subdue drench is used every 6 to 8 weeks on the cuttings as a preventative against *Phytophthora*. We use a rate of 2 oz/100 gal of water and drench with one pint/ft^2. In 6 to 8 weeks callus appears and in 10 to 12 weeks roots appear. Once we see roots we begin a fertilization program. We apply 9-45-15 liquid feed at 100 ppm N constant feed until the cuttings are ready to be potted. We pot 'Green Gem' and 'Wintergreen' in 2¼ in. Nu Pots and 'Green Velvet' and 'Green Mountain' in 3 in. Nu Pots. We use Fafard No. 3 potting medium.

Growing-on of rooted cuttings is done in polyhuts.

In summer the huts are covered with 40% shade. In winter we use a double layer poly (one layer clear and one opaque) with minimum heat. Fertilization is 500 ppm 21-7-7 acid special every 10 to 14 days from March to August. After two years we have a 4 to 6 in. branched liner ready to go to the field.

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MIKE YANNY: Do any of the Sheridan hybrids flower and set seed?

JOERG LEISS: If you do not fertilize them they will flower.

GRAFTING VIBURNUM CARLESII 'COMPACTUM'

DIXON P. HOOGENDOORN

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Middletown, Rhode Island 02840

Viburnum carlesii 'Compactum' was discovered several years ago in our nursery by my father, Case Hoogendoorn, in a block of *V. carlesii*. It is a slow grower with distinct dark green shiny leaves that develops into a very compact plant; it is ideal for use in foundation planting. It buds up heavily when mature. The size, color, and fragrance of the flowers are exactly like those of *V. carlesii*.

Viburnum dentatum is used as the understock. We have experimented with other types of understock, *V. lantana* for example, but we found *V. dentatum* to be far superior (1). When purchasing understock make sure that you find a reputable seedling grower that understands your needs. We use a one-year seedling approximately 3/16 in. caliper. We receive our understock in February before the busy spring season begins. The buds are removed from the lower third of the stem to help control suckering, a common problem in grafting this species. The roots are trimmed and the seedlings are potted into 2¼ in. clay pots. After potting, the plants are trimmed to a uniform height (usually 12 in. above the pot) and placed pot to pot in a ground bed of a poly house with a 1-in. covering of sand placed over the top of the pot to increase moisture retention and minimize watering. Plants are watered-in thoroughly and checked for moisture content periodically. The plastic is removed completely around April 15th when the threat of a hard freeze has subsided. Plants remain in this location until approximately September 10th when the grafting procedure will take place and there will be a good established understock.

Stock plants are cut back and fertilized with a side dressing of 15-15-15 in early March. Strong vigorous growth usually develops when good cultural practices are administered.

The peat moss should be shredded and put in the greenhouse bench several days prior to the actual grafting operation. This enables us to turn over and uniformly dampen the peat in order to attain the best possible results. The peat moss can be put in a windrow and sealed with water until time of use.

We usually start grafting *V. carlesii* 'Compactum' around the second week of September. Scions are harvested from our stock plants one to two days prior to their actual use.

We select the heaviest current year's growth possible in order to insure a stong plant from the start. Scion material is cut and kept moist in refrigerated storage at 45°F. This will ensure that scions will be in a turgid, workable condition at the actual time of use.

Scions are made to a length of approximately 12 in. with at least two sets of leaves remaining on the upper portion and the lower leaves trimmed flush with the stem in order to allow a sufficient surface for the grafter to make his cuts. Larger leaves may have to be trimmed in half at the discretion of the propagator as the foliage may be too dense under a high humidity environment. Flower buds should also be eliminated at this time.

The understock is watered one day prior to grafting to insure proper moisture levels. However, all external surfaces should be dry at grafting time.

The conventional side veneer graft is used in all our grafting operations. An extremely sharp grafting knife is required for this process. The understock is cut off 2 in. above the pot. We make approximately a 1½ in. long cut in the understock on the straightest side and as close to the pot as possible. The scion is cut slightly more than 1½ in. on one side and slightly less on the parallel side in order that a fresh angle cut can be made on the scion. Understocks and scions of approximately the same caliper should be used in order to match up the cambium layers on two sides. However, this is not always possible, but it is essential to line up cambium layers on one side to insure good results. The scion is inserted into the understock with the lip covering the outside cut. A budding strip (¼ x 4 in.) is used with medium tension. It is applied from the top of the union down leaving enough space for callus tissue to form. The bottom lip should be left completely open as this is where the majority of the callus formation occurs. We use a half hitch in the final turn of the budding strip in order to simplify its removal at the time of planting.

When a flat of grafts has been completed it is immediately taken to the greenhouse and the potted grafts are set on the bed. The peat is leveled off and a trench is made so that the unions are buried. The grafts are placed on an approximate 60° angle to insure that they fit under the glass sash. Bottom heat may become necessary at night depending on varying temperatures associated with that time of year. We keep the bench temperature at a minimum of 68 to 70°F. Depending on size and fullness of the scions we may want to open the rows a little to help eliminate fungal problems. We apply Benlate and captan on an alternating spray schedule at the rate of 1 tbls/gal water. The solution is applied with an Ortho Spray-ette proportioner (a portable sprayer that connects to a garden hose). The fungicide must have sufficient time to dry before the sashes are put down. Once the grafts have been set in the bench they are syringed on sunny or bright days and the sashes are put down. A linen cloth is rolled over the sashes to protect the grafts from direct sunlight. On dark days the grafts are aired with no syringing and the sashes put down in place without the linen.

Approximately 4 weeks after the grafts have been placed in the

sweat box or grafting case, the callus should be fully developed. It is now time to set them on top of the peat and begin hardening them off. As soon as they are brought up they are watered as the pots may be getting dry and also to keep some moisture around the callus tissue. The sashes are gradually left open a longer period each day to allow more air circulation. After 4 days we put a 2 in. block under the sash. After approximately 6 days they are kept completely open. After the 7th day they are ready to be moved to a new environment.

Potted grafts are then moved to our deep pit storage house for the winter. They are set pot to pot and covered with approximately ½ in. peat moss and watered in. This process enables potted grafts to hold adequate moisture levels for extended periods of time. We find that 2 or 3 waterings are usually all that is necessary during the winter months under normal conditions. We like to keep dormant plants on the dry side. We reach a minimum temperature of 28°F in our deep pit storage house which is ideal for sensitive plants. The pit house provides the proper dormancy period and the plants respond by breaking extremely well in the spring. We open the door during mild periods to air the house. The potted grafts are periodically checked for proper moisture content.

As the days lengthen and the outside temperatures rise, it is necessary to increase ventilation procedures. We have a 3 ft fan set in one end of the house for this purpose. However, it is necessary to remove four staggered filon panels on each side of the storage pit to increase air circulation. They are replaced with 50% lath shades. The remaining filon panels are sprayed with shading paint to reduce the sun's intensity. This enables the grafts to be properly hardened-off prior to transplanting.

The grafts remain in the deep pit storage house until the early part of June. At his time it is essential that the budding strip be completely removed. If the budding strip is not removed before planting, it will not deteriorate and girdling will result. Grafts are now planted in nursery beds 7 in. apart with approximately 8 to 10 in. between the rows. The grafts are planted with the top of the union approximately 1 in. below the soil surface in order to protect against breakage. After planting, a granular herbicide (Ronstar) is applied at the rate of 200 lb/acre. The beds are mulched, watered in, and covered with a 50% lath shade. The newly planted grafts remain in this location for one year and are then harvested for our lining-out stock trade. The remaining plants are transplanted into field rows or containers.

In conclusion, I would like to say that our summer grafting program has been very beneficial to our operation. While minimizing our heating requirements, we consistently achieve a high percentage (95%) of successful grafts. We are able to utilize our propagation facilities more efficiently as our winter grafting schedule is

very demanding. This method adapts to our total production cycle.

LITERATURE CITED

1. Hoogendoorn, C. 1971. *Viburnum dentatum* as an understock for *Viburnum carlesii* or *V. carlesii* 'Compactum'. Proc. Inter. Plant Prop. Soc. 21:384–385.

VOICE: Have you tried *Viburnum lantana*?

DIXON HOOGENDORN: We do not use it because it is susceptible to a leaf spot disease that weakens the plants in late summer.

ABNORMAL GROWTHS ON MICROPROPAGATED RHODODENDRON

R. WAYNE MEZITT

Weston Nurseries, Inc.
P. O. Box 186
Hopkinton, Massachusetts 01748

At last year's IPPS meeting in Chicago I participated in a panel discussion focusing on industry sensibilities from the perspective of a new plant introducer. We considered the values of new introductions along with potential problems, especially in relation to tissue culture propagation. My part of the presentation also outlined my views of the propagator's particular obligations relative to new plant introductions.

During the past year I find that my situation as an introducer of new rhododendron cultivars has become affected by an alarming development. Micropropagation of many of the cultivars my nursery has introduced is apparently producing significant numbers of plants that have characteristics different from those of the parent plants.

Let me first note that the vast majority of micropropagated plants now in the market appear to be normal. It is not my intent to discredit responsible use of the micropropagation technique. However, I am very concerned that the problem of abnormal plants produced during micropropagation, now very evident among some growers, be addressed immediately.[1]

[1] Knuttel Nurseries, East Windsor, CT grows over 90 rhododendron cultivars on 57 acres and produces 100,000 plants a year. In 1985 Anna Knuttel was forced to quickly rebuild her supply of plants after experiencing a problem with incorrectly manufactured fertilizer that destroyed much of her crop. She chose to rely upon micropropagated plants as a major source of stock because of the large numbers she needed on short notice. She estimates that she has lost to date over $59,000 in revenues on the plants that are abnormal and cannot be sold.

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The following abnormal growth conditions have been observed in micropropagated plants. Foliar variation in size, shape and color of leaves appear, as well as apparent increased susceptibility to disease and stress problems. Flowers are sometimes affected by added or subtracted parts, or refusal to flower normally. Plant growth itself is often altered. In some plants the root-stem connection is weak and the resulting plant is not properly supported. Dwarfing, "brooming", or contorted stems and branches occur in others. Susceptibility of the entire plant to disease has also been reported.

It is possible for variations to be induced by factors involved with growing the plants, such as herbicides, fertilizers, soil conditions, or other environmental variations. However, among the growers I know experiencing similar problems, the only consistently common factor seems to be that these plants were propagated by tissue culture.

One of my personal horticultural interests is searching for mutants and variants, such as witches brooms, that occur occasionally in natural populations. If variations such as I am describing occurred in nature I would be very excited and interested in propagating them to see how they perform as individual plants. Perhaps this is a possibility with these as well, and it is interesting that these abnormalities can apparently be tissue-culture-induced. But the fact that they are being improperly sold as a clone of the original creates a moral dilemma for every nurseryman who handles them. I also believe it poses a serious long term challenge for our entire industry.

Many of the cultivars now exhibiting abnormalities were developed by my father, Ed Mezitt, and introduced by our nursery. They are all the result of many years of breeding, selection, testing, and evaluation. One of the primary assets of any business is its reputation. If the cultivars we developed turn up in the market different from what the customer expects, there is a high potential for damaging the name and reputation of our nursery, thereby threatening our future business.

In addition, every unsuspecting grower is also a big loser when plants that are not true-to-type are grown. Both short term profit and long term reputation stand to be diminished. If the plants are not recognized as different from what they are supposed to be and sold as usual, a grower becomes an unsuspecting perpetrator of the problem. This can affect how customers perceive a grower's competence and expertise. If a grower does recognize a problem, a number of questions arise: is this really the right cultivar or not; did I do something wrong; how serious is the problem; will it correct itself naturally; and should I sell the plant anyhow?

These and many other perplexing questions soon compound and become entangled with economic considerations. The question

then becomes one of obligation and increases in complexity as long as it remains unresolved. Who is responsible for the problem? What should I do to correct it? Does the lab know there is a problem? What recourse do I have? What should I do with the abnormal plants if I can't sell them? Should I be buying tissue culture propagated plants at all?

Examples of the type of problems I have seen include the following.

1.) A white-flowering *Rhododendron* 'Sidestep' that we mistakenly micropropagated for what we thought was a pink-flowering cultivar. The explant tissue was taken from the wrong plant and the mistake went unrecognized for over three years. By then we had over a thousand plants growing in our fields. Examples of mistaken identity are relatively common in any type of propagation. They are also easy to correct providing communication is properly handled once the situation is recognized.

2.) *Rhododendron* 'Henry's Red' exhibits petaloid flowers on a micropropagated plant. The normal plant has single flowers.

3.) Tissue culture propagated *Rhododendron* 'Scintillation' is more compact than normal and exhibits cupped foliage. *Rhododendron catawbiense* 'Album' has shown variegations in the leaf and apparent susceptibility to disease. Even though neither of these two cultivars are our introductions, they are standards in the industry and commonly grown by many nurseries.

4.) *Rhododendron* 'Molly Fordham' at Knuttel's Nursery in Connecticut. This nursery bought 2,000 micropropagated plants from a tissue culture propagator in 1986; 929 of them are growing in an abnormal manner with leaf distortion and "brooming", and 477 have already died. Only 597 of them appear normal. Of 2,000 *Rhododendron* 'Algo' micropropagated plants purchased in 1987, only 430 appear normal. The remaining 1570 plants show varying degrees of congested branching and abnormal foliage.

5.) *Rhododendron* 'Milestone' has shown severe stem contortion and compression, and deformed foliage.

6.) *Rhododendron* 'P.J.M.' shows variations in growth, "brooming" of stems and branches, as well as apparent increased susceptibility to root disease problems.

Why does our industry face this situation now? It seems to me there are three major reasons. *First,* tissue culture, by its very nature presents new types of decisions that are probably foreign to us as propagators. The particular pressure of very large numbers of

plants being rapidly produced from tiny bits of plant tissue magnifies the problems exponentially. This is a tremendous acceleration in the rate of propagation over the traditional propagation techniques. It is extremely difficult for the propagator to effectively compensate for errors that might occur, especially if their nature is unknown. By the time a problem is recognized, thousands upon thousands of plants may already be "in the pipeline".

Secondly, is the newness of the tissue culture technology itself. Within less than 10 years we have created an entirely new industry for woody plant propagation. It has supplanted many times over what could have been produced by conventional means. It seems some propagators may be pushing the technology to its limit (and perhaps beyond). Many unknowns are involved and the methods are open to experimentation, conjecture, and improvement. Many questions must be answered, such as: what parts of the parent plant are still best to use, what chemicals are most effective, how many plantlets can be produced from a culture, what is the "life-span" of a culture, at what stage might alterations of characteristics appear, what characteristics might be unknowingly altered in the tissue-culture-propagated plant that appears "normal"?

A *third* consideration probably embodies the greatest threat. We are seeing new tissue culture labs being started by individuals unfamiliar with horticulture and often with little previous association with the industry. These people are lured by what appears to be a great untapped potential for success in a fledgling industry: seemingly insatiable demand from anxious buyers for new plants; easily replicable production methods; relatively small initial investment; and a relatively short payback period. New entrants to this industry operate with minimal resources and have not yet developed any major assets or reputation to maintain. Thus their customers have little recourse if an error occurs.

The number of units produced is so high that the value per unit (and thus the relative importance of each unit) seems to be negligible to them. The grower who is supplied by them thereby bears the brunt of the cost because any problems that develop often take several growing seasons to become evident.

Obviously, it will not take many years for the market itself to eliminate imprudent and dishonorable business people; but by then a lot of damage will have already been done to our industry.

I believe many of our problems have occurred because we are trying to accomplish too much too quickly. For us as propagators, especially those of us who are "old school", this unbridled enthusiasm that seems to dominate some aspects of micropropagation is quite out of character. The nursery industry and professional propagators are, by the nature of the business, quite conservative and committed to the long term. It seems that short term considerations of profit and productivity may be becoming overly dominant

here. Perhaps setbacks, as we are apparently seeing here, will cause us to approach new technologies, such as micropropagation, with a bit more caution.

Over the years the International Plant Propagators Society and other professional groups have excelled in their efforts to educate their members. I believe this same approach must now be applied to the problems that are developing as a result of micropropagation. We must focus upon the positive benefits of this technology and also learn how to deal with the negatives to create a solution that benefits us all.

It seems to me the real issue comes down to one of ethics. In our haste to keep pace with what is happening around us we have not taken the time to effectively define why we do what we do, and what we believe in. The developments I have just outlined deliver a clear message: the time has come to write down the goals, values, and ethics of our industry. Perhaps this exercise will only restate what most of us already know and believe and practice. But for those of us who are new to the industry or perhaps unaware of its underlying precepts, it will form a clearer guide for acceptable practices. Failure to effectively self-regulate our industry will most certainly initiate enforcement of standards from outside our industry.

ANNA KNUTTEL: I used to deal with six tissue culture propagators, now I only deal with two. I use those that grow their product so if I have a problem I can go back and talk to them and they understand what the problem is. It is also important to know a plant *before you grow it so you can tell if it is growing properly.*

HARRY SCHWARZ: Some of the changes you see in tissue-cultured plants can be related to genetic changes, some to growth phase changes, and others to susceptibility to agricultural chemicals used in the nursery business. Tissue-cultured plants appear to be more susceptible to agricultural chemicals, such as herbicides, and some of the changes you mentioned could be induced by such chemicals. We just don't have enough information on such possible interactions.

WAYNE MEZITT: You are saying that some of the changes we see could be for reasons that we do not understand and not genetic in origin.

HARRY SCHWARZ: The point is that we need to watch the agricultural chemicals we are applying because micropropagated plants are more sensitive. With strawberries, when we see offtypes we find that if we use them as parents in breeding, they tend to throw the same offtypes in their seedlings. Such changes may indicate a genetic weakness in that type/cultivar and it should not be propagated by tissue culture.

EASTERN REGION QUESTION BOX

The Question Box Session was convened at 4:20 p.m. with Ralph Shugert and Bruce Briggs serving as moderators.

MODERATOR SHUGERT: The first question is: does the Society have copies of the early publication, *Propagator*, prior to the bound Proceedings?

RALPH SHUGERT: I have a copy of the meeting held in Louisville, Kentucky in 1929. There are three other Proceedings that are in the Library of Congress. I will be glad to photocopy the copy that I have for the individual who asked the question.

MODERATOR SHUGERT: What cover crops, etc. are used to restore the soil after a B&B or in a field-potted crop? Please outline the steps.

RAY HESER: In the fall we plant winter rye, plow it in, then millet, buckwheat, or a similar crop for the summer, and then back to the winter rye. We use ammonium nitrate to help break down the organic matter.

RALPH SHUGERT: We have a 2 year program with sudan, rye, sudan and rye, for our low organic soils. We try to use an application of animal manure (turkey manure that is available to us) with every cover crop planting.

CLAYTON FULLER: The first step is a soil test to measure the pH, and then lime to adjust the pH if necessary. We also like to use animal manure if we can get it. We start with winter rye, plow it under, and then in the summer plant sudan. The sudan is mowed four times during the growing season with a bush hog when it gets to about 2 ft. We lime again if needed, check the nutrient level, usually add 15:15:15, or 19:19:19 fertilizer. We use Roundup to remove perennial weeds, plow down in the fall, and then we are ready for the spring planting.

FRANK GUOIN: We have lots of composted sludge for improving soils and some of our growers are using it. Apply composted sludge at 100 tons per acre. We recommend tall fescue, not sudan grass, because it contains Johnson grass seed as a contaminant.

MODERATOR SHUGERT: Please have someone explain C.O.P.F.

JOERG LEISS: It is a voluntary contribution fund that promotes plants. Contributions go to support the promotion of plants with some also going to the plant originator.

MODERATOR BRIGGS: How do you deal with moss growing on seed trays—especially those containing seeds that have double dormancy and must be kept in the same flats for 2 years?

KATHY JALKANEN: AgroBrome works, but use it before you get the problem.

JIM CROSS: Maneb just after putting the cuttings in the flat will stop algae and moss buildup in winter.

MARK RICHEY: We had the problem with *Taxus cuspidata* 'Capitata' seedlings in flats. Once established it had to be removed by hand. This past year I increased the pH of the medium to about 7 and have not had any moss.

MODERATOR BRIGGS: How do you prevent damage to bud wood when using Surflan?

TOM SIMPSON: We use the liquid form in September with no problem on crabapples, hawthorns, or pears. It may be the September application is late enough not to cause the problem.

MODERATOR BRIGGS: Question for Ken Roe. Was the herbicide used on boxwood 'Green Velvet' Surflan?

KEN ROE: At planting time we use Treflan at the recommended rate, 6 to 8 weeks later Surflan or Surflan XL, and in the winter use Casoron. We have not seen any herbicide damage with that schedule. However, soil type and herbicide rate must be watched closely to prevent injury. I should also note that boxwood does not do well when cultivated around its roots.

In containers we use OH-2 but only in summer when our polyhouses are not covered. Goal-containing products should not be used when polyhouses are covered. Devrinol is applied for winter weed control and then Surflan XL in February/March.

MODERATOR SHUGERT: If you are growing *Taxus cuspidata* 'Capitata' from seed, do you germinate the seeds and/or grow seedlings on with bottom heat?

MARK RICHEY: Bottom heat is not necessary but we grow them in a polyhouse. The seeds are given 12 months outdoor stratification before spring planting. When germination starts cover the seedlings with saran. The seedlings are allowed to grow in the polyhouse for 3 years.

RALPH SHUGERT: You must stratify taxus seed for more than 7 to 8 months; 12 months is minimum with 13 to 14 better.

MODERATOR SHUGERT: What procedures are used to germinate *Ilex verticillata* seed?

JOERG LEISS: Two years stratification is necessary.

MODERATOR SHUGERT: Question for Richard Munson. If a plant was first registered outside the U.S. under a different name, in the long run does the original name take precedence in the horticultural literature?

RICHARD MUNSON: If registered with an international authority, regardless of country, that name should take precedence.

MODERATOR BRIGGS: Please elaborate on the possibility of IBA being withdrawn from the market.

ED WOOD: Last week, (December, 1988) the largest producer of IBA in Mexico decided to go ahead and work on the registration.

MODERATOR BRIGGS: I'm getting cutting burn from Wood's Rooting Compound at almost every dilution, especially on softer cuttings. Any suggestions?

BRUCE BRIGGS: All I can suggest is that there is a difference between a liquid and powder with regard to active hormone availability, and you need to remember that point. Liquids are much stronger than powders.

ED WOOD: I agree with that point, Bruce. In addition, toxicity problems can result because liquids give better penetration, and at high concentrations the alcohols will cause toxicity problems. The strongest we recommend is 1:5 dilution for hardwoods, while with softwoods a 1:15 or 1:20 dilution is recommended.

BILL BARNES: With any plant it is important to run a concentration gradient to determine how that plant will respond to a hormone. Higher may not always be better.

MODERATOR SHUGERT: What is the shelf life of powdered forms of IBA?

DICK BURR: I believe Mike Dirr published that information in Vol. 36 of the IPPS Proceedings, or at the Southern Nurserymens Association meeting.

BILL BARNES: Two to four years with no problems.

MODERATOR SHUGERT: What is the procedure for the cutting propagation of *Ilex decidua* and *I. verticillata*.

BILL BARNES: I would use the following: June cuttings, wound, IBA 1000 ppm, mist, and peat:perlite medium. Cuttings will be rooted in 4 to 6 weeks. [Editor's note: *Ilex decidua* is more difficult to root. The following has been reported: early July cuttings (Indiana), 5 to 6 in. long, 7,500 ppm IBA, peat:polystyrene medium, and mist. Cuttings will be rooted in 4 to 6 weeks.]

MODERATOR BRIGGS: Please advise on getting started in tissue culture propagation.

DICK ZIMMERMAN: The first step is to know what you want to propagate, and where you will sell it. Some of the biggest tissue culture labs failed to address those questions to their sorrow. They tried to produce the same crops which resulted in a lot of plants being dumped in Florida. It is not difficult to set up a lab. However, it doesn't do any good to propagate plants if you don't know how they will perform afterwards. We emphasize subsequent performance in our program. Micropropagated plants have to be field evaluated and that takes time. I feel that tissue culture propagation has a lot to offer, and there is a lot being done around the world. There have been problems, but these when investigated are often the result of short cuts.

There are several technical papers in the IPPS Proceedings for those interested in what it takes to set up a lab.

MODERATOR BRIGGS: Is anyone using the polybag in tissue culture propagation?

DICK ZIMMERMAN: Someone in Texas is using it, but I am not sure how wide spread its use it. Available from Carolina Biological Supply, Curtin Matheson, and, I think, AgriStar in Texas. The bags are gas permeable.

MODERATOR SHUGERT: How do you prevent black stem from occurring overwinter on *Vinca minor*?

TOM KIMMEL: Banrot after sticking.

MODERATOR SHUGERT: Does anybody use Zyban on *Euonymus fortunei* 'Emerald and Gold' and 'Emerald Gaiety' for anthracnose and what are the results?

KATHY JALKANEN: Zyban 45 is satisfactory for us.

VOICE: This has also worked well for us when used weekly in the spring.

MODERATOR SHUGERT: Question for Ken Roe. At what time after your boxwood cuttings are stuck do you apply Subdue and at what rate?

KEN ROE: As soon after sticking as possible; mix 2 oz/100 gal water and apply 1 pt/sq ft every 6 to 8 weeks during winter.

MODERATOR BRIGGS: Who has or is now conducting specific research on the effects of herbicide(s) on plant propagation?

DICK BURR: Walt Straud at North Carolina State University has some long term studies. His address in Box 7609, Raleigh, NC.

MODERATOR BRIGGS: What is the relationship between top and root pruning to encourage the most and quickest growth?

CHARLIE PARKERSON: I am very interested in this. We have observed that plants go through growth cycles. Research is beginning to show that if you make a pruning cut and then plant a rooted cutting, the root/top relationship can be upset with a liner. The recommendation is to allow the roots to initiate a growth cycle, then prune the top, and the growth then will come dramatically. I recently fall-planted some juniper liners that were a little leggy. At planting time I pruned the liner tops. The potted liners just flat shut down.

BRUCE BRIGGS: With tissue culture plantlets we have found that you don't cut them back when they are moved. If cut back, allow them 2 to 3 weeks to break bud and grow before transplanting or you will set them back.

TOM McCLOUD: I have observed the same thing with azaleas. Cut them back and let them break bud before transplanting.

CHARLIE PARKERSON: With dormant transplants we have the recommendation to bring the top back into balance with the roots. Is that recommendation true for dormant plants? I'll bet Bill Flemer can answer that.

BILL FLEMER: For us, and we have transplanted millions of trees and tried all methods, a balance between top and root gives the

best results.

MODERATOR BRIGGS: Is it possible to chip bud on root pieces?

JOHN BAKKER: We have done it with roses.

Thursday Evening, December 8, 1988

The Thirty-Eighth Annual Banquet was held in the Shadford/York Rooms of the Omni International Hotel, Norfolk, Virginia.

On behalf of the Society—Eastern Region, a research grant of $1500 was presented to Professor M. A. L. Smith and M. T. McClellan, University of Illinois. Their proposal was titled "Response of Woody Plant Microcuttings to In Vitro and Ex Vitro Rooting Methods."

John McGuire made the following presentation:

AWARD OF MERIT

Our recipient has a varied and productive history. He was one of 12 children, so if he is somewhat rotund today perhaps he can attribute it in part to his need to get to the table fast and to appreciate food. He was a talented athlete as a boy and he played semipro baseball against the likes of Clem Labine. He was also a pool shark. I understand he earned his spending money at this craft while attending Providence College.

His parents hoped he would be a priest, but instead he chose to join his brothers in the nursery business in 1946. Once he chose this path he focused entirely on making his company successful. His accomplishments were many. He joined the International Plant Propagators' Society in 1954 and since that time he has served continuously on Society committees. Today he serves on the Nominating Committee. Our recipient was president of our Region; he has been president of his State Association and the New England Nurserymens' Association, and he represented his state as governor in the American Association of Nurserymen.

Our recipient epitomizes the philosophy of the Society, "to seek and to share." I have seen members seek him out during our annual bus tours so they may sit with him to learn from him. He always takes the time to share his knowledge with members, particularly the younger ones.

He has presented numerous talks at our meetings and he has hosted you when you came to Rhode Island. Perhaps you remember him as one of the stars of our video film on grafting. Our recipient was the one with only one thumb.

Seriously though, we have few members who deserve this award more than our recipient for 1988. He has proven himself on every arena of life. He is and has been an active member of his com-

best results.

MODERATOR BRIGGS: Is it possible to chip bud on root pieces?

JOHN BAKKER: We have done it with roses.

Thursday Evening, December 8, 1988

The Thirty-Eighth Annual Banquet was held in the Shadford/York Rooms of the Omni International Hotel, Norfolk, Virginia.

On behalf of the Society—Eastern Region, a research grant of $1500 was presented to Professor M. A. L. Smith and M. T. McClellan, University of Illinois. Their proposal was titled "Response of Woody Plant Microcuttings to In Vitro and Ex Vitro Rooting Methods."

John McGuire made the following presentation:

AWARD OF MERIT

Our recipient has a varied and productive history. He was one of 12 children, so if he is somewhat rotund today perhaps he can attribute it in part to his need to get to the table fast and to appreciate food. He was a talented athlete as a boy and he played semipro baseball against the likes of Clem Labine. He was also a pool shark. I understand he earned his spending money at this craft while attending Providence College.

His parents hoped he would be a priest, but instead he chose to join his brothers in the nursery business in 1946. Once he chose this path he focused entirely on making his company successful. His accomplishments were many. He joined the International Plant Propagators' Society in 1954 and since that time he has served continuously on Society committees. Today he serves on the Nominating Committee. Our recipient was president of our Region; he has been president of his State Association and the New England Nurserymens' Association, and he represented his state as governor in the American Association of Nurserymen.

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Seriously though, we have few members who deserve this award more than our recipient for 1988. He has proven himself on every arena of life. He is and has been an active member of his com-

munity and church. He is a very wealthy man as a result of his endeavors. However, I know he considers his greatest wealth to be his many friends, and they are legions because he has done much for so many.

Ladies and gentlemen, our Award of Merit recipient for 1988 is Leonard Savella.

Friday Morning, December 9, 1988

The Friday morning session convened at 8:00 a.m. with David Schmidt serving as moderator.

VENTILATED HIGH HUMIDITY PROPAGATION

DANIEL C. MILBOCKER

Hampton Roads Agricultural Experiment Station
1444 Diamond Springs Road
Virginia Beach, Virginia 23455

Ventilated high humidity propagation research began in 1974 as an effort to improve nursery propagation. Intermittent mist was the method of propagation commonly found in nurseries at that time and still remains in common usage. Losses of cuttings from poor management were common and indicated that improvement was needed. Excessive drenching of the cuttings and the resultant evaporative cooling were contributory, if not the cause of propagation failures. Vigilant care minimized these problems, but in practice, too many nurserymen were not that vigilant. They needed a method of propagation that would reliably produce better results with less care.

The concept of ventilated high humidity propagation was developed by 1978 and the Agritech humidifier was introduced to make it into a workable propagation system. Several other types of humidifying equipment were also introduced but none were based upon the ventilated high humidity concept. The poor performance of some of these installations dampened the enthusiasm for propagation with high humidity. Better humidifiers and closer adherence to the original concept of ventilated high humidity propagation was needed before the full value of this system of propagation would be known.

A humidifier was designed and built for ventilated high humidity propagation by 1983. It was designed to be reliable and efficient at producing large quantities of fog and delivering it in a 30 mph air current. After four years of testing, this humidifier was

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introduced as the "Humidifan." It is portable, easy to set up and satisfies the requirements for ventilated high humidity propagation. It is easily operated and requires relatively small amounts of attention.

Ventilated high humidity propagation solves many of the problems associated with intermittent mist. Saturation of the propagation medium is not a problem because most of the water remains suspended in the air as fog. Any excess is eliminated through the exhaust fan. Evaporative cooling at the location of the cutting is eliminated by transferring evaporation to the area of the humidifier. In the absence of evaporative cooling in the propagation bed, cuttings are warmed by solar heating. The temperature of the cuttings is controlled by directing the high velocity humid air from the humidifier over them. This warming of the propagation bed is found to be beneficial for promoting rooting to such an extent that rooting hormones are no longer beneficial for rooting cuttings of relatively easy-to-root species.

Several practices commonly used for nursery propagation are no longer necessary. Propagation facilities are no longer considered to be permanent since humidifiers are portable. Cuttings can be propagated without transplanting or moving the plants. The humidifier is moved instead. Cuttings can be prepared without leaf area reduction because wilting during the initial days of propagation is eliminated. Changing of intermittent mist intervals with weather changes is also eliminated since the humidifiers run constantly throughout the day and require less adjustment for weather conditions. Ventilated high humidity propagation simplifies propagation when used properly.

In addition to simplifying propagation, ventilated high humidity propagation improves rooting and produces better plants. In order to understand how it produces better plants, a well entrenched concept of intermittent mist must be examined. The concept is well established that cooling of the top and warming of the bottom of the cutting produces favorable conditions for root initiation. Cool tops are thought to suppress shoot growth which occurs at the expense of rooting and weakens the cutting. When using intermittent mist, evaporative cooling conveniently lowers top temperatures. Installing bed warmers raises bottom temperatures. While this practice may be beneficial for intermittent mist, the same type of practice has not been useful for ventilated high humidity propagation.

Bed warming is beneficial and occurs as a characteristic of ventilated high humidity propagation (2) but cooling of the top to the extent found in intermittent mist propagation does not occur. With warm bed and air temperatures, cuttings tend to grow shoots as well as roots. Instead of weakening the cutting, actively growing buds and leaves promote root initiation (1) and recovery of the cutting to

become a larger and healthier plant than is ordinarily propagated under mist (Fig. 1).

Figure 1. Comparison of *Photinia serrulata* cuttings propagated under ventilated high humidity (left) and intermittent mist (right).

Leafy cuttings that root quickly and easily, root before shoots can grow regardless of which method of propagation is used. Most of the cuttings that root more slowly begin or continue new shoot growth under ventilated high humidity propagation and root as newly grown leaves mature to full size. Dormant deciduous cuttings prepared during the winter and propagated during the spring similarly grow new shoots with roots initiating at leaf maturity. Cuttings of some species root with difficulty under either mist or ventilated high humidity. Even though some of these cuttings grow shoots without rooting, they persist in remaining alive much longer under ventilated high humidity than under intermittent mist.

The idea that cuttings are weakened by shoot growth does not appear to be valid under ventilated high humidity propagation. If cuttings were weakened by regrowth, rooted cuttings with regrowth would make weak plants. Instead, plants with regrowth make strong plants capable of rapid recovery after transplanting. Stronger plants from rooted cuttings with regrowth are common from ventilated high humidity propagation and are typified by crapemyrtle, *Lagerstroemia indica*, grown in a nutrient experiment. Five hundred dormant 5 in. cuttings were propagated during April and 432 of them were transplanted during May to one gallon containers. They grew rapidly, flowered profusely, and became top

heavy because of their large size by the end of the season. October fresh top weights averaged 0.5±0.1 lb, a large amount of growth for one gallon containers. Performance of this type is expected of liners propagated the previous year and is exceptional for rooted dormant cuttings. It is not the performance of weak plants.

Cuttings that remain unrooted would also be expected to be short lived if regrowth weakened them. Instead 100 unrooted cuttings from a hard-to-root mature tree of *Cryptomeria japonica* remained alive for a year. Fifteen percent rooted within 60 days, but the remainder rooted sporadically until approximately 85% eventually rooted. For comparison 50 cuttings of an easy-to-root cultivar, *Cryptomeria japonica* 'Elegans' rooted 98% within 60 days. The persistent viability of cuttings shown to be difficult-to-root because of factors other than the method of propagation indicates that regrowth during propagation is not always a weakening influence on cuttings even though they are unrooted.

The objective of propagation is to propagate healthy plants from cuttings. Research to develop the concept of ventilated high humidity propagation has succeeded in producing an easy and reliable method of producing quality plants.

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DORMANCY REQUIREMENT AND GREENHOUSE FORCING OF THREE EUONYMUS CULTIVARS

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Abstract. Summer-rooted cuttings of *Euonymus fortunei* 'Sarcoxie', 'Emerald Gaiety', and 'Gold Tip' transferred from outdoors to a greenhouse between Dec. 15, 1987 and Feb. 15, 1988, grew vigorously under greenhouse conditions (23°/14°C day/night) indicating that 1128 chilling hours below 7.2°C was adequate. In contrast, rooted cuttings brought in between Sept. 15 and Nov. 15 remained dormant. There was no visible growth except for the occasional basal shoot sprouting intermittently throughout the forcing period, and uneven or suppressed bud burst and shoot growth towards spring. Vigorous growth was restored when these plants were later chilled at 4°C for 3 weeks (500 chilling hours) in a cooler.

INTRODUCTION

Winter forcing of *E. fortunei* in a heated greenhouse can significantly shorten the production cycle. However, some nurseries in Ontario have experienced uneven or poor growth and significant plant losses during the winter. These problems appear to be related to improper scheduling and (or) cultural practices during fall and winter.

When seasonal growth ceases in the fall due largely to short days and low temperatures, buds of woody temperate species first enter predormancy, a reversible transitional phase (4). Plants in predormancy still have the capacity for growth but conditions under which growth occurs become narrower until plants are truly dormant. During dormancy or "rest", no growth occurs even under the most favorable conditions (4). After the chilling requirement has been satisfied, a transition to postdormancy occurs, and buds resume growth, at first under narrow but later under widening environmental limits (3, 4, 5).

The present study was undertaken to determine the chilling requirements of three *E. fortunei* cultivars and to elucidate their cycle of dormancy and growth to facilitate better scheduling for winter forcing.

MATERIALS AND METHODS

In early Sept. of 1987, 8 to 12 cm long summer-rooted cuttings of *E. fortunei* 'Sarcoxie', 'Emerald Gaiety', and 'Gold Tip' were potted in 10-cm square pots and placed outside under lath.

A total of 240 rooted cuttings of each cultivar were divided into 6 groups of 40 cuttings. Each group was subdivided into 4 replications, each with 10 cuttings. The first group was placed in a greenhouse with 23°/14°C day/night temperature regime on Sept. 15,

1987. The others were kept outdoors and transferred by group to the greenhouse on Oct. 15, Nov. 15, Dec. 15, Jan. 15, and Feb. 15, respectively. On each date, the number of hours of temperature exposure below the base temperature of 7.2°C was calculated (2, 5). The experimental design was a split plot with the 6 dates as the main plot and the 3 cultivars as subplot treatments.

In the greenhouse, rooted cuttings were watered and fertilized weekly with 20-20-20 only after shoots showed signs of new growth activity. Once per month, the following observations were recorded: number of shoots; length of new shoots; and position of new shoots (terminal, lateral, basal). Final observations were recorded on Apr. 28, 1988.

RESULTS AND DISCUSSION

Rooted cuttings, transferred to the greenhouse on Dec. 15 or later, initiated rapid bud break and grew vigorously throughout the forcing period (Table 1), indicating that adequate chilling (1128 hours) was received outdoors (2, 4, 6). In comparison to the Jan. and Feb. groups, the Dec. group produced the greatest shoot extension, probably due to the extra time in the greenhouse (Table 1). All cultivars reacted similarly when transferred to the greenhouse, but 'Emerald Gaiety' and 'Gold Tip' produced significantly more and longer shoots than 'Sarcoxie' (Table 2).

Table 1. Chilling hours and total winter growth of *E. fortunei* rooted cuttings brought in from outdoors to greenhouse at monthly intervals between Sept. 15, 1987 and Feb. 15, 1988.

	Date of transfer to greenhouse						
	Sept.15	Oct.15	Nov.15	Dec.15	Jan.15	Feb.15	LSD 5%
Accumulated chillings hours[z]	0	104	480	1128	1816	2544	
Total no. of new shoots per plant[y]	0.9	1.0	1.1	5.0	5.5	4.7	1.0
Total shoot extension (cm) per plant[y]	4.3	4.3	4.3	19.7	10.5	5.9	3.5

[z]Number of hours that the mean air temperature was below 7.2°C

[y]Mean over 3 cultivars measured in April 1988. Data between Sept. 15 and Nov. 15 are for basal shoots mainly. Data between Dec. 15 and Feb. 15 include terminal, lateral and basal shoots.

Rooted cuttings brought in between Sept. 15 and Nov. 15 were dormant (Table 1) due to lack of or to incomplete chilling (4, 6, 7). There was no visible top growth except for the occasional basal shoot sprouting intermittently throughout the forcing period (Fig. 1). Towards spring, terminal buds began to swell but bud burst and

shoot growth were sporadic and(or) suppressed. When these plants were chilled at 4°C for 3 weeks (500 chilling hours) in cold storage during May, then returned to the greenhouse, all plants showed active growth. In relation to the amounts of chilling received, the Oct. and Nov. groups, receiving accumulated outdoor and cold room chilling hours of 604 and 980, respectively, exhibited more rapid and prolific growth activity than their Sept. counterparts receiving 500 cold room chilling hours only.

Table 2. Total winter growth of three *E. fortunei* cultivars.

	Sarcoxie	Emerald Gaiety	Gold Tip	LSD 5%
Total no. of new shoots per plant[z]	2.2	3.6	3.4	0.7
Total shoot extension (cm) per plant[z]	3.4	9.8	10.0	2.5

[z]Mean over 6 dates measured in April 1988.

Kramer and Kozlowski (4) indicated that metabolic activity continues throughout dormancy but dormant buds do not elongate. However, as in the present study, Crabbe (1) observed spontaneous outgrowth of basal buds in certain shrubs in late summer and into autumn when dormancy peaked. This phenomenon, which he referred to as "autumnal basitonic dormancy gradient", is related to the shrubby habit of these species. In the present study, each new sucker grew for 6 to 8 weeks, sometimes becoming taller than the parent shoot, and then remained inactive for the rest of the forcing period. 'Emerald Gaiety' and 'Gold Tip' produced more basal shoots than 'Sarcoxie'. The proximity of roots or even the potential for rooting of these basal shoots seem to play a significant role in morphological development (1).

Figure 1. Basal shoot sprouting from dormant rooted cutting.

At nurseries where problems occurred, rooted cuttings were placed in heated environments after receiving little or no chilling. The presence of basal shoots suggested to growers that these plants were in the active phase. Continued application of fertilizer and water probably induced excessive salts build-up and/or water-logging in the medium, resulting in plant loss. Sluggish growth that persisted after rooted cuttings were planted in container or field nurseries might possible be attributed to incomplete chilling of these plants (4, 5, 7).

Dormancy can be induced in most plants by altering temperatures, day length, light quality, mineral availability or water supply (4,6). In view of the key role of short days and low temperatures in triggering dormancy (8), a study of the interaction of these two factors should yield useful information on the winter forcing of this species.

CONCLUSIONS

This study demonstrated that summer-rooted cuttings of *E. fortunei,* receiving less than 480 hours of chilling below 7.2°C outdoors between Sept. 15 and Nov. 15, remained dormant throughout the winter in a heated greenhouse. Subsequent chilling in a cold room at 4°C for 500 hours allowed normal growth resumption. Chilling of 1128 hours received by Dec. 15 broke dormancy. Between this time and spring a significant amount of winter growth, equivalent to about one year's growth in a field or container nursery, was achieved in the greenhouse.

Acknowledgements. Plant material for this research was generously supplied by Niagara-Holland Nurseries, Niagara-on-the-Lake, Ontario. The technical assistance of Bob Hamersma is appreciated.

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HERBICIDE UPDATE FOR CONTAINER WEED CONTROL

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Weeds are a persistent problem in container nursery production. Hand-weeding is time-consuming and expensive. Herbicides offer an alternative to hand-weeding.

HERBICIDES FOR USE IN ENCLOSED STRUCTURES

There are few herbicides that can be used in greenhouses. Temperatures in greenhouses can increase to high levels on sunny days, often causing volatilization of herbicides. Since greenhouses are enclosed structures, herbicide vapors can be trapped around plant foliage and cause damage. For this reason, there are no herbicides registered for use in containers for plants propagated in enclosed structures. There are three herbicides that can be applied under greenhouses benches for weed control. They are: diquat (Ortho Diquat), oryzalin (Surflan) and glyphosate (Roundup). There are special restrictions that apply to use of these chemicals in greenhouses.

HERBICIDES FOR USE IN OUTDOOR CONTAINERS

There are a number of herbicides available for use in containers maintained outdoors. Weed control relies on repeated application of preemergence herbicides since there are few selective postemergence herbicides available for nursery production. Most preemergence herbicides can only be applied to well-rooted cuttings or seedlings, thus limiting use primarily to production rather than propagation. Most preemergence herbicides should not be applied to unrooted cuttings or to seeded pots until the plants develop a root system. Certain preemergence herbicides, such as the dinitroaniline class [ex. oryzalin (Surflan)], inhibit new root development and thus could injure germinating seed or unrooted cuttings. These chemicals are safe once a plant has an established root system. Certain other herbicides, however, can be used during propagation. Oxyfluorfen (Goal), for example, can be applied at planting of conifer seed. The preemergence herbicides available to nurserymen can be divided into granular and sprayable formulations.

Granular Herbicides. For certain herbicides, granular formulations provide greater crop safety than sprayable formulations. Compounds in this group include oxadiazon (Ronstar) and the granular combination products that contain oxyfluorfen (Ornamental Herbicide 2, Rout). If the wettable powder formulation of

oxadiazon or the sprayable formulation of oxyfluorfen (Goal) is applied to sensitive species such as azalea, foliar injury could result. Formulating these compounds as granules reduces the potential for foliar injury. For other preemergence herbicides, such as metolachlor (Pennant) and napropamide (Devrinol), granular and sprayable formulations are equally safe to many nursery crops.

The granular products, Rout (oxyfluorfen plus oryzalin) and Ornamental Herbicide 2 (oxyfluorfen plus pendimethalin), provide broad spectrum annual weed control. These two products provide good to excellent control of the predominant container weed problems in Virginia: large crabgrass, *Oxalis*, common chickweed, prostrate spurge, and common groundsel. Oxadiazon (Ronstar) provides good control of many annual weeds but does not control common chickweed. The granular formulations of these herbicides are safe on a wide range of nursery stock. None of these three products will control perennial weeds such as yellow nutsedge, which occasionally is a problem in container production due to contamination of the pine bark commonly used as a media component.

Members of the dinitroaniline class of herbicides, which include trifluralin (Treflan), pendimethalin (Southern Weedgrass Control), and a combination of oryzalin plus benefin (XL), control annual grasses very effectively, but generally provide lower control of certain annual broadleaf weeds than oxadiazon or oxyfluorfen. For example, members of the dinitroaniline group control prostrate spurge but provide poor control of common groundsel. The dinitroaniline herbicides will not control perennial weeds.

Napropamide (Devrinol) is sold in both granular and sprayable formulations. Napropamide provides excellent annual grass control but lower control of prostrate spurge and common groundsel. It will suppress but not control yellow nutsedge. Metolachlor (Pennant), also available in granular and sprayable formulations, controls annual grasses but is ineffective on most annual broadleaf weeds. A major advantage of metolachlor is control of yellow nutsedge, a weed that is not controlled by most other preemergence compounds.

Sprayable Formulations. Oxyfluorfen (Goal) can only be applied to conifers due to the risk of foliar damage to other nursery species. Oxyfluorfen provides preemergence and early postemergence control of most annual broadleaf weeds found in container production. Oryzalin (Surflan) is very similar structurally to trifluralin and pendimethalin, and thus provides a similar spectrum of weed control. Oryzalin, like metolachlor and napropamide, are safe on a wide range of nursery stock.

Experimental Preemergence Herbicides. There are several experimental herbicides that could shortly receive registration for nursery use. Prodiamine is similar in weed control and crop safety

to oryzalin and trifluralin, although it may provide longer soil residual control. Isoxaben (Gallery) is a preemergence herbicide for annual broadleaf weed control. Combinations of isoxaben with trifluralin (Snapshot 2.5G) or oryzalin (Snapshot 80DF) has provided good control of annual grasses and broadleaf weeds. Prodiamine and isoxaben appear to be safe on a wide range of nursery stock, but will probably not be registered for use in enclosed structures or during propagation.

Postemergence Herbicides. There are few postemergence herbicides registered for nursery use. The nonselective herbicides paraquat (Gramoxone Super) and glyphosate (Roundup) could be used to control weeds growing in land near container-production areas, but will cause damage if ornamental foliage is contacted. Paraquat, a contact herbicide, controls annual weeds but only temporarily suppresses perennial weeds. Glyphosate, a systemic compound in plants, controls both annuals and perennials.

Sethoxydim (Poast) and fluazifop (Fusilade) are selective herbicides for the control of grasses in many nursery crops. These two chemicals only affect members of the grass family and will not control yellow nutsedge, wild onion, or any broadleaf weeds. Presently there are no selective herbicides for controlling emerged broadleaf weeds in nursery production.

Table 1. Effectiveness of preemergence herbicides for controlling the major weeds found in container production in Virginia.

Herbicide	Yellow nutsedge	Large crabgrass	Common groundsel	Prostrate spurge	Common chickweed
Ornamental Herbicide 2	N[1]	G	E	G	E
Rout	N	G	E	G	E
Ronstar	N	G	G	F	N
Surflan	N	E	P	G	E
Pennant	G	G	P	P	P
Devrinol	P	E	P	P	G
Southern Weedgrass Control	N	E	P	G	E

[1]E = excellent ((90–100%) weed control, G = good (80–90%) weed control, F = fair (70–80%) weed control, P = poor (40–70%) weed control, and N = no control.

MONITORING MEDIUM NUTRIENT LEVELS DURING PROPAGATION

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The use of controlled release fertilizers, water soluble and dry fertilizers, and fertilizers applied through the mist during propagation have been shown to promote root and shoot growth in various woody plant species (2,3,4,5,6,7). Booze-Daniels *et al.* (1) have also demonstrated that fertilization during propagation of *Ilex crenata* 'Helleri', before the appearance of roots is of little practical value. However, the longer after roots appear that fertilization is delayed the smaller the plants will be at a particular date in the future.

Nutrient absorption and subsequent plant growth are related to an adequate supply of nutrients in the medium solution (Figure 1). As the nutrient levels around the root increases up to a certain point, there will be a proportional increase in nutrient uptake and growth. The level of nutrients required for optimal growth is different for different species. However, it has been shown that the level of nutrients required for optimal growth of young seedling or rooted cuttings is basically the same as for much older plants. The

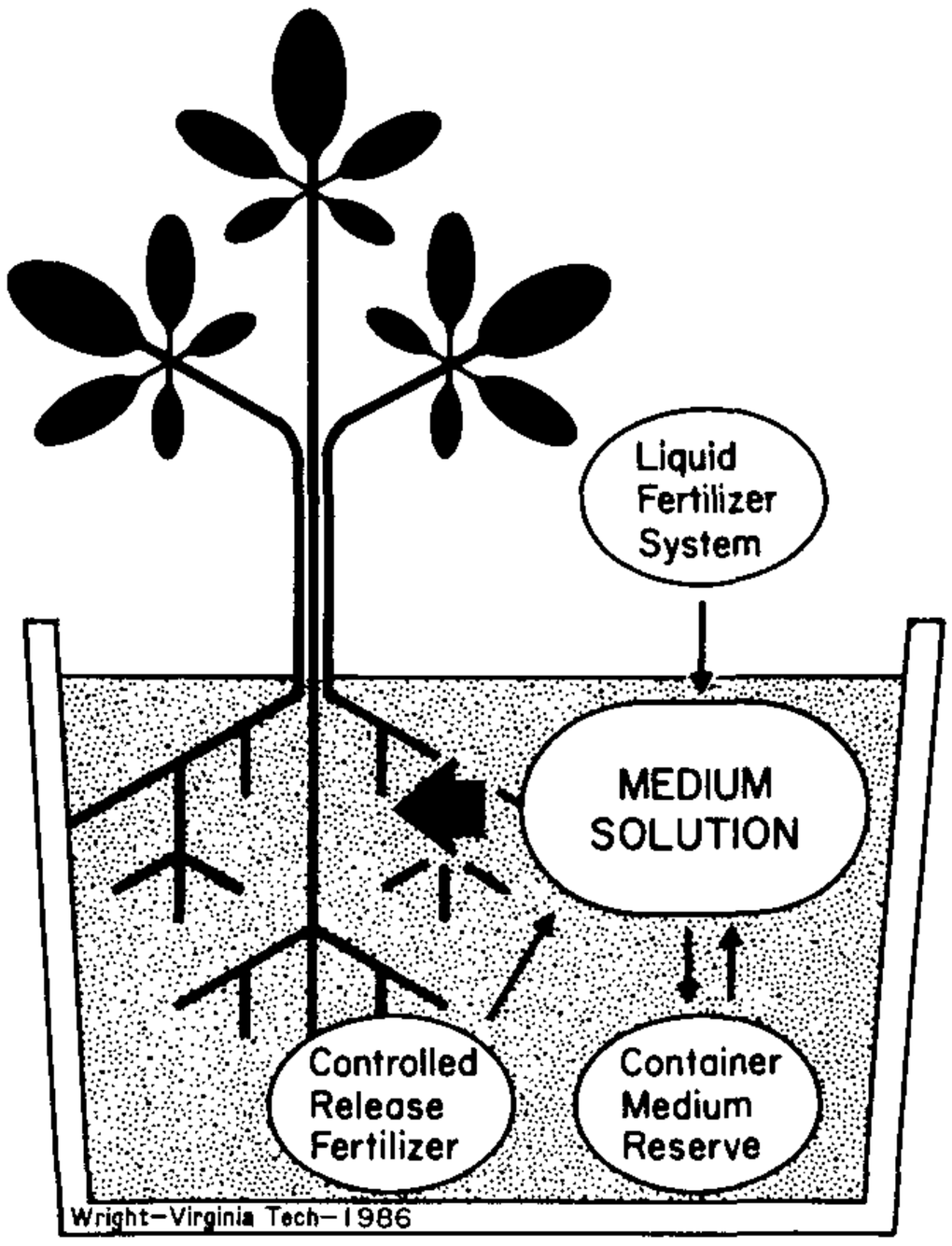

Figure 1. Illustration of the interrelationship between the plant, medium solution, container medium, and nutrient supply.

increased nutrient demands of larger plants are satisfied by an expanding root system which can absorb more nutrients. Thus the application of fertilizers to newly rooted cutting and to seedlings at the proper rates becomes an important management decision if optimal plant growth is to be expected.

The best way to determine the amount of nutrients available for plant uptake from the container medium is to analyze the medium solution for individual nutrients or soluble salts. The level of soluble salts is related to the total amount of dissolved nutrients in the medium solution but tells nothing about the level of individual nutrients available. Excess nutrients can adversely affect plant growth, both directly and indirectly, through a variety of mechanisms. Low soluble salts levels indicate insufficient levels of nutrients for optimum growth.

Soluble salts levels can be measured with a conductivity meter that costs under $300. By testing for soluble salts on a regular basis one has an idea of the relative level of fertility under which the plants are growing. Adequate nutrient levels depend upon species and the time of year, but soluble salts readings between 0.4 and 1.5 mmhos give optimal growth of most species. During fall and winter when plants are not growing as rapidly, lower levels of soluble salts may be adequate and probably desirable to promote proper cold acclimation (8).

The nutrients in the medium solution for container-grown plants or plants in flats or small propagation pots can be conveniently extracted by the Virginia Tech Extraction Method (VTEM), or more commonly known as the Pour Through Method that was developed and tested at Virginia Tech. It is a simple procedure and, after some adaptation to fit individual grower needs and preferences, has been shown to be an effective technique to monitor container nutrient status and needs.

DESCRIPTION OF THE VTEM

- The container and medium in question are placed on a suitable platform to elevate the container bottom above the surface of the collection vessel. If cuttings are in flats or cell packs, then a whole flat can be used from which to collect leachate. If small pots are used (2 to 4 in.), then enough pots should be placed together in the collection vessel to give a medium volume of about 2 quarts.
- Add sufficient distilled or good quality tap water to the surface of the medium so that about 50 ml of water is accumulated in the collection vessel. The moisture level of the medium should be at or near its water-holding capacity (about 2 hours after irrigation). The moisture level must be similar at the time of each extraction or the moisture level of the medium will influence the level of nutrients extracted. For most media, about 5 minutes is sufficient time for the leachate to drain into the collection vessel. At least 3 containers or

tests should be run from the block of plants in question to obtain a better representation of the level of nutrients or soluble salts for the plants in question.

• The leachate is then poured into a suitable container and is ready for pH, soluble salts, and nutrient analysis. If only soluble salts readings are desired, the leachate can be poured or collected directly into the vial of a portable conductivity meter and discarded after reading.

ADVANTAGES OF VTEM

Other methods of nutrient extraction for soil-less container media involve the addition of water to a volume of medium. Procedures vary from saturating the medium (saturated soil extract method) to adding different amounts of water to a known volume of soil (2:1, 3:1, or 5:1, v/v etc.). All these procedures entail the removal of the medium from the container and subsequent extraction in the laboratory. The advantages of VTEM are: 1) nutrient extraction and soluble salts analysis occurs in the field, 2) the time required for each extraction is short, 3) no medium is actually handled, 4) there is no danger of rupturing slow-release fertilizer particles and causing erroneously high nutrient readings, and 5) no specialized equipment is required for extracting the solution from the medium.

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PHYSICAL AND CHEMICAL CHARACTERISTICS OF SPENT COMPOST

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Abstract. Physical and chemical characteristics of spent compost were studied to ascertain how it compares with commercial greenhouse growing preparations, and with top soil. Water holding capacity, drainage, aeration, and other characteristics of compost compare favorably with other mixes. Soluble salts, nitrate nitrogen, magnesium, calcium, and certain trace elements were significantly higher in spent compost. The pH of compost from most samples was above 7.5, and its ion exchange capacity was within desirable limits to facilitate satisfactory growth and development.

REVIEW OF LITERATURE

Previous work has addressed the feasibility of using spent compost as a horticultural growing mix (2,3,4,6,7,8) for greenhouse and nursery crops. Data support the viability of spent compost as a growing medium or medium additive for ornamentals that have been evaluated to date.

Indications are that spent compost has definite potential as a horticultural growing mix, particularly when amended with additives such as peat moss, Gro-Lite mixes, and certain organic materials like wood chips, bark, and ground corn cobs. Easter lilies, poinsettias, chrysanthemums, and several types of bedding plants have been successfully grown in compost alone and in combination with certain additives (2,3,4,6,7,8).

The high salt level seems to be the greatest limiting factor in using spent compost as a growing mix. Other attributes, such as water holding capacity, drainage, and aeration compare favorably with commercial mixes. However, certain nutrient elements are sometimes present at toxic levels. Nitrate nitrogen, magnesium, calcium, and potassium are often excessively high among the major elements. Iron, boron, manganese, and molybdenum are highest among the trace elements. Comparisons are listed in Table 1.

The salt content is naturally reduced to tolerable levels by leaching, when exposed to the elements for two to three years. The high nitrogen and magnesium content, governed in part by the amounts of certain additives in preparation of the compost, are also lowered through leaching.

This study compares physical and chemical characteristics of spent compost with Pro-mix Bx, peat moss, and top soil because of their wide use in the industry. Thus, favorable comparisons with these media would strengthen the potential for compatibility of compost with numerous commercial crops.

Table 1. Nutrient analysis of spent compost after aging for 2 to 3 years.

Element	Concentration (ppm)
Nitrate nitrogen	462.00
Ammonium nitrogen	6.58
Phosphorus	7.76
Potassium	236.00
Calcium	940.00
Magnesium	147.00
Boron	0.590
Copper	0.117
Manganese	0.147
Molybdenum	0.104
Iron	0.246
Zinc	0.056
pH	7.80
Soluble salts (mmhos)	5.04

MATERIALS AND METHODS

Samples of spent compost were obtained from Pennsylvania mushroom growers. Typical materials, although not an industry standard, used to prepare compost for mushroom production are illustrated in Table 2. The samples were prepared for determining water holding capacity, aeration, and drainage according to the methods described by Cheng and Evett (1). Ion-exchange capacity, pH, soluble salts, organic matter, nutrient, and ash content were determined by a commercial soils testing laboratory.

Specifications for physical and chemical characteristics of commercial mixes were obtained from the manufacturers of the products. Samples were then sent to the same commercial laboratory for confirmation. These data are listed in Table 3.

Table 2. Ingredients used in the preparation of compost for mushroom production.

Material	Quantity (lb)
Straw-bedded horse manure	39,375
Hay	25,000
Cottonseed hulls	6,500
Gypsum	4,000
Chicken manure	3,600
Urea	240

RESULTS AND DISCUSSION

The standards of good water holding capacity, drainage, and aeration are apparent in spent compost. In addition, the proportion of organic matter is sufficient to provide satisfactory ion exchange, particularly for greenhouse-grown crops. However, decreased water availability resulting from the high salt content increases

osmotic forces and, thereby, can result in injury to certain plants.

Spent compost differs most from other commonly used greenhouse mixes in its soluble salt, pH, and nitrate nitrogen levels, as illustrated in Table 3. Compost also has higher levels of magnesium and calcium, and the trace elements boron, magnesium, and molybdenum. Available water and free space of spent compost, measured at 52.8% and 6.3%, respectively, compare favorably with sandy loam soils, which were measured at 33% and 11%, respectively. Minimum desirable free air space after drainage is 8%, according to Mastalerz (5). Drainage in compost alone is noticeably slower than in commercial mixes, however, when two parts of peat (by volume) is added it drains comparably to all mixes with which it was compared.

Table 3. Comparisons of chemical characteristics among spent compost, peat, top soil, and Pro-mix Bx. (All nutrient values are in parts per million).

	Compost	Peat	Soil	Pro-Mix	Normal Range
pH	7.8	3.9	6.6	7.00	5.2 – 6.5
Nitrate nitrogen	462.0	Trace	55.0	22.9	35.0 –180.0
Ammonium nitrogen	6.6	Trace	4.0	8.8	0.0 – 20.0
Phosphorus	7.8	55.0	15.0	11.9	5.0 – 50.0
Potassium	236.0	275.0	45.0	12.8	35.0 –300.0
Soluble Salts[1]	5.0	0.7	1.3	0.5	0.75– 3.5

[1]Salt concentration is measured in millimoles.

Conductivity of compost samples measured between 3.45 and 5.04 mmhos. The acceptable range is 0.74 to 3.5, with most crops having desirable growth responses at or near 1.25 mmhos.

The variations in soluble salts, pH, and nutrients in spent compost obtained from different sources are high because of both content and methods of preparation. Similar differences are common in different batches of compost obtained from the same source. Horse manure, along with added gypsum, hay, and urea have the greatest effects on subsequent nutrient quality of the compost.

In previous growing comparisons with greenhouse crops there were no deleterious effects on Easter lilies, poinsettias, petunias, and chrysanthemums, although there was a growth retarding effect in lilies and chrysanthemums. Thus, the salt effects are apparently a species/cultivar specific effect.

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RESPONSE OF WOODY PLANT MICROCUTTINGS TO IN VITRO AND EX VITRO ROOTING METHODS

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Abstract. Direct, side by side, comparison of *ex vitro* and *in vitro* produced roots on woody plant microcuttings reveals several important differences likely to influence the qualities that control survival of micropropagated nursery stock. In preliminary observations, *ex vitro* root systems are well-branched with normal root hair development, whereas roots initiated *in vitro* lack secondary roots and have a comparatively sparse development of root hairs. The *in vitro* roots tend to have extremely enlarged cortical cells (a false secondary thickening) and poor vascular connections. *Ex vitro* produced roots are more slender and have greater tensile strength. This research project will follow the fate of roots initiated *in* or *ex vitro* through acclimation, greenhouse growth, and in field environments, to determine if the root differences established by either root initiation method early in production continue to influence the root morphology and growth of the ultimate landscape plant.

INTRODUCTION

Micropropagation has recently become an important technique for insuring rapid, uniform delivery of new plant selections to the nursery industry. The speed by which plants can be multiplied and the reliability of the clonal nature of the plants produced is unsurpassed when compared to conventional propagation methods (3). The usual time, space, and materials restrictions on production are eliminated, and very quick release of new clonal propagules is now possible. Many woody plants are responsive to microculture propagation, although they may be recalcitrant to other clonal propagation methods (5).

Even though micropropagation is an accepted technique, there are surprisingly few standards within the industry on production methods. For example, the formulation of propagation media is determined empirically on a producer by producer basis. A wide

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INTRODUCTION

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Even though micropropagation is an accepted technique, there are surprisingly few standards within the industry on production methods. For example, the formulation of propagation media is determined empirically on a producer by producer basis. A wide

variety of containers, facilities, and acclimation techniques are also used. This diversity is especially surprising given the differences in quality that can result (2). Informal observations have revealed that the same propagule produced under different culture methods can vary substantially in quality, size, and degree of development. But these differences have never been well documented.

During production of a micropropagated plant, the root initiation phase is particularly critical to future plant performance. Just as is the case for softwood cuttings, the initial distribution of the microcutting root system has direct bearing on the eventual root branching pattern of the full-grown landscape plant. The integrity of the new root system can predetermine plant susceptibility to stress and ability to survive.

Yet, little research has been done to elucidate the factors that govern production of good, initial root systems on a microcutting. Growers supplying micropropagated woody shrubs and trees to the industry often root the cuttings *in vitro* (in tissue culture medium) in a 100% humid environment. For the *in vitro* method, microcuttings are transferred from shoot proliferation medium to a rooting medium (usually auxin supplemented), where rooting will occur over a 2 to 4 week period. The rooted microculture is then carefully removed from culture and transferred to the greenhouse for acclimation.

Other research and commercial labs elect to excise microcuttings, then place them directly into a rooting medium *ex vitro*. They may or may not be treated with rooting compound at this point. Depending on the individualized lab protocol and type of plant, the microcuttings might be inserted into trays of vermiculite, sand, peat and sand, or other medium, or into Techniculture plugs (Castle and Cooke, Techniculture, Inc.) in a mist or high humidity environment. Acclimation and rooting steps may be combined. Or, the supply labs may sell cuttings unrooted, leaving it to the nurseryman to perform *ex vitro* rooting.

The resultant differences in initial root system qualities can be substantial. A few scattered and isolated studies have implied, for example, that *in vitro* methods fail to stimulate normal root hair development, or that vascular connections might be discontinuous if rooting is accomplished *in vitro* (9,6). Another study suggested that *in vitro*-produced roots may die after transplanting to greenhouse conditions and are completely replaced by new *ex vitro* roots before the plants are established (1).

On the other hand, the *in vitro* method is widely practiced, and some believe it is more efficient and results in better uniformity (4). The two alternative routes for root production on microcuttings are characterized by differences in production timing, costs, and degree of required expertise (8, 10). Unfortunately, almost no side by side comparisons of roots generated *in* and *ex vitro* have been reported.

The consequences of using different rooting media or methods are largely conjecture.

One reason that this important comparative information is not available to nurserymen is that, by nature, the root system is very difficult to evaluate. Usually, it is hidden with soil or medium, so it is difficult for a grower to assess the distribution or quantity. The very act of removing the roots from the soil disrupts the root system. A woody root system can be quite extensive and complex even for a young nursery plant, making it difficult to achieve a thorough or objective evaluation. Conclusive evidence about the effect of root quality on plant performance is not available, yet the scattered reports that have appeared are certainly enough to raise serious questions, and to justify some comprehensive tests on the alternative techniques.

To recap on the background that has motivated our research project: 1) the quality of the initial root system is of critical importance to woody plant survival, stability, and performance; 2) there is little consensus in the industry on rooting standards, yet substantial differences in the product can result from different methods; 3) these differences are not well documented because roots, by nature, are difficult to examine.

The objectives of this study are to investigate and assess the effect of *in vitro* and *ex vitro* microcutting root initiation methods on root quality and distribution, for the young rooted propagule, for the acclimating plant, and for later growth stages. Anatomical sectioning and analysis of root systems at several stages in the production cycle reveals key contrasts between *ex* and *in vitro* generated roots at the cell and tissue level. Video image analysis techniques are adapted to provide a quantitative record of root system development and distribution, and explore in depth aspects of root integrity that might otherwise be overlooked due to inherent obstacles to root examination.

MATERIALS AND METHODS

Plant material. Proliferating shoot cultures of *Malus* × *zumi* 'Calocarpa', *Acer rubrum* 'Red Sunset', and *Betula nigra* provide microcuttings for rooting experiments. Shoot cultures are uniformly maintained by monthly subculture of horizontally explanted microshoots. *Malus* and *Acer* cultures are maintained on medium supplemented with 1 μM benzyladenine (BA) and 0.05 μM thidiazuron, whereas *Betula* cultures are maintained on a different salts medium with 2.2 μM BA.

All of the microcuttings are produced in Magenta GA7 vessels under standard light and temperature regimes (25°C, light intensity 45 μM m^{-2} s^{-1}, 24 h photoperiod). Uniform microshoots are excised with upper leaves intact when they are 2 to 3.5 cm long (approximately 4 to 5 weeks from the last subculture).

Rooting procedures. For *in vitro* rooting experiments, the cuttings are inserted vertically to a depth of about 1 to 1.5 cm into 20 ml of rooting medium contained in test tubes. Indole-3-butyric acid (IBA) at a concentration of 1 μM supplements *Acer* rooting medium. *Malus* and *Betula* require a slightly higher concentration of IBA. *Malus* cuttings require a brief dark pretreatment prior to rooting.

For parallel *ex vitro* rooting treatments, comparable microcuttings are excised from culture and inserted into trays containing sterile sand or a sand and peat mixture. Both *in vitro* and *ex vitro* treatments are held in identical growth chamber facilities (25 to 30 μM m^{-2} s^{-1}; 25°C day, 21°C night; growth chamber humidity 30 to 65%) for the duration of the rooting period.

In vitro rooting is usually accomplished in less than 4 weeks. After rooting, agar is gently washed away from the *in vitro* rooted plants, which are next transplanted into pots containing a standard greenhouse mix of peat/perlite/soil. The pots are placed under mist for acclimation, then moved onto a standard greenhouse bench with supplemental high intensity discharge (HID) lamps and saran cloth. Day temperature is kept at 24°C, night at 21°C, in a 16 h photoperiod. Plants are hand-misted periodically for the first few days in the greenhouse bench as they make the critical transition to the lower humidity conditions. Standard greenhouse fertilization and irrigation regimes are continued.

Treatment of the *ex vitro* cuttings is similar. Like the *in vitro* cuttings, these cuttings remain in their initial rooting medium a total of 4 weeks. Once roots are well initiated (approx. 2 weeks), the humidity in the plastic boxes is gradually reduced by cracking open the seals and later lifting up the lids. For the remainder of the root initiation phase, these plants are simultaneously becoming acclimated to lower humidity environments. Plants are then transplanted to the greenhouse bench with the same conditions as the *in vitro* rooted samples.

Plants from both the *in* and *ex vitro* rooting treatments will eventually be transplanted to larger-sized pots (in the same potting mixture) for an additional 60 to 90 days growth in the greenhouse, and then transplanted into nursery field plots in the spring. The production schedule has been designed to parallel standards used in *commercial nursery operations.*

Evaluation Methods. Evaluations are scheduled at root initiation, transplant and acclimation, transplant into the larger pot size in the greenhouse, transplant to the field, and after 1-year in the field nursery. Information on a variety of root parameters is collected at each observation, including number of days until root initiation, root fresh mass, tissue color, root branching patterns, sites of root initiation, and distribution of the root system.

Routine time course measurements of root system development are facilitated by a novel adaptation of microcomputerized

video image analysis. Entire cultures are staged for non-destructive observation, and root systems *in vitro* are imaged with a CCD video camera. The entire image is captured with the aid of an Imaging Technologies image analysis board housed in an IBM PC/AT microcomputer. The information is rapidly and automatically recorded (within seconds), calibrated in terms of two dimensional area, and broken down into component colors corresponding to visual density of the root system image.

This unique technique converts the irregular, complex information of a developing root system to a quantitative form. The visual data from digitized images has been previously correlated with manual measurements of fresh mass and length. Manual collection of the same root data would be extremely time consuming, tedious, and subjective. *Ex vitro* root systems are observed in the same way after gently removing any medium adhering to the roots. For each subsequent root observation during the production cycle, entire washed root systems as well as smaller subsamples are imaged to collect the required information.

Sample live root segments are transversely sectioned to approximately 80 to 100 μM (or 2 to 3 cell layers thick) at each observation with a vibrating microtome to analyze the anatomical layout of root tissues. The vibrating microtome allows thin, fresh sections to be taken from microculture tissue without prerequisite staining or embedding, which would otherwise create artifacts in observation (7). The live sections are viewed using an inverted microscope at 4x, 10x and 20x magnification. Cross sectional area, vascular system dimensions, cell types and cell sizes are determined. The presence or scarcity of root hairs is noted, and sections can be stained to determine the degree of root tissue lignification. A video camera is also mounted to the inverted microscope, and views of root sections are displayed on a video monitor for rapid, objective image analysis of anatomical measurements.

RESULTS AND DISCUSSION

Direct comparisons have helped to pinpoint clearcut differences between *in vitro* and *ex vitro*-produced roots at early stages of development. For example, root systems produced *in vitro* tend to have sparser root hair development. As *in vitro* roots develop and mature they continue to grow in length, often circling the base of a test tube if not transplanted, but branch root formation is rare. *In vitro* roots are formed at the base of microcuttings inserted into rooting medium, not at sites higher on the cut microcutting stem unless associated with callus. *In vitro* formed roots have a fat, fleshy composition. In some species the *in vitro* root has an almost "carrot like" appearance, but the roots are actually quite fragile and have poor tensile strength.

Sample *in vitro* roots readily tear (break and separate into short

pieces and different cell layers) when tested by gently applying tension along the longitudinal axis. This may signify, as some older literature has implied, that the vascular connections are incomplete or lacking. Older roots (30 to 60 days) are resistant to desiccation, and remain turgid up to 20 min. or more after removal from the agar medium.

In contrast, ex vitro-produced root systems are profusely branched indicating the presence of more absorptive surface area. The roots tend to be more slender and fibrous. They resist breaking and instead separate into long, continuous layers of cells when pulled apart.

In transverse sections of six-week-old *in vitro* roots, the most conspicuous feature is the lack of secondary growth (Fig. 1). The cortical cells develop without evident vascular cambium. Root cell size is expanded, and since *in vitro* roots are exposed to the light during initiation, they often contain chloroplasts and have a greenish cast. The cortex occupies the largest relative area in the root section. Overall root diameter is consequently much greater for *in vitro* roots, as compared to the more slender *ex vitro* roots.

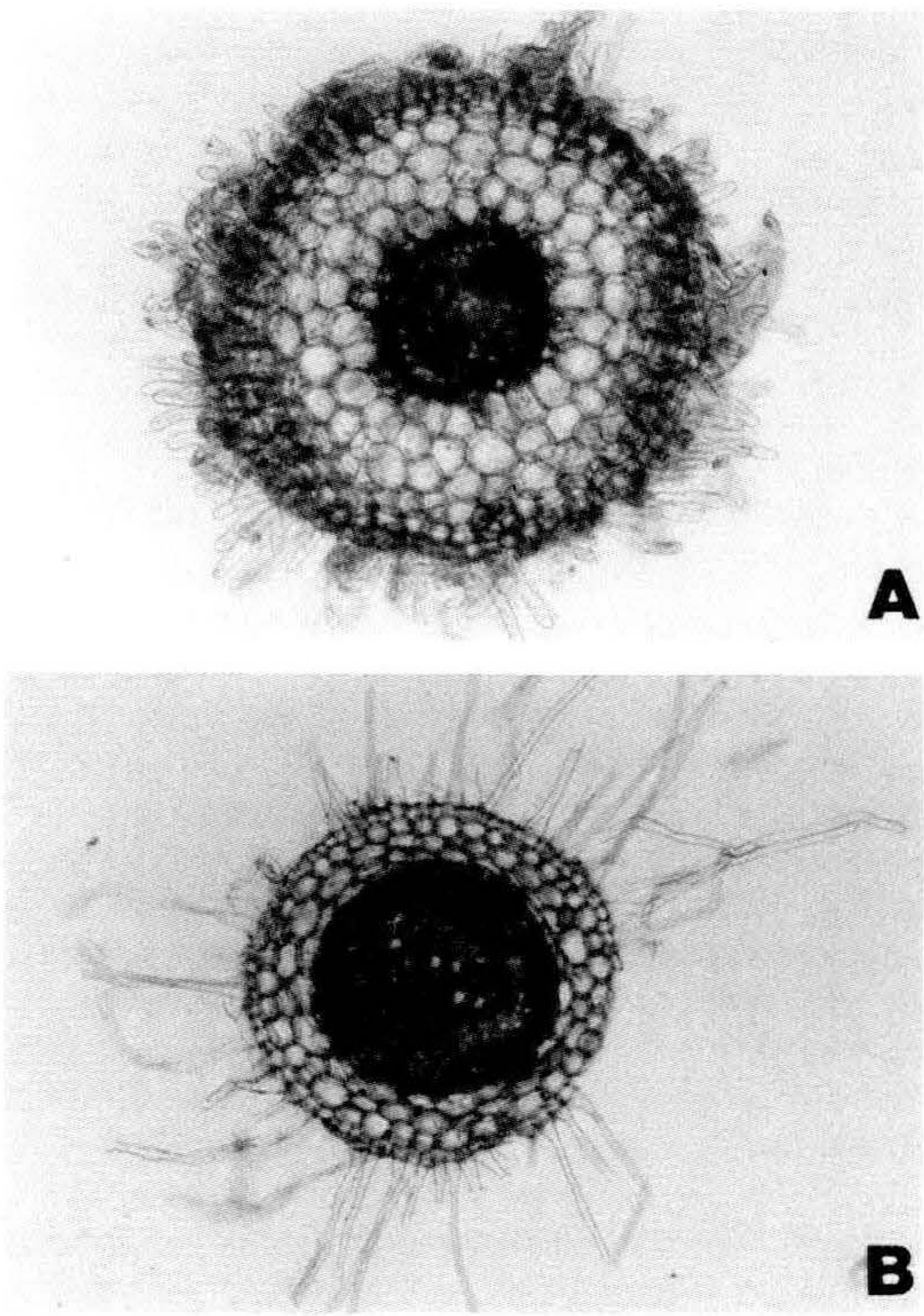

Figure 1. Comparison of transverse sections of six-week-old *in vitro* (A) and *ex vitro* (B) *Acer rubrum* 'Red Sunset' root system anatomy.

The *ex vitro* sections exhibit what could be considered normal root development, with a large amount of secondary xylem occupying the majority of the root section (Fig. 1). Comparative staining tests to confirm the presence of lignin, a substance abundant in secondary tissue, will be conducted for parallel *in* and *ex vitro* root treatments for each of the woody species. Cell size *ex vitro* is reduced, vascular systems are more compact and extensive, and cells have a dense cytoplasmic composition (Fig. 1). Some differences (distribution and texture) are apparent between *ex vitro* roots produced in sand, versus the sand and peat mixture, but these are yet to be characterized.

This preliminary comparison of initial root systems will continue throughout several subsequent stages of woody plant nursery production, with direct side by side comparisons at later stages of acclimation, transplanting, and adaptation to new environments.

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NEW PLANT FORUM

JACK ALEXANDER, MODERATOR

DICK LIGHTY: *Ilex verticillata* 'Maryland Beauty', selected by Mr. David Jenkins of Maryland around 1932 for cut stem production, has branches tightly clothed with long-lasting berries of medium size to within an inch or two of the stem tips. It is a shrub to 5½ ft and therefore of wider usefulness than 'Winter Red'. Simpson's Nursery has this plant and Mt. Cuba Center for the Study of Piedmont Plants will be distributing it in the future.

CHRIS ROGERS: *Rhododendron* 'New Patriot' is an open pollinated selection of a plant whose parentage is R. 'P.J.M.' crossed with an evergreen form of a pink *R. mucronulatum*. 'New Patriot' blooms in Hopkinton, MA one week before *R.* 'P.J.M.' in late April. It is very floriferous with nearly red flowers that tend to bloom two inches down the stems. It blooms over a week period. The flower buds seem to be hardy to Zone 5. It is a vigorous, wide-branched plant and, after 10 years, we can expect a plant that is 4 ft tall and 3 ft wide. It was registered (American Rhododendron Society) in 1988. 'New Patriot' is our step towards a red 'P.J.M.' type plant. We are still using this cultivar in our hybridizing program to produce a plant that is more evergreen and exhibits redder flower color.

Rhododendron 'Frank Abbott' was crossed by Ed Mezitt in the early 1960's. The cross was *R. prinophyllum* (or "*R. rosea*" in those days) with a selected *R. mollis*. We chose to name this plant after the man who first made this cross in the late 1930's. 'Frank Abbott' flowers in mid-May with very fragrant shocking-pink to nearly-red flowers. The buds are hardy to Zone 4. Plant habit is wide and upright with strong rigid branches. After 10 years we produced a plant that is 4 ft tall and 3 ft wide. It seems to be resistant to powdery mildew for us.

DEBORAH McCOWN: *Syringa* 'Albert F. Holden' (P.P.A.F.) (S-II) is characterized by its deep purple blooms which possess a silver blush on the reverse of the petals. This mid-season lilac displays large, loosely-open, somewhat reflex panicles of moderate fragrance. It is a vigorous plant of dark green foliage, moderately rounded in habit to about 7 ft. It is disease resistant.

In 1980, at the dedication of the Lilac Garden in the Holden Arboretum, Fr. Fiala presented this outstanding cultivar in honor of Albert Fairchild Holden (1867–1913) whose vision and fortune led to the establishment of the Arboretum.

Syringa 'Wedgwood Blue' (P.P.A.F.) (S-III) is true to the distinguished blue-tinted background of Josiah Wedgwood's fine English pottery. Fr. Fiala's 'Wedgwood Blue' is a neo-classic in it's own right. This cultivar, a Rochester hybrid, displays large, somewhat wisteria-type panicles. Its habit is moderately rounded to slightly upright. It has dark green foliage, moderate fragrance, and is disease resistant.

Syringa 'Blanche Sweet' (P.P.A.F.) (S-III) is a lovely hyacinthiflora cultivar that is also a Rochester hybrid. It is early blooming, growing to about 10 ft. It's very large panicles have recurved florets and are of pale blue to whitish blue color and good fragrance. This cultivar takes its name from a silent-screen movie actress, Blanche Sweet.

(For additional scientific information concerning these lilac cultivars, contact Falconskeape Garden, 7447 Branch Road, Medina, OH 44256.)

ANDY HARDING: The Round Table Series of genetically dwarf flowering crabapples was produced by Jim Zampini. Over 15 years ago he began to select superior dwarf flowering crabapples from seedlings of *Malus baccata*. *M. sargentii*, and *M. sieboldii* parentage. The growth rate of the Round Table Series is approximately ½ to ⅔ of the standard growing cultivars now being produced.

During the years of testing none of these cultivars have shown any symptoms of the usual crabapple diseases.

Malus 'Camelot'™
Height: 10 ft
Spread: 8 ft
Flower: fuchsia pink on white
Fruit: bright red
Foliage: dark green with wine-red overcast
The spring flowers of fuchsia pink on white are followed by thick, leathery, dark-green leaves with a deep wine-red overcast. Early fall is a show of ⅜ to ½ in. size scarlet fruit on slightly arching branches. A disease resistant tree.

Malus 'Lancelot'™
Height: 10 ft
Spread: 8 ft
Flower: white, red buds
Fruit: gold with orange-red blush
Foliage: green
Spring starts with the bright-red flower buds, opening to pure white flowers. In summer the tree is layered in crisp green leaves. In autumn ¼ in. golden fruit appear with a orange-red blush holding well into December. A very low maintenance tree with a compact structure presents a tailored look.

Malus 'Cinderella'™
Height: 6 ft
Spread: 4 ft
Flower: white, red buds
Fruit: red
Foliage: wine with frost
An extremely compact, upright flowering crab displaying red flower buds and white flowers followed by small, deeply lobed leaves. In fall, ¼ in. gold fruit is an added *attraction. A low maintenance tree.*

Malus 'Canterbury'™
Height: 10 ft
Spread: 10 ft
Flower: light pink
Fruit: red
Foliage: dark green with wine overcast
Light pink flowers in the spring followed by dark wine-green leaves in the summer and bright scarlet fruit which persists into the winter. A low-maintenance dwarf tree with a mounding habit.

Malus 'Guinevere'™
Height: 8 ft
Spread: 8 ft

Flower: red with white
Fruit: red
Foliage: dark green with wine frost

This attractive dwarf flowering crab starts off the spring season with a mass of nostalgic red and white flower buds and blooms, followed by waxed green leaves with a dark wine frost which is quite showy in itself. Autumn brings on bright red ¼ to ½ in. fruit. A disease resistant tree.

Malus 'Hamlet'™
Height: 10 ft
Spread: 10 ft
Flower: rosy-pink
Fruit: red
Foliage: wine-red

In spring there is an abundance of bright rosy-pink flowers, followed by red-wine foliage. Fall produces a nice set of bright ¼ to ½ in. cherry-red fruit. A low maintenance tree.

Malus 'King Arthur'™
Height: 12 ft
Spread: 10 ft
Flower: white
Fruit: blushed red
Foliage: dark green

A strong-growing, dwarf tree that produces a mass of white blooms in the spring and dark green leaves in the summer. Bright red ¼ to ½ in. fruit adorn the tree in the fall. A low maintenance tree.

Malus KOH 1-83-51

Extremely showy white flowers start the spring. Summer foliage is an attractive light green, followed by brilliant gold ¼ in. fruit in the fall. A disease resistant tree.

Malus PK 4-86-33

A dense, round, compact tree with white blooms in the spring and small deeply-lobed leaves in the summer. This tree produces no fruit and is low maintenance.

DAREL APPS: *Asteromoea mongolica* (*Calimeris pinnatifida* 'Hortensis', *Aster indicus* var. *pinnatifida*, *Aster indicus* var. *pinnatifidus* 'Hortensis', *Boltonia incisa*), double Japanese aster or orphanage plant, is an Asian plant reaching 30 in. in height with solitary flowers about 1 in. across. Its main attributes are: 1) small double white flowers which senesce unobtrusively, 2) continuous bloom from the end of June until hard frosts, and 3) no apparent insect or disease problems. In silhouette it is a broad mound covered with white jewel-like flowers. The leaves are narrow (oblong-lanceolate) giving an overall fine texture. Plants spread by underground stems and can be easily propagated from the new shoots which arise in the spring.

In the United States the plant is often found labeled as *Asteromoea mongolica*, but may be of a different genus. In the *Flora of Japan* it is listed as *Calimeris pinnatifida* cv. Hortensis. A closely related plant, commercially sold as *Calimeris integrifolia*, differs in having single flowers rather than double.

(Plants are available from Hollbrook Farm & Nursery, Rt 2, Box 223B, Fletcher, NC 28732; Montrose Nursery, P.O. Box 957 Hillsborough, NC 27278; North Creek Nurseries Inc. Rt 2, Landenberg, PA 19350; and Sunny Border Nurseries, Inc. 1709

Kensington Road, P.O. Box 86 Kensington, CT. 06037

Aster lateriflorus 'Horizontalis', starved aster or calico aster, is a North American plant that was first introduced to Great Britain in 1929. The species grows from Nova Scotia to western Ontario and south to North Carolina, Louisiana, and Texas. 'Horizontalis' is unique because of its lilac flowers and tiny leaves that become coppery purple by September. The flowers are 5/16 in. across and borne in panicles; the ray flowers are pale purple while the disc flowers and stamens are rosy-purple. Plants reach 30 in. in height and may spread 3 to 4 ft. Bloom time in southeast Pennsylvania is from the middle of September to late October. It grows well on either moist or dry sites. Plants can be propagated from cuttings in late spring. (This cultivar is commercially available from North Creek Nurseries, Inc. RR 2 Box 33, Landenberg, PA 19350; and Canyon Creek Nursery, 3527 Dry Creek Road, Oroville, CA 95965.)

GALEN D. GATES: *Cassia hebecarpa,* wild senna is a member of a large genus of over 500 species. *Cassia* sp.are widely distributed in tropical, subtropical and temperate regions of the world and is classified within the pea family—Fabaceae or Leguminosae. The hardiest of cultivated cassias are two North American herbaceous perennial species called wild senna: *C. marilandica* and *C. hebecarpa*. The latter is heavier flowering, hardier, and with smaller leaflets.

Cassia hebecarpa is a dramatic perennial growing from 4 to 6 ft in height. The many-flowered racemes arise from the leaf axils forming showy terminal panicles. The individual flowers are bright yellow, ¾ to 1 in. across and provide a backdrop for the conspicuous brown anthers. Blooming from mid-July to mid-August, this plant makes a splendidly colorful addition for naturally landscaped areas, herb gardens and the rear of larger-flower borders in summer.

The seed pod is slightly curved, flat and up to 4½ in. long by approximately ⅓ in. wide. These pods are persistent and during winter provide interest in otherwise "non-existent" perennial beds. In my experience, self seeding is not a problem.

The leaves are 6 to 8 in. long, pinnately compound with 5 to 10 pairs of oblong, blunt leaflets about 1 in. long. The leaflets are arranged feather fashion, without an odd leaflet at the end.

Naturally occurring from Massachusetts to Wisconsin and southward to North Carolina and Tennessee, it is well adapted with no pest or disease problems. It can be seen and grown in full sun or partial shade on stream banks, fens, open woods and dry thickets. It is adaptable to both alkaline and acid pH soils as well as heavy clay and rich loam soils.

A tea has been made from the leaves for centuries and was widely used by the American Indians as a laxative. There is scientific documentation to support this use, but with a caution—to limit ingestion to 1 cup in a diluted form. The plant also has potent cathartic qualities and if consumed in quantities greater than the 1 cup recommended, cramps and other side effects may be experienced.

Cassia hebecarpa is of easy culture, only needing to be cut back, (as with any perennial) in either spring or fall, and it is easily propagated from seed. Seed will benefit from mechanical scarification, or in a 10 min treatment with concentrated sulphuric acid, then stratified for 60 days at 40°F.

SIDNEY WAXMAN: *Tsuga canadensis* 'Julianne' originated as a selection from among several hundred 10-year-old witches'-broom seedlings. From an early stage in its development it was of interest because of its unusual form.

'Julianne' is a symmetrical dwarf shrub, very broadly obovate; it has a form

similar to that of a spinning top. It grows approximately 4 to 5 in. annually and, after 10 years it has grown 48 in. wide by 40 in. tall. Its branches are spreading, very dense, and highly uniform in length, almost as if they were sheared. 'Julianne' can be rooted by stem cuttings.

Larix laricina 'Newport Beauty' was selected from among 97 11-year-old witches'-broom seedlings obtained from an Eastern larch in Newport, Maine.

'Newport Beauty' is a low-growing, spreading shrub with light blue-green foliage. Its branching consists of many short twigs that grow outward. The plant is occasionally asymmetrical with some horizontal branches becoming more dominant than others. Its annual growth rate is approximately 3 in. per year.

'Newport Beauty' can be rooted from cuttings or grafted. Grafting, which has been done using Japanese larch as the rootstock, is the preferred method because its own roots are intolerant of dry soils. In 11 years, 'Newport Beauty' has grown 30 in. wide and 15 in. high.

Larix laricina 'Deborah Waxman' was selected from among 70 seven-year-old seedlings obtained from a witches'-broom on an Eastern larch in Prospect Harbor, Maine.

All of these seedlings differ from "typical" witches'-broom seedlings in that they are upright and generally ovate in form, and are mostly twice as high as wide. This particular selection was chosen because its growth rate was lower than most of the others (6½ in. annually) and because of the beautiful light blue cast of its foliage.

Its many closely spaced branches are ascending with the outer shoots becoming vertical. After a shower tiny droplets of water are held by the needles and sparkle like diamonds. Cones are violet-red when young. 'Deborah Waxman, has grown 5 ft high and 3 ft wide in 7 years. It roots easily from cuttings taken in August.

Pinus strobus 'Coney Island' originated as a graft taken from a witches'-broom located on a white pine in Woodstock, Connecticut. Its form is horizontally elliptic and is approximately twice as wide as high. The leaves are variable in length ranging from ⅝ to 2½ in., very dense, and slightly tufted at the ends. The foliage color is also variable giving both blue-white and green needles. White pine needles are three-sided in cross section with the inner two sides often a glaucous blue-white while the outer edge is green. The bicolor needles in this selection arise because many of the fascicles have not separated but remain stuck together and appear as a single thick needle which shows only the outer green color. The remaining needles, typical of normal white pine, separate exposing the two inner sides of each needle and as a consequence the blue-white color becomes apparent.

Its annual growth is about 3 in. In 13 years 'Coney Island' has grown 5-ft wide and 2½ ft high. Propagation is by grafting.

A major feature of this selection is the large number of miniature grayish-blue cones (female strobili) that regularly develop over the periphery of this bun-like shrub; a veritable island of cones. I just couldn't resist naming it 'Coney Island'.

BRUCE BRIGGS: *Kalmia latifolia* 'Minuet' was selected by R. A. Jaynes and introduced by Briggs Nursery in 1987. 'Minuet' is a minature (f. *myrtifolia*) like 'Elf' but also banded (f. *fuscata*). The flowers are large relative to the reduced plant habit. The band is broad, and an solid bright cinnamon maroon color. The pigment pattern is much like 'Goodrich' but the color redder and brighter. The buds are light pink. The leaves are glossy, dark green and narrow; growth and habit somewhat diminished compared to 'Elf'. From a cross of miniature banded ('Star Cluster')/redbud. R. A. Jaynes, Kalmia, The Laurel Book II, 1987. p 53.

Rhododendron 'Centennial' (Mossman) 'Washington State Centennial':

Deciduous azalea. (*R. occidentale* × *R. bakeri*) × 'Santiam'. Cross, raised, registered by Frank D. Mossman, Vancouver, WA; named by Washington State Centennial Committee (WSCC); introduced by WSCC through Briggs Nursery, Olympia, WA. Received award, Portland Chapter show (1982), Best New American Azalea; chosen by WA Centennial Commission for 1989 celebration. Photo in *ARS Journal*, Vol 39, No 3, p 143 (1985), under the name 'Centennial'. Flowers tubular funnel-shaped 3½ in. across × 1½ in. long, 10–12 per truss, 5-lobed, very deeply ruffled edges, very fragrant. Early buds have orange-yellow, red, and green petal backs with red tubes; flowers are light orange (16C), paling to white. Prominent strong orange yellow (17A) blotch covers entire upper petal, with occasional extensions on adjacent petals; color persists. Petals have a discontinuous strong pink (50C) edging, as wide as ¼ in., and irregular strong pink (50C) veins. Calyx to ¼ in. strong yellow green (143B). Ball-shaped truss, 6 in. across × 5 in. high. Leaves 3⅞ in. × 1 13/16 in, elliptic and narrowly obovate, revolute, margin undulate, apiculate, cuneate, smooth, very shiny, dark green (132A); under surface moderate yellow green (138B); hairy on leaf margins and underleaf primary and secondary veins; autumn color bronze, red, and yellow. Plant upright, open, moderately-branched, 5 ft high × 3 ft wide in 10 years from seed. Blooms May. Hardy to at least −10°F.

Rhododendron, 'Centennial Celebration' (Peste): 'Purple Lace' × *R. yakushimanum.* Crossed (1976) and raised by Fred Peste, Shelton, WA. Named by Washington State Centennial Commission, described by Sharon Johnston, introduced and registered by Bruce Briggs, Olympia, WA. Flowers 20/truss, c 3 in. across × 2¼ in. long, openly funnel-shaped, 5-lobed, wavy margins, very light purple 75C, sparse tan spotting upper lobe, outside deep purplish pink 68A stripes, fragrant. Truss c 6 in. across × 4 in. high. Calyx rudimentary. Leaves held 2 years, c 5½ in. × 2⅛ in., narrowly elliptic, acute tip, cuneate base, dark yellowish green 139A, under surface moderate yellow green 146C. Plant upright, rounded, semi-dwarf, 22 in. tall × 25 in. wide in 8 years from seed, compact, well-branched, very floriferous. Photo *ARS Journal,* Vol. 39, No. 3, p 143 (1985). Blooms in late April. Hardy to at least 0°F.

COST-EFFICIENT METHODS FOR NURSERY COMPLIANCE WITH ENVIRONMENTAL REGULATIONS FOR HAZARDOUS MATERIAL STORAGE

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CHEMICAL USE AND REGULATORY AUTHORITIES

Nursery growers routinely rely on regulated chemicals during plant propagation and production. Fungicides, insecticides, herbicides, fertilizer materials, and fuel are all resources that growers use to profitably produce high quality plant material.

Public concern for protecting the environment has resulted in the establishment of governmental authorities empowered to develop rules that regulate chemical storage and use. A primary concern is the contamination of ground water by hazardous materials including pesticides, fertilizers, and fuels. When introduced into the soil, these chemicals can move downward into the water table and eventually can be drawn toward wells supplying public drinking water.

The development of regulations on hazardous material storage and use is required by the federal government, but has been delegated to state and local governments. In some areas this responsibility has been assumed at the state level, such as the Department of Environmental Protection in Connecticut. In other areas it is delegated to county governments, such as the Environmental Quality Control Board in Broward County, Florida. The specific regulations are developed locally and can vary greatly from region to region.

The regulatory authorities are often composed of a policy or advisory board representing a cross-section of the community, including agriculture. This presents the opportunity for nursery growers to become involved in the development of regulations, with the goal of having those that are both effective and reasonable to implement.

ENVIRONMENTAL REGULATIONS

The establishment of environmental regulations has had many ramifications. Permits for storage and use are required and inventories of chemicals on hand are often required. Employees must be provided with protective clothing and equipment and are protected by the "right-to-know" law. For many nurseries, the most costly and difficult aspect of compliance is the storage of chemicals.

In areas where potential for ground water contamination is high, regulations governing chemical storage may stipulate the

requirement for double containment. To achieve double containment, a pesticide or other hazardous material packages must be stored within a container that must also be within a container. The objective of this system is to greatly reduce the risk of ground water contamination in the event of a chemical spill by providing two containment areas. Accomplishing double containment has the potential to be very expensive because each containment must be capable of catching all materials stored in the area.

LOW-COST COMPLIANCE CASE STUDY

The challenge of low-cost compliance is to modify existing storage areas to achieve compliance with a minimum of new construction. The following description is a case study of a storage system which was brought into compliance with very little expense to a grower, located in Broward County, Florida. This application may be adapted to meet the specific requirements of other regions.

This nursery grower had a below-ground storage tank for gasoline storage, an above-ground tank for diesel storage, and a concrete block shed with a cement floor and garage door for pesticide storage. With the promulgation of new regulations, no part of this storage system was in compliance.

The nursery grower decided to abandon the below-ground gasoline tank by draining it and filling it in with concrete. The high cost of replacing the tank was not deemed economical by the grower. However, the above-ground diesel tank and the pesticide storage area were brought into compliance at very little expense.

The diesel tank was moved into the pesticide storage building to consolidate the locations of hazardous materials. A concrete block retainer wall built eight inches high inside the building, forming a simple retaining wall (Figure 1). This formed the first containment area.

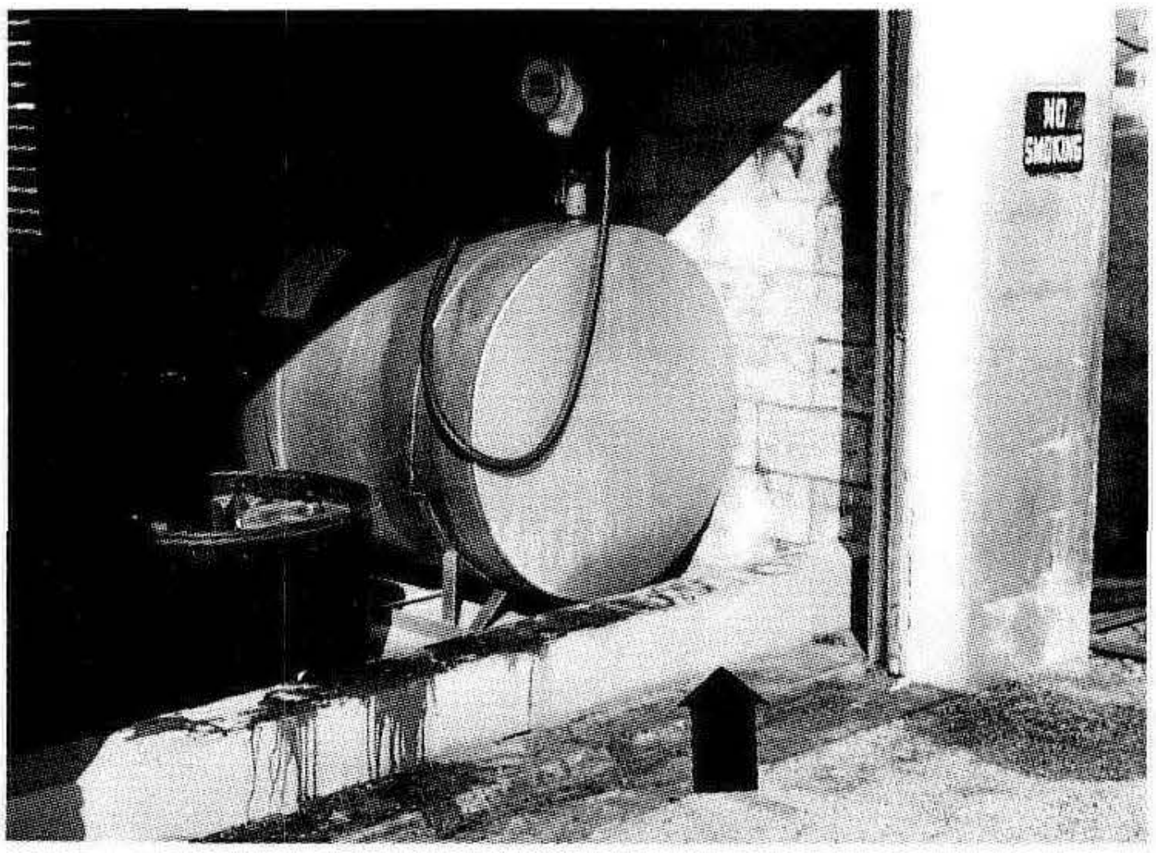

Figure 1. Pesticide storage building brought into regulatory compliance with the construction of a retainer wall across the opening to the building (indicated by arrow).

The second containment required for pesticides was also achieved with a minimum of expense. This grower specially ordered large nursery containers without drainage holes (Figure 2). The bottom of the container was covered with a layer of absorbent material, such as cat litter or sawdust, and the pesticide packages were placed inside. This system is both effective and inexpensive. A similar containment could be achieved by sawing a 55-gallon drum in half and sealing the inside with epoxy or other liner. These case studies have been used in training programs to satisfy in-service requirements for extension agents (1,2).

Figure 2. Double containment of pesticides is achieved by placing the pesticide packages inside a large nursery container, specially ordered without holes, with the bottom covered with absorbent material.

SUMMARY

As hazardous material users, nursery growers have liability for contamination to areas nearby the nursery. It is important for growers to become aware of environmental regulations affecting them and to strive for compliance to reduce their risk. In many cases compliance with regulations can be effectively achieved with minimum expense to the nursery grower through the use of commonly available materials.

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