YOUNG PLANT PRODUCTION

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This paper deals with plant production in two sections: (A.) the setting up of the production unit and (B.) practicalities of propagation and production on the resultant nursery.

A. **Setting up the Production Unit.** Points to consider before choosing the site.

1. Type of nursery it is to be: for example, Pot Grown, Field Grown, etc.
2. The location (this was decided before-hand in my case), and the size of the piece of land (3 acres in my case).
3. Accessability of the site to road, water and electricity.
4. Ease of location of the site; e.g. situated on a main road, etc.
5. Location of horticultural suppliers.
6. The physical properties of the site. These include: soil type, frost pockets, drainage, liability to flood and exposure to wind.

The site was then tile-drained and subsoiled so as to improve soil structure etc., as the parent soil was of a clay loam type.

The main areas of the nursery were:

1. Stock plants
2. Cold frames (low capital cost)
3. Growing areas
4. Standing out/Collecting Area

1. The first step was to plant the stock plants with the main cultivars grouped. The rows were, on average, 3′ apart.

2. The cold frames were then constructed on the driest part of the nursery; railway sleeper sides were used to the width of 4′6″ internal measurement. The length of the frames is 50′. Dutch lights are used for the covering. Water was then laid on to the maximum bore available which was only 1 inch, so a 5,000 gallon reservoir was installed with a Grundens CP 3R pump. Enough stand pipes were installed so as to reduce to a minimum hose pipe movement.

3. A 80 × 14′ Dutch Light House was erected for growing and later housed a mist unit. A second-hand 10′ × 8′ shed was bought for potting, etc. An access road was put into the site making sure it included a large turning space for lorries with standing out beds adjacent for ease of loading.

During this second year a mist unit was built in the glasshouse at ground level. The measurements of the unit was 75′ × 4′ wide at both sides of the house, leaving a 6′ wide path.

The concrete base was placed on 4″ of ashes to deter earthworms and to provide drainage. The sides of the mist unit consists of kerb edges obtained from the local council. Once the base was set, 1/2″ diameter holes at 1′ square intervals were knocked through to the ashes below.

The mist bed was now made up and consisted of the following:

Two inches of 1/8″ grit. Electric cables were laid down. One 3KW section and one 2KW section on either side. This gave four independent, thermostatically controlled sections. One inch mesh chicken wire was placed on top, to give even heat distribution. On top was placed 1/2″ of 1/8″ grit.

The mist line was then suspended over the bed. It was of an aluminum type with straight brass anvil nozzles. This was later found out to be a mistake for the following reasons:

1. The amount of water discharged from the jets was too great due to the coarse spray pattern, resulting in some damping off.
2. The hard water reacts with the aluminum pipe causing aluminum oxide deposits, thus blocking nozzles. The line is now being replaced with galvanized pipe and MacPenny mist nozzles.
3. Next to the access road two 65′ × 14′ poly tunnels were erected. One tunnel was planted with stock plants for the production of early cutting material. The other was for potted material. Spray lines were placed in them, but these only partly eliminated hand watering as there are still dry spots along the backs after being sprayed.

The production unit is still being built up and 8 more 65′ × 14′ tunnels and a 30′ × 12′ potting shed have been erected. One of the new tunnels houses more stock plants, which are mainly *Viburnum davidii*. Nicofence 27 covers the tunnel and it has been found to create optimum growing conditions.

B. **Practicalities of propagation.** Stock plants cover 1 acre of the 3 acre nursery at present and, to me, they are the central core of the nursery. The main objective is to keep them vigorous and weed-free. During the month of February the stock plants are pruned fairly hard to keep them tidy and to promote vigorous growth in the spring.

A 1:1:1 semi-organic fertilizer is spread at the rate of 5 cwts/acre; 50% Simazine at the rate of 1 lb 4 oz per acre is sprayed on at the end of April for weed control. This low rate is used as the whole stock area is treated and this includes some non-Simazine tolerant plants. This low rate gives good weed control up to mid-September and if any weeds appear 2,4,5-T is used as spot treatment for thistles and knot grass and is applied on a very cool day so as to minimize the risk of vapour damage. Kerb (50 W), applied in November, has been used to control grass at the rate of 3 lbs/20 gals/acre. Gramoxone, plus washing up liquid, is also used for spot treatment throughout the summer. Paths are sprayed with Weedex where surface run-off is not a problem, as this material can result in damage to nearby plants. Headlands are sprayed with 2,4,5-T, plus Weedazol.

Cold frames are used for the protection of Lavander, Rosemary, *Hypericum*, *Berberis*, *Cotoneaster*, *Cistus*, *Phlomis* and Senecio.

The rooting medium consists of the parent loam + 2″-3″ of grit and 2″ of peat, well forked to a depth of 9″. After this it is rotovated to obtain a more consistent tilth.

When the frames are vacant during the summer, Basamid at the rate of 4 oz/7′ of 4′6″ wide frame, is used as a sterilant.

Cuttings are taken from early September to the end of October. The first are 4″ long cuttings of lavanders and rosemaries which are treated with Seradix 3 and generally these will root before winter. This reduces winter losses. Deciduous *Berberis* are then taken, using a mallet or nodal type cuttings. Berberis *b., thunbergii* and *B., ottawensis* cultivars lend themselves to both types of cuttings. Seradix 3 is used as the rooting powder.

Evergreen Berberis cuttings are taken at the end of September to early October and given the same treatment as the deciduous types. *Berberis stenophylla* lends itself to a nodal type of cutting.

Of the other genera mentioned for Cotoneasters, heel type cuttings are taken. Those of *Cistus*, *Phlomis* and *Senecio* are nodal. Seradix 3 is used in all cases.

A spray line is placed along the center of the frame, and shading is applied immediately. This shading is removed during the November to January period and replaced during February.

When rooted, the cuttings are hardened off and potted as soon as they have a large enough root system.

The Mist Unit is in use most of the year with the exception of the winter months. Due to the decline in demand for conifers and the cost of electricity, a system of seed trays is used so as to facilitate ease of handling.

The rooting medium in most cases consists of 50% peat and grit mix but occasionally coarse sand is used for subjects needing a drier medium, which includes *Lonicera* and *Ceanothus*.

The bottom heat is set at 18°C which is left on throughout the summer so as to keep an even basal temperature during the night.

Once the cuttings have rooted they are weaned off by placing them on the path for a week. There they receive some spray but no bottom heat. Once weaned they are placed in a poly tunnel and fed with a liquid feed diluted to 1 in 200. After a period of 3 weeks they are then potted. It has been noted that once the rooted cuttings have taken up the liquid feed and started growing they withstand any root disturbance much better.

Polythene Tunnels. These consist of railway sleeper sides at 3′9″ spacing with heavy gauge wire hoops fixed to pre-drilled holes at 3′ spacings. The frame is dug over to improve drainage. On this is placed 2″-3″ of peat and grit. Old mix from the mist unit is ideal. This is followed by a 2″ layer of plasterer's sand which is fairly coarse, giving good drainage. An irrigation line is placed along the center of the frame suspended 8″-9″ above the rooting medium.

Cuttings are normally taken from mid-June onwards: 4″-5″ long cuttings are placed into pre-formed holes and watered in.

A roll of 6′ wide 250 gauge white polythene is placed over the hoops and secured with battens to the sleeper sides. An important point is that the nails are only hammered in half way so as to facilitate ease of removing the battens to check on the progress of the cuttings.

The irrigation line is turned on every 2 hours for 1 minute on warm days. On cooler days every 3 hours. It has been noted that if the number of sprays are decreased in hot weather, some scorching does take place.

The irrigation lines are permanently connected to the mains so as to prevent foreign matter entering the lines and so causing costly blockages.

The cuttings are normally rooted within 4 to 5 weeks and, once rooting has taken place, some air is admitted to the tunnel. An important point to note is that, if possible, cuttings of the same duration in rooting should be placed in the same tunnel so as to get uniform rooting.

Most cultivars of plants on the nursery root very well with this method. These include *Viburnum*, *Weigela*, *Cornus*, *Callicarpa*, and *Kerria*. It has been noticed that with *Cornus*, in particular, if the polythene is left on too long after they have rooted, botyrtis soon starts, so constant checking is vital.

One other method tried in these tunnels is rooting the cuttings in trays of sand. This seems to work equally well and, in fact, we shall be using this method next year. A great advantage is that when the cuttings have rooted they can be moved and the tunnel can be used again the same year. Instead of peat and grit, a 2" layer of gravel is placed under the trays.

Potting is carried out from the beginning of February to the end of August. Any done after that date gives poor results due to plants not being established before the winter.

All potting is carried out by hand using 3" poly pots. These are a little slower to use but the compost used consists of 50% peat, 25% loam, 25% grit by volume and made up to J.I.2 strength with Vitax Q4.

Once potted, the plants are placed in an Airfax or Correx tray at 40 per tray. They are placed in a polythene house to become established. Shading is needed during summer.

Once established, the liners are placed in a standing-out bed to harden off. At this stage Vitax 101 liquid feed is used at the rate of 1 in 200 in 50% of the waterings. This has been found to give a steady mature growth.

EFFECT OF TWO TEMPERATURE REGIMES ON ROOTING CUTTINGS

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Abstract: Cuttings of 19 different genera and cultivars were rooted by the warm bench and plastic system. The base temperature was thermostatically controlled at 21-24°C. The air temperature was 15.6°C minimum. In most cases rooting was as good or better when the heating current was cut off for 12 hours daily than when it was available for 24 hours, with economy in cost of electricity.

In these days of high energy costs, economy in the use of electricity for the maintenance of base temperature in the propagating bench is an obvious necessity.

In a previous season (January 1971) an attempt was made to save electricity by reducing the base temperature in a mist unit from the standard 21°-24°C to 16°-18°C. In several species the result was reduced rooting (Table 1). *Viburnum davidii*, however, gave better rooting at the lower temperature. *Ilex* 'Golden King' also showed some indication of higher rooting percentage at 16°-18°C.

Similar results were obtained with cuttings of the same species rooted under plastic instead of mist. Although these were unreplicated observational trials they indicate some scope fact, we shall be using this method next year. A great advantage is that when the cuttings have rooted they can be moved and the tunnel can be used again the same year. Instead of peat and grit, a 2" layer of gravel is placed under the trays.

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Table 1: Percent rooting of cuttings under 2 temperature regimes.

Species	Base temperature °C	
	21 - 24	16 - 18
Mahonia japonica	87%	79%
Osmanthus heterophyllus 'Variegatus'	20	0
Camellia 'M. Pratt'	60	52
C. 'Nagasaki'	65	35
Viburnum davidii	37	56

for further work on those species which will root as well or better at lower temperature regimes. The results, though, may not prove advantageous with many species.

In more recent trials (November 1976, March 1977) promising results have been obtained under the warm bench and plastic system by cutting off the electric current for 12 hours each day as compared with leaving it on continuously. The thermostat was set at 21°-24°C, and a time switch set to cut off the current at 10 a.m. and on again at 10 p.m. each day. Over a wide range of genera, as good or better percent rooting was obtained as when the current was not switched off (Table 2).

Table 2. Percent rooting of cuttings with 12 or 24 hour base heat.

Species	12 hours	24 hours
Prunus laurocerasus 'Otto Luyken'	77%	60%
Rosmarinus 'McConnell's Blue	92	92
Chamaecyparis l. awsoniana 'Fraseri'	75	42
Juniperus chinensis 'Pfitzerana Aurea'	47	42
J. chinensis 'Pfitzerana Glauca'	70	55
Juniperus virginiana 'Skyrocket'	55	55
Elaeagnus pungens 'Maculata'	30	32
Berberis verruculosa	12	0
Berberis × *ottawensis*	37	30
Ceanothus 'Southmead'	87	35
Choisya ternata	97	97
Hypericum 'Rowallane'	63	48
Senecio greyii	90	94
Camellia 'Salutation'	20	16
Ilex 'Handsworth 'Silver Queen'	97	100
Grevillea rosmarinifolia	80	87
Cupressocyparis leylandii	22	50
Viburnum davidii	62	95
Coronilla glauca	57	70

Only in the last four species out of 19 listed was rooting reduced by the shorter period of electricity supply. The number of units of electricity saved over 3.53 m^2 of bench space varied from 74.5 for a quick rooting species like *Prunus laurocerasus* 'Otto Luyken' to 225.75 for slow rooting species such as *Chamaecyparis lawsoniana* 'Fraseri'. If the cost of a unit is taken to be 2.5p, this represents savings of from £1.86 to £5.65

from this limited area of bench for periods of 27 days and 57 days respectively, in a glasshouse with a minimum air temperature of 15.6°C. These results indicate the possibility of quite substantial savings in costs, with as good or better percentage rooting, for many woody plants propagated from cuttings. The warm bench and plastic method employed would have the advantage over mist of greater insulation and of the absence of cooling effect due to the evaporation of water which takes place in a mist unit.

Thanks are due to F.J. Nutty for assistance in carrying out these trials.

STOCK PLANT MANAGEMENT

JOHN STANLEY

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The first stage in any production cycle is obtaining the propagation material of the right quality in the quantity required. As techniques become more exacting it is becoming increasingly important to have full control over propagation material from the earliest possible stages. This thinking has brought about an increasing awareness of the use of ornamental stock beds for vegetative propagation material and seed orchards for seed.

Sources of Vegetative Material. Cuttings can come from one of three sources:

1. *Saleable plants in the nursery*. It is only feasible to take cuttings if this fits in with normal trimming, otherwise you may be cutting away saleable material.

2. *Plants outside your control*. Many nurserymen still collect cuttings from local gardens, the wild and parkland areas. This material inevitably has an unknown history and often involves excessive labour and transport costs to obtain.

3. *Stock Beds/Hedges*. The advantage of a stock area is that the history of the plant is known and can be controlled. The plant is grown purely for the purpose of producing the right type of cutting at the right time. Large batches of cuttings are within easy reach, which reduces time and money when collecting. The plants can be easily managed and even manipulated to produce the cutting material required. The disadvantages of a stock area are that it takes up valuable land and that costs are involved in managing this area. Many people often imagine a small arboretum mushrooming in their nursery, but by planting hedgerows in lines 3m apart and 450 mm apart in

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the row, it is possible to plant 6,500 stock plants per ha and still manage the crop using a tractor.

Siting of Stock Grounds. Cutting hedges or beds are a long term crop and therefore initial preplanting preparations must be thorough. A site should be selected that is fairly sheltered (from wind and frost pockets), yet has plenty of light, (plants in shade often produce undesirable material for cuttings). The soil should be of the correct structure and of a suitable pH for the plants being selected. The site should be suitably drained and free of perennial weeds, pests and soilborne diseases.

Planting. Plants should be true to type, uniform and correctly labelled as far as name and source are concerned. At Merrist Wood, newly purchased or received plants that go into the Stock Ground are given an entry number. The first two digits signify the donor and the last two the year in which they were received, e.g. *Hamamelis mollis* 1577 indicates Schumacher, U.S.A., obtained in 1977.

There are many plants in the trade that are grown under different names or have clonal variations. It is essential that we, as propagators, know the source of our stock and continually check and compare the identities of those stock plants being propagated. Where possible the best clone or form for the particular species required should be used. In Denmark at the Hornum Research Station, research work is being carried out with this in mind. A trial ground has been established where different clones of particular species have been gathered. The Research Station propagates 100 plants of the best clone and sends these to the F.S.H. (similar to N.S.A.).* The F.S.H. bulks up these plants and distributes them to the trade. The plants will be sold as O.P.G. (Optimum Pathogen and Genetic Plants). To date, *Forsythia*, *Pyracantha*, *Hypericum*, *Ribes* and *Rosa* have been completed in the trials. At present *Cotoneaster horizontalis* and *Berberis* are being tried.

Similar interest is now being shown at Long Ashton Research Station, Bristol.

Plants should also be pathogen-free when planted. In the British Isles this often means free of *Phytophthora*, especially in conifers and ericaceous plants.

When I toured the United States I was able to visit Forest Keeling Nurseries in Illinois. They have an interesting project of selecting *Quercus robur* 'Fastigiata' which is resistant to Oak Mildew whilst in the nursery. They felt this would be an excellent landscape tree if this problem could be overcome. Once 'clean' material was obtained this plant would be incorporated into their stock areas.

* Nuclear Stock Association.

The same time of work could be carried out in this country to "clean up" such plants as *Vinca* to reduce losses at propagation, but to select for genetic variation for disease resistance is harder in genera that are not conveniently propagated from seed.

Stockbed Management. At the end of this paper is the routine maintenance programme for the Stock Ground at Merrist Wood. It must be pointed out that this is a rather extensive programme, but we have the advantage of large student participation.

A number of important points are worth considering when managing these plants:

1. *Nutritional Status of Stock Plants.* It is important to maintain a vigorous mother plant, but also remembering that the rooting of cuttings depends on the nitrogen:carbohydrate ratio in that plant. An excess nitrogen feed can result in the wrong type of cutting and a reduction in rooting potential.

In the U.S.A. they feed stock plants at higher rates than in this country.

Example: Chase Nursery, Alabama:

Every spring	45% N (Urea).	Rate equivalent to 450 kg/ha.
Every other year also	0-20-20 Feed.	Rate equivalent to 340 kg/ha.

In this country very little work has been carried out on stock bed feeding. Foliar feeding is preferred by many as the nitrogen and potassium can move freely within the plant. Information, at present, is lacking on the number of applications to get maximum response from the plant or the number which causes harm. A suitable foliar feed for stock plants is a 20-20-20 (N, P_2O_5, K_2O), fertilizer applied at the rate of 225 g of the compound fertilizer per 450 litres of foliar feed to be applied.

2. *Age of Stock Plants.* Generally juvenile material roots better than adult material. This cannot be taken as a golden rule, as some subjects, e.g. *Thuja occidentalis*, seem to root just as well from old as young material.

The effects of juvenility on stock plants has been mentioned before at IPPS Conferences, but the importance of it cannot be overstressed. This seems to necessitate a planned removal and replacement programmed for stock plants. At Merrist Wood *Calluna* and *Erica* cultivars are replaced every three years enabling us to keep a healthy and young stock bed.

3. *Pruning Treatments.* Pruning methods can help maintain or induce juvenility. At planting many subjects should be pruned back to induce them to bush out near the base and produce vigorous cuttings.

4. *Weed Control.* Residual herbicides can be root pruners if used consistently on the same piece of ground around the same plants. Because of this, a selection of herbicides should be used, both residual and contact.

5. *Irrigation.* The rooting of cuttings is in relation to their water content, although the water content of cuttings varies with species and age. It is therefore important that the cutting is removed from the stock plant in a turgid state and remains so until it is in the rooting environment. With this in mind it is important that the stock plant be healthy and turgid when cuttings are removed which, in dry spells, may mean irrigating the plants the day before cuttings are taken.

The cuttings must not be allowed to wilt in transit to the cutting preparation area. In the United States, where they have very large numbers of cuttings to handle, they often have elaborate storage chambers with mist units in the ceiling where cuttings are stored in a turgid state until time is allocated for their preparation.

The Future. I feel a few major developments may occur in stock plant production.

Firstly, if the trend continues in nursery production, as it has in other areas of horticulture, we may see our stock plants grown hydroponically under cover. Although initially this would prove expensive, it may be an ideal method for certain subjects, either producing more crops per year or inducing the right type of cutting for propagation.

The second advancement may be by our scientists inducing stock plants to start rooting whilst on the mother plant. We can already see this with the dwarf cherry rootstock, 'Colt', and other plants may be induced to react similarly.

In many American nurseries they are using gibberellic acid to manipulate plant growth and it seems a logical progression to use this type of chemical in the Stock Ground.

It may now be time to question our traditional technique of stooling certain plants, e.g. apple rootstocks; either an alternative technique should be sought, such as hardwood cuttings as a propagation method or, if the plant does not respond, then an alternative method to "earthing up" should be considered. Synthetic foams would give the darkness and moisture required and would be a far easier method to handle during the stooling programme.

ROUTINE MAINTENANCE OF MERRIST WOOD STOCK GROUND

Area: 2.5 ha. Plant Entries: 1,000.

	STOOL BEDS	LAYERING	PRUNING	SPRAYING	COLLECTING	LIFTING	MISCELLANEOUS	PLANTING
JAN	Unearthing, lifting, grading.		Fruit and ornamentals for budwood production.	Propyzamide for couch control.	Hardwood cuttings (ornamentals and fruit) and hard prune s/plants. Buddleia cuttings. Conifer cuttings.	Perennials for division and plants for root cuttings.	Drainage. Ditch maintenance.	
FEB		*SIMPLE LAYERING*. Lift tip layers of blackberries and loganberries. Lift ornamental layers.			Hardwood cuttings (ornamentals and fruit) for E.M. cutting bin. (Hard prune S/plants). Conifer cuttings.	Perennials for division.	Check labels and tree ties and stakes.	
MAR		*TRENCH LAYERING*. Peg down Prunus F12/1 FRENCH LAYERING Pegging down.	Stock for soft and semi-nature cuttings. Stock for hardwood cuttings.	Simazine to weed-free beds.	Scion wood for grafting and hard prune s/plants. Conifer cuttings and pruning.			Final planting and moving of deciduous stock.
APR	1st earthing up of Malus rootstocks, quince A & *Aronia prunifolia*.	*SIMPLE LAYERING*. Ornamentals, pegging down.	Broadleaved evergreens for cutting production.	Lenacil - perennials, heathers, etc. Fruit and ornamentals for aphids. Junipers for webber moth.	Softwood cuttings. e.g. Hypericum Spiraea.		Set up irrigation for these.	Perennials, Conifers, Evergreens.
MAY	2nd earthing up of stool beds.	*TRENCH/ FRENCH LAYERING*. 1st earthing up. SIMPLE LAYERING. Ornamentals - pegging down.		Kelthane against conifer-spinning mites (esp. junipers). Benomyl soil drench to cherry layer beds to prevent *Thielaviopsis basicola*. Rate: 150 gm to 90 m row.	Softwood cuttings.		MULCHING rhodos, heathers.	Perennials (then spray Lenacil) (irrigation)
JUN	3rd earthing up of stool beds.	*TRENCH/ FRENCH LAYERING*. 2nd earthing up.	Summer pruning of conifers.	Paraquat if necessary. Spray Aphicide.	Scion wood for budding. Cuttings of heathers & other ornamentals.			

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JUL	Final earthing up of stool beds.	*LAYERING.* Strawberry runners. *TRENCH/ FRENCH LAYERING.* Final earthing up.		WEED CONTROL. Hand weeding of layer beds. Repeat residual herbicide applications if necessary.	Cuttings of ornamentals. Scion wood.			
AUG		*LAYERING.* Tip layering blackberries and loganberries.		Early Aug. spray against juniper webber moth (Malathion). Spray weeds as necessary.	Cuttings of ornamentals. Scion wood.			
SEP				Apply Basamid granules for new heather & conifer beds.	Cutting material of conifers and broadleaved evergreens.		Check labels and tree ties and stakes.	Conifers and broadleaved evergreens.
OCT			Raspberries, blackberries and loganberries.		Cutting material of conifers, evergreen shrubs. *Berberis*, etc. Seed of trees/shrubs.		Deep ploughing of fallow land inc. FYM prior to planting.	Conifers and broadleaved evergreens.
NOV	Unearthing, lifting, grading.	*SIMPLE LAYERING.* Lift layers of ornamentals then prune mother plants.			Hardwood cuttings (fruit/ ornamentals) and hard prune s/plants. Cuttings of cofifer and broadleaved evergreens.	Raspberry spawn for lining out.		Deciduous stock, through to March.
DEC	Unearthing, lifting, grading.	*TRENCH/ FRENCH LAYERING.* Lifting and grading.		Fruit with tar-oil or DNOC/ petroleum oil to control over-wintering pests.	Hardwood cuttings of ornamentals and fruit and hard prune s/plants. Conifer cuttings.	Plants for root cuttings.		Replant for future root cutting material.

AN INVESTIGATION OF THE PLANT *HOSTA FORTUNEI* 'AUREO MACULATA' ('ALBOPICTA') TO FIND RAPID METHODS OF PROPAGATION

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As hostas are valuable ground cover plants and also in demand for flower arrangers, it was decided to look at this plant from a propagation viewpoint. The work was a practical project carried out with 5 BSc III degree students at the West of Scotland College over 10 hours of the October-December Term (the rest of the practical work being carried out by nursery staff). We found very few references to the propagation of hostas and relied on the R.H.S. Dictionary for basic information (1). Hostas are named after the Austrian Botanist Nicolaus Thomas Host (1761-1834) and the plant belongs to the family Liliaceae.

Methods of Propagation

1) *Seed.* As *H. fortunei* does not set seed regularly and progeny would not be true-to-type, we discounted this method.

2) *Division*, the usual method of increasing hostas. Five plants were lifted on 13th October, soil washed from them, placed in peat and put in the cold store (4-6°C; 90-100° R.H.) for 50 days (to simulate the winter dormant period). On December 2nd the plants were removed, two used for division, and two held for "In Vitro" culture, and one for use of buds in leaf cuttings and roots for root cuttings.

After removing the peat it was concluded that instead of just obtaining 3 or 4 plants from division, thorough washing revealed the available buds and roots to be 16 on 1 plant and 12 on the other. After cutting into individual buds plus roots, they were then dusted with Captan at the cut surface and the 16 individual buds + roots potted directly into J.I. No. 1 in 4" (10 cms) black poly bags and kept in a cool greenhouse. The reason for using 4" bags was the length of roots, plus the growth habit of the plant. The 12 from the other plant were planted directly into a frame and covered with dutch lights.

3) *In Vitro.* The remaining two plants were used for *in vitro* culture. As the result of hearing an American speaker at the Eastern Region Conference at Rutgers University in August 1976, it was decided to try this method too. It is easy to make up the medium as one is able to buy packeted units of Murashige & Skoog medium and then add plant hormones as required. We carried out the work on a lamina flow bench and

then placed the tubes in an incubator with a 16-hour/day illumination.

No contamination occurred but unfortunately no growth either. This was possibly due to the procedure not being attempted at the correct time. It may be better to use plants which have overwintered outside, and to attempt the method in the spring. We hope to continue with this by contacting the U.S.A. speaker.

4) *Leaves.* As this plant is a member of the Liliaceae it was decided to try the individual leaves in a manner similar to lily scales. Some leaves stayed alive for several weeks but no sign of regeneration occurred.

5) *Roots.* These were made into root cuttings but again no success.

In Conclusion. Until we can be successful with *in vitro* culture we concluded that by very thorough washing of the lifted plants which revealed many more buds than first apparent, it is possible to use a single bud + roots which did make reasonable sized plants and in fact were sold in July. The plants in the frame also developed well but would have to be left for a season before being lifted and potted up or planted out.

LITERATURE CITED

1. Dictionary of Gardening. Royal Horticultural Society, London, 1951.

PRODUCTION OF EUCALYPTUS

JOHN J. COSTIN

Sap, Ltd.,
Carbury, Co. Kildare

The eucalyptus embody many of the desirable characteristics that a diligent plant breeder would endeavor to collect into one plant, if set the task of breeding a modern tree. They are evergreen, fast growing and virtually without pests and diseases in this country and have both amenity and forestry values. Nevertheless eucalyptus are not as widely planted as they should be. A popular misconception is that they are soft and will not grow in the greater area of the British Isles. Our experience suggest that with the proper seed provenance and exact cultural programme, excellent results can be obtained with eucalyptus.

Eucalyptus have many modern potential uses because of their rapid growth and evergreen canopy. They must be considered as a serious contender as a quick temporary replacement in areas ravaged by Dutch Elm Disease, or as a screen for industhen placed the tubes in an incubator with a 16-hour/day illumination.

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Eucalyptus have many modern potential uses because of their rapid growth and evergreen canopy. They must be considered as a serious contender as a quick temporary replacement in areas ravaged by Dutch Elm Disease, or as a screen for industrial and mining sites, and in our parks where vandalism would only improve their growth. Species such as *Eucalyptus viminalis* will stand some oil around their roots.

The table below shows the growth rates achieved by various species in Great Britain and Ireland (1).

Species	Measurement (ft.)	Location
Eucalyptus aggregata	59′ × 2′4″ in 15 years	Cornwall
coccifera	105 × 6′9″	Avondale, Co. Wicklow
dalrympleana	80′ × 6′4″ in 30 years	Mt. Usher, Co. Wicklow
glaucescens	52′ × 2′6″ in 12 years	Devon
globulus	47′ × 1′9″ in 5 years	Co. Kerry
gunnii	35′ × 1′3″ in 6 years	Oxford
johnstonii	111′ × 9′2″ in 65 years	Mt. Usher, Co. Wicklow
	62′ × 2′2″ in 14 years	Co. Down
mitchelliana	25′ × 1′4″ in 8 years	Surrey
nitens	37′ × - in 4 years	Argyll
perriniana	70′ × 4′ in 32 years	Co. Down
	44′ × 1′8″ in 11 years	Hampshire
pulverulenta	31′ × 1′0″ in 10 years	Devon
simmonsii	55′ × 2′11″ in 21 years	Edinburgh
viminalis	35′ × 1′5″ in 9 years	Devon
	118′ × 14′7″ in 65 years	Mt. Usher, Co. Wicklow

Botanical. Over 500 species have now been recorded and the work continues (2). Of these over 150 species have been grown or assessed for hardiness in Ireland (2). They are members of *Myrtaceae* family. Most have simple straightforward leaves, untoothed and unlobed. They have well marked stages in the two year growth of their evergreen leaves. These stages are commercially important for some enterprises. The juvenile foliage is very often round shaped, and leaves appear opposite each other in pairs. The adult foliage is alternate and isobilateral. They are totally different in shape, usually being long, narrow and willow-like. Grey green is the most common foliage colour. Leaves of some species are apple green, silver grey, blue grey and even purple or pink tinged in the young stages. The juvenile foliage, which is often used for floristry, can be maintained by annual cutting.

Most of the hardier species have the typical strong eucalyptus oil fragrance. Leaves of most quiver continuously in the wind, a feature rare in evergreen trees. The bark peels on many species, to reveal smooth trunks of great beauty; white in F. *dalrympleana*, E. *niphophila* and E. *viminalis*, orange in E. *johnstonii* or salmon pink in E. *rubida*. The bark shedding species are the main types grown in Ireland.

Hardiness. The eucalyptus are more associated with Australia than any tree is with any country. No other single genus of tree dominate so vast and climatically so diverse an area. According to the F.A.O., there are 512 million acres of forest in Australia. Broadleaves dominate 97% of these forests and in these broadleaf forests, 94% are dominated by eucalyptus (3).

Their ecological range is therefore enormous from the tropical forests at Darwin to the snowy mountain passes in Tasmania. The genus does not occur naturally in New Zealand. Within this enormous range of ecological niches, surely many provenances of species exist which when properly grown and systematically tested should be suitable for our climate.

Seed Provenance. The name of a species is no guide to its hardiness. The natural occurrences of most of the 500 species found in Australia are localized. However within the locality of natural occurrence of a species there may be a great range in altitude - over 1200 m in some cases. Thus trees at the lower level rarely encounter frost whilst at the higher reaches the same species may be surviving frequent and severe frosts.

Table 1. Lowest temperatures eucalyptus species are known to survive.

− 12°C	− 14°C	− 16°C	− 18°C or more
E. cordata	*E. glaucescens*	*E. johnstonii*	*E. coccifera*
E. dalrympleana	*E. parvifolia*	*E. perriniana*	*E. gunnii*
E. mitchelliana		*E. urnigera*	*E. nitens*
E. rubida			*E. niphophila*
E. stellulata			

Minimum temperatures are in any case a poor guide but they are only simple facts readily available. Other factors which influence hardiness depend on:

1. The rate of freezing.
2. The age of the plant.
3. Exposure to the wind.
4. Time of planting.
5. Seed provenance.
6. Cultural treatment in raising the plants.

The older the plant the more certain it is of surviving severe cold. For trees with substantial stems even if cut back they will invariably grow away from the live bark at the bottom and become within 12 months even more handsome and better furnished specimens. Thus in 1971 there were some notable recoveries on tender species damaged by an unusually severe frost of − 16°C in the Dublin area.

Hard, cold, incessant winds do more damage than frost. Young plants should be unstaked in order that the plant develop a strong sturdy stem. We plant out in the summer and early autumn and cut back the resultant growth to 45cm the following May and to 150cm the following year. This we find gives us a sturdy, windfirm tree well furnished and minus stakes.

Seed Sources. Altitude is the most important factor, when looking for a seed source. Seed from New South Wales should be from an altitude higher than 1200m and higher than 900m in Tasmania (4). Throughout the world eucalyptus is raised from seed, as no worthwhile method of vegetative propagation has yet been found. In our climate selection of clones for special purposes has not taken place. Consequently there has not been a pressing need to develop vegetative propagation methods. We have succeeded in rooting some juvenile stems of *E. globulus* while some success in grafting red flowered species has been made in California (5).

Seed Treatment. Eucalyptus seed is extremely small, as shown in the table below.

Seeds of various species of Eucalyptus (6).

Species	No. of seeds per gram
Eucalyptus dalrympleana	450
Eucalyptus delegatensis	360
Eucalyptus globulus	90
Eucalyptus regnans	350

Seeds of alpine species can be erratic in germination. A cold, wet treatment improves germination of *E. perriniana* and *E. johnstonii*. We mix the seed with water, shake well, seal the vessel and place it in the bottom of a domestic refrigerator as per the method outlined by Barnard (4,6). Watch the seed for germination after 3-4 weeks.

Germination. We produce 20,000 seedlings per year at present. We mix a compost of 2 parts peat to 1 part of sand and fill the seed trays. We put 0.5 cm of granite sand on top of this mixture and we sow the seed uncovered on top of the sand. The seed trays are placed in a heated propagation house at a temperature + 18°C in March, and the trays are covered with 50 gauge clear polythene.

Germination starts in 6 to 14 days. As the cotyledons emerge, the plastic is gradually cut and eventually removed within 7 days as the seedlings harden off. No water is given until there is a good stand of seedlings. As soon as the first true leaves emerge the plants are pricked off into 8 cm peat pots. The young plants are established in these pots on true capillary beds (where the water is controlled by a ball-cock) in an opaque polythene tunnel which prevents sun scorch. If necessary we seal the doors of 30 × 5 m plastic houses to get even more rapid establishment. When the roots start emerging through the peat pots the plants are 15-20 cm tall, we pot on again into 15 or 17.5 cm polythene containers.

We use pure peat for all our potting composts. At the pricking out stage we use Osmocote at one quarter of the recommended rate (0.6 Kg/M^3). For the final potting we use 1.4 Kg/M^3. These rates give excellent growth on capillary beds.

Eucalyptus roots. Eucalyptus have a rapid growing tap root system. The plants are very sensitive to root damage and are intolerant of any root restriction. A nurseryman's natural inclination is to pot on a small seedling into a 10-12 cm pot. However a 17 cm holds twice as much compost as a 12 cm pot. When we place this size container on a capillary bed not only do we not get any rooting through but the adequate supply of water seems to retard the development of a coarse and fangy root system.

For subsequent establishment, a young vigorous root system is preferable to a coarse root. For these reasons we find that 17 cm container is ideal for the production of quality plants provided watering is by automatic capillary beds.

Worldwide research indicates that young plants not more than 4 months old and 45 cm tall give best establishment. Our production system offers a good compromise between what is the ideal plant and planting time for eucalyptus and popular prejudices favoring traditional tree planting practices.

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1. Mitchell, A., private communication.
2. Official Yearbook of the Commonwealth of Australia, 1973.
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6. Raising Eucalyptus Seedlings. Commonwealth of Australia, Forestry and Timber Bureau.

SOME OBSERVATIONS OF THE NURSERY INDUSTRY IN AUSTRALIA

R.F. MARTYR

Pershore College of Horticulture
Pershore, Worcs.

The initiative for my six months visit to Australia came from the Queensland Nurserymen's Association; the reason was their concern about the absence of adequate training facilities for the nursery industry and the opportunity was provided by a temporary vacancy at the Queensland Agricultural College. The objective was to encourage and advise on setting up courses — particularly technical and technological courses — directed towards the needs of the nursery industry. Horticulture has a very low status in Australia — and the ornamental section is quite mended rate (0.6 Kg/M^3). For the final potting we use 1.4 Kg/M^3. These rates give excellent growth on capillary beds.

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Australia is a very large country, about the size of the U.S. but with only 13 million people. It is easy, therefore, for us over here to get the impression of a thinly spread rural community. Nothing is further from the truth. It is an overwhelmingly urban and suburban population. Brisbane, alone of the state capitals, has less than 50% of the whole population of its own State. As land is not the limiting factor that it is in Europe the homesteads are generous and the potential for plant consumption is enormous. There has been tremendous property development in the past two decades and the market for plants has been extensive. Thanks to the generosity of the Q.N.A. and other organizations I had the opportunity of visits to Sydney, Canberra and Melbourne (twice) speaking at meetings and conferences and visiting nurseries and educational establishments.

Statistics of the nursery industry are somewhat misleading. In most States anyone who sells any plants must register as a nurseryman, so one gets a large number of inactive, or purely amateur, part-time and substandard enterprises as well as the *bona fide* nursery businesses and garden centres. This arrangement no doubt has its advantages but I do feel that it is one of the causes of the low status that the industry undeservedly has in most quarters. The industry has evolved a long way from its back garden ancestry but I found most Australians quite unaware of the sophistication of modern plant production and certainly completely unaware of its possibilities as a career for young people.

Each State has its own Nurserymen's Association and their membership lists give a better idea of the size and strength of the industry in Australia. Until a year or two ago these State Associations were loosely joined into an all-Australian Federation but now an Australian Nurserymen's Association has been formed which is active in the political field and can speak with an authoritative voice. It has recently started its own publication — "The Australian Nurseryman". The A.N.A. can also sponsor schemes such as the Green Survival campaign, Plant of the Month scheme, and it is currently working hard for the establishment of a Plant Variety Rights scheme. There is a tremendous demand for information. Conferences organized by the A.N.A. or other responsible bodies are eagerly attended from all over the country. Hence, of course; the very rapid and successful development of the I.P.P.S. Australian Region.

The Development of the Nursery Industry. If a date has to be given for the start of the present vigorous buoyant Nursery Industry in Australia it would have to be 1960 — and the event, the arrival of Dr. Kenneth Baker from the University of California to the Waite Agricultural Research unit at Adelaide on a Fulbright scholarship. He brought not only his expertise on the U.C. composts and plant nutrition but developed the aerated steaming techniques of soils. Every large established grower to whom I spoke agreed that this was a turning point if not indeed *the* turning point of large scale nursery development in Australia. The same principles apply today though the mechanics have changed — viz. by mixing 6-1/2 lbs air to 1 lb of steam at 212°F you get aerated steam at 140°F which provides effective pasteurization, without problems of re-infection, always a serious problem under their conditions, when a biological vacuum is caused by raising the temperature to 212°F. Furthermore there is less toxicity and less cost. Much of their seed is treated in this way before sowing also. This breakthrough in sanitation made their modern nursery production possible. In the U.K. we have no conception of the dominating importance of disease control in those warmer climates. Ruin is the inevitable result of a failure to control *Phytophthora*.

But Baker's visit did more than introduce a valuable new technique. It broke an isolation and provided the catalyst for further co-operation and development. Without the support at that time from Government Research Stations or Universities, the expanding industry learned the importance of self reliance and found its own sources of information and developed its own technology.

This inventive skill and highly developed ingenuity throughout their production must be my most vivid impression in all my contacts with the horticultural industry in Australia. Two examples of this: Firstly their attitude to plant tissue culture, which is more positive than is the case in the U.K. Growers are seeking training in the techniques and they see a wide use of the methods in the future; perhaps under their conditions and with important families, such as the palms, it will have a deeper impact upon the Australian nursery production than will be the case over here. Certainly they are preparing for such a contingency.

It is difficult to choose from the several ingenious examples of mechanical adaptation for the second example but I was particularly impressed by their use of suction pressure and a template to sow seeds in boxes (or beds). One nursery (and indeed perhaps more) have mechanized the whole operation of boxfilling, seed sowing and spacing out.

Containerized Production. The industry is almost entirely based on containerized plants, hence the importance of mastering hygiene and the value of the U.C. experience. Bare-root production is virtually unknown for ornamentals and found only in raising citrus and some other fruit stocks.

There are no real supplies of peat in Australia — and such as there is does not approximate the standard we know. It has been imported mainly from Germany but its cost (more than 3 times the cost here) is pricing it out of the market. Sawdust and shredded bark are both used as substitutes and the Scoresby Horticultural Station in Victoria is evaluating different materials and trestments. Sawdust is rather more variable than supplies which are available in the U.S.A. and care is needed. I saw variable results and some disasters — in one case a saprophytic fungus causing a brick-hard layer mid-way down the pots (I notice that this was also reported in N.S.W. in the 1975 I.P.P.S. Proceedings.) Eucalyptus sawdust (hard wood) is said to contain resin and decays very slowly — it remains in excellent physical condition after 18 months in containers. It is also acid and needs careful adjustment both to pH and nitrogen to stabilize the correct C/N ratio. Many growers seem to use it without composting and, when used alone, this can cause overheating. Also I think that ammonium release causes damage with seedlings and cuttings. The reluctance to compost is due to problems of space and stock piling as well as the labour it would entail but I would not like to take such a risk. Recommendations for the detailed treatment of sawdust with water and urea from the N.S.W. Research Station at Gosford are given in the 1976 I.P.P.S. Proceedings. Their recommendation also is to mix sawdust and medium sand in equal quantities.

The more I see of the problems of using peat substitutes the more I hope that peat of the quality and uniformity we get in the U.K. does not price itself out of the grower's market.

The good natural growing conditions in Australia are exploited to the full, and unnecessary operations are cut out ruthlessly. Hence the tendency to strike cuttings individually in containers. Space is used to the fullest economy.

Australians use the term "greenhouse" and, wisely so, for in Queensland, at least "glasshouses" are comparatively rare and need protection from hail which comes with a severity and frequency quite unknown in Western Europe. Wire netting is an essential outer protection.

Standing grounds. Usually shading is an essential requirement. Shade houses of saran cloth or lath are used but it was interesting to see how the natural shade canopy of the Gum trees is sometimes used. Standing grounds may be graded out of the natural forest. The base must be capable of complete insulation from *Phytophthora* — black plastic may be the cheapest but infection can spread rapidly from plant to plant as the drainage water flows. The only satisfactory standing medium is a deep enough layer of gravel so that the seepage from infected plants runs vertically through.

The tremendous potential of Australian plants. This is my second vivid impression of my stay in Australia. Imagine the feelings of Joseph Banks in 1770 on landing at Botany Bay — faced by an entirely new and different flora — a new world! An extraordinary rich flora of some 850 general and perhaps 15,000 species — about 3,000 brought into cultivation and it is estimated that some 6 to 8,000 are worthy of horticultural development. What a fantastically challenging and inspiring state of affairs! But the tasks of clonal selection, improved forms and hybridization has hardly begun. There is a reason for this in that the demand for native plants has grown so rapidly that the nurseryman has been hard put to propagate sufficient material of what is easily available let alone spend his time in further selection.

Incidentally this is probably one of the reasons why the Australian buyer is less critical about quality than his European or American counterpart. Some of the material which found a ready market would not be saleable elsewhere.

The introduction of many of the Australian native plants into commercial production is fraught with difficulty, for their requirements can be remarkably specific and they are often disappointingly short lived. Nevertheless the development of more reliable and better species and cultivars is a task which will face the propagator for many years.

Amongst the best examples of nursery improvement are the callistemons of which fine named cultivars are now available. The importance of perfecting techniques to propagate the eucalyptus vegetatively soon becomes evident when one sees the range of form and flower colour available in seed grown plants. To me one of the most fascinating was *Eucalyptus ficifolia* with every shade of pink, red, orange or maroon flowers — furthermore, of course, eucalyptus hybridize readily and it is becoming more and more difficult to ensure true seed.

When the early colonists went to Australia the desire was to make it as much like home as possible — hence the introduction of as many of their European garden plants as would stand the changed conditions and even now some suburban gardens around Melbourne look remarkably like their counterparts in Britain. It is not surprising however that a reaction has set in and that to the members of the Australian society for growing native plants the term 'exotic' is almost a dirty word.

Sometimes their case is stated with vehemence. At a Conference I attended at Canberra tempers got quite frayed until someone quietly reminded the assembly that everyone in the room (save only a single delegate from Papua - New Guinea) was an exotic and that it was therefore obviously a problem which demanded reason and compromise.

Rich though the Australian flora is it has added no major food plant to human knowledge — the nearest being the macadamia or Queensland nut (*Macadamia ternifolia*) and I believe that production is now greater in Hawaii than in Australia. Sadly it is too expensive for the European market for I considered it outstandingly the best flavoured nut.

Status of the Amenity Horticulturist. Some of the prestigious Botanic Gardens — Canberra, in particular, are superb and the large cities have creditable parks but, generally speaking, the status of the amenity horticulturist is abysmally low. It has hardly any claim to professional status. There are few horticulturally trained people and higher supervision in the Parks service is normally in the hands of the City or Shire Engineer or Surveyor whose horticultural knowledge was low and his interest sometimes non-existent.

In Queensland, apart from the main cities, the misuse of plants in roads and public places made one despair. Shrub pruning frequently meant hacking down to ground level irrespective of horticultural habit and the time was decided by the availability of (unskilled) labour without reference to the needs of the plant. Along the highways every Authority seemed to have the right to hack, remove or burn the trees at will; electricity authorities, telephone and road engineers left behind them a trail of vandalism, mutilation without compunction and, more regretfully without any apparent expression of public indignation. It was the accepted norm. Doubtless this was not true of all districts but I saw enough to appreciate the extent of the problem.

All this, of course, has had a disastrous effect on the status of the horticulturist in the amenity field — and into recruitment into horticulture generally. No one in the careers advisory field would consider ornamental horticulture as being able to provide worthwhile careers at all and there will be an uphill battle to change public opinion. This degree-oriented society has neglected to train the technician. There are certainly no shortages of training courses for the landscape architect — but an acute problem exists to turn their plans into fact and to provide the skilled maintenance once a scheme has been planted up.

An Australian Institute of Horticulture has been formed comprising graduate membership of all those interested in horticulture and it numbers amongst its aims that of improving the status of the professional horticulturist. It merits the active support of every such person in Australia.

Need for technical staff. The limiting factor in the extension of many nurseries must be the need for technical staff. Many enterprises have grown as large as the family can supervise and manage themselves. Any increase in production must be sufficiently large to pay for the necessary injection of additional managerial and/or technical staff — of which, of course, there is an acute shortage. The Federal Government tends to consider all horticultural jobs as being suitable for the unemployed.

Horticultural education. The opportunities for horticultural education have reflected the generally low status of the profession and industry in Australia and at all levels from degree to apprenticeship they have been less than is available in any other developed country. In a degree-oriented economy, horticulture has suffered by having no degree except a final year elective and this is no way to attract the plantsman. The nurserymen or Parks Superintendent has as yet no flow of people trained technically at OND or NCH level. Day release or short courses at technical colleges such as Ryde and Canberra give training roughly comparable to City and Guilds Stage I and II. But there are large areas where even this was unavailable. I thought the practical facilities much too basic.

However, things are beginning to change and the needs are well recognized by the leaders of the nursery industry. They will be seeking to fill the monstrous gap in technological and higher technical training for they have outstripped the educational and training facilities available to them. Australia's most famous horticultural college, Burnley in Melbourne has entry requirements and course content roughly equivalent to an HND in this country (without, however, the "sandwich" content). Without disrespect to that college — for it has a famous and honoured history — yet I felt that in this present day the Burnley student was tending to fall between two stools. In the graduate-oriented world he found himself he was not qualified to compete for the higher professional posts; however his training was not sufficiently orientated to industrial needs to enable him to fall into jobs of responsibility on the nursery. Labour costs are high and no grower can be expected to pay "fancy college wages," as he calls them, and teach the practical and supervisory skills himself. Hopefully, this is a gap which the Queensland Agricultural College is seeking to fill.

Lest any Australian who chances to read this and feels that these personal observations are too critical particularly in view of such a limited experience of this vast country, let me conclude by emphasizing that my strongest impression was that of a dynamic and effective industry with a potential which must make anyone in the U.K. envious.

BENCH ROOT GRAFTING OF WISTARIA

D.J. WICKENS
Waterers Nurseries
Bagshot, Surrey

Understocks. Sow the seeds, which are usually obtained from the Continent, in prepared seed beds at the beginning of May. Cover with 1/4" sand. Inspect after about ten days to check that they have chitted; if so add a further 1/4" of sand. Do this in two stages as we have found decay to be a problem if the seeds are covered too deeply initially.

About early December, or when the leaves have fallen, lift the understocks. It is important to lift them with as much fibrous root attached as possible. If using an undercutter, check that the blade is 10" to 12" below the surface. Store the seedlings in boxes between layers of moist peat in a cold glasshouse.

Bench Preparation. In January prepare a heated bench with a 50/50 peat-sand mix to a depth of 5". Ensure this is well moistened. Heat bench to 55°F. Switch on 2 to 3 days in advance. Cover with a polythene tent.

Collection of Scion Material and Preparation of Grafts. Take scion material from stock plants and dip in Captan solution. Cut scions into sections about 6" long with three buds. The scions should have 1-1/2" of stem below the bottom bud. The rootstocks should be washed free of soil. Place on a wire tray to drain.

Head the rootstock below the cotyledons and trim the roots. It is possible to use sections of the understock. Use a reverse veneer graft; ensure that the cambium layers meet. Use rubber ties about 5-1/2" × 1/8", starting the tie from the lower end. Leave 1/8" gap between ties for callus expansion. Tie the full length of the cut, finishing with half hitch with end coming out on top so that it does not run.

Place grafts in trenches in the prepared case, space evenly and neatly. Cover union to 1/2" to aid callusing. The polythene should be about 6" above the top of the scion. Leave for about six weeks. Ventilate about once a week for first three weeks, then more frequently. Check for damping off and that the compost is still moist.

When root development starts, pot plants into 50/50 peat sand mix, making sure union is below compost level. It is important to be able to shade the plants at this time of the year. When potting, return plants to a similar environment to that of the propagation house.

WHY GRAFT?

PHILIP McMILLAN BROWSE

Brooksby Agricultural College
Melton Mowbray, Leicestershire

"Grafting is the technique of joining two plants or parts of plants together in such a manner that they will unite and continue their growth as an integrated individual."

The operation requires skill and expertise which essentially comes in two parts:

1) The Carpentry aspects, which are specifically manual and

2) The Husbandry aspects which are concerned with the knowledge and ability to prepare the rootstocks prior to grafting and to give subsequent aftercare.

These operations, however, are inevitably costly despite available skills, training to improve speed and efficiency, and the availability of knowledge which will ensure adequate productivity. This system of propagation is expensive. It is not, therefore, surprising that so much of modern research programmes are concerned with looking for alternative methods of plant propagation so that plants may be produced both more simply and cheaply.

On occasions, however, grafting cannot be avoided or, alternatively, it may be used as a positive technique. These notes have thus been produced to provide a brief summary of the reasons why plants may still be grafted on the nursery, and hence the title, "Why Graft?"

Thus, despite the complexity of the technique, grafting is still used as a tool of plant propagation and the following constitute some of the major reasons for its continued use:

a) To propagate vegetatively a plant which is not easily or conveniently propagated by any other conventional method.

b) To obtain the benefits of a particular rootstock.

1) *Pest and disease resistance*; e.g. the Malling-Merton series of apple rootstocks with their resistance to wooly aphid and the mazzard F12/1, with its resistance to bacterial canker.

2) *Toleration of particular or changeable soil conditions*; e.g. *Rhododendron* 'Cunningham's White', which will withstand higher pH than the traditional *R. ponticum*; and *Rosa* × *noisettiana* 'Manettii', with its ability to withstand a wide range of soil moisture deficit and pC ranges.

3) *Control of vigour*, e.g. the clonal fruit tree rootstocks: the E.M. and M.M. series, the various quince rootstocks, and 'Colt', 'Pixie', etc.

c) *Changing the cultivar of established plants*, e.g. family trees, pollinating branches, stem building, framework grafting, etc.

d) *Hastening the development of seedling selections*; this technique appears to overcome juvenility and induce earlier flowering, thus accelerating breeding programmes for plants with long periods of juvenility.

e) *Repair of ornamental/amenity subjects*, e.g. bridge grafts to repair bark ringing; crotch strengthening, etc.

f) *As a tool in plant study and especially as a technique in virus indexing.*

All these reasons for grafting may decline in importance with time as plant breeders screen plants for other than purely ornamental characters, but that day is still in the future. However, one day all bush roses will be grown on their own roots, and clonal tree selections will be selected for their rootability and life may be easier!

In conclusion, there is one certainty when grafting plants — that the resultant crop must warrant the expense and that this is recouped in its selling price.

IDEAS FROM THE NURSERY PRACTICE FIELD PRODUCTION UNIT

DAVID A. HUSBAND

Somerset College of Agriculture and Horticulture
Somerset, Cannington, Bridgwater

INTRODUCTION

The aim of the unit is to be basically self-perpetuating, enabling students to gain an insight to field production of fruit and ornamental subjects. We have no glasshouse on site. It is an old site, with many years of horticultural use behind it comprising 0.557 ha, or so, total land, with approximately 60m^2 of seed beds, and 800m^2 of layer beds, and seven cropping plots averaging 440m^2 each.

Where possible, the propagating material — (i.e. cuttings, bud sticks, or grafting scions) comes from stockplants lined out as "hedges" in between plots.

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PRODUCTION FIGURES

The figures we give are what we aim for. These are arrived at by multiplying the number of students requiring tuition by the number of plants each student will require to reach an acceptable standard during the teaching time; e.g., 20 students requiring 30 stocks to bud/graft will require 600 stocks — all of which must be of a suitable subject for the type *of graft proposed* (e.g. chip-bud, whip and tongue graft).

Our 1976/7 statistics were:

1. Worked trees: 1500 stocks in all; approximately 800 apples, 300 prunes, 100 pears, 300 ornamentals.
   - APPLES: 600 domestic fruit cvs., 200 ornamental crab apples
   - PRUNUS: 60 domestic plums, 100 ornamental prunus, 140 ornamental cherries
   - PEARS: 20 ornamental pears, 80 domestic pears (40 to show double working)
   - ORNAMENTALS: 20 ash - weeping, cut leaved, 50 *Acer platanoides* 'Crimson King', *A. pseudoplatanus* 'Brilliantissimum,' 50 *Aesculus* × *carnea* 'Briotii,' 50 *Sorbus* - Joseph Rock, matsumurana, poterifolia, 50 *Betula* b. *papyrifera*, *B. pendula* 'Youngii,' *B. utilis*, 80 *Crataegus* - double red, Glastonbury thorn

2. Roses: 1000 to 1200 stocks are planted; worked as bush roses to floribunda and tea roses.

3. Soft Fruits: Bushes, approximately 1000, comprising 500 blackcurrants, 20 redcurrants, 300 gooseberries.

4. Slow-Growing: shrubs, conifers. Approximately 500.

5. Quick-Growing Trees: *Salix* from H/W cuttings, a) Made and lined out November, b) Made and lined out through black polythene, c) Made November. Cold stored, and planted out in April/May. Approximately 100.

6. Herbaceous Plants: Approximately 1500 - Various spp and cvs.

7. Shrubs From Hardwood Cuttings: Approximately 1500 - Various spp and cvs.

8. Strawberry Runners: Approximately 1000; 3 or 4 cvs, bought in as 'A' Certificate Stock each year.

Plans of the area show the way in which these crops rotate, with a grass ley following the worked trees, and the 1 year crop following the roses, before the worked trees.

The worked trees are grown in 1 plot for 3 years.
Year 1. Plant rootstock in November; bud in July
Year 2. Graft in April; cut hard back in November
Year 3. Train/feather; lift in November

These worked trees are either (a) disposed of at this stage - (fruit trees mainly), or (b) lined out in plot J for a growing-on period of 2 or more years, or (c) used for teaching and assessment purposes.

An important feature of the Unit is the area allocated to layers. The keynote of this area is the production of usable stocks and ornamental trees and shrubs, without the use of heated or other glass structures, without recourse to expensive equipment of any source.

Layering is in two main parts.

1. Raising of fruit tree rootstock, and ornamental rootstocks.
   A. Mound layers - Apples: M.9, M.26, M.7, MM.106, MM.111, M.16, and M.25.. Pears: Quince A. Syringa: *Syringa tomentella*, *S. vulgaris*.
   B. Trench layering - Cherry: 'F/12/1. Plum: 'Myrobalan B,' 'Brompton,' 'St. Julien A.'
2. Raising of ornamental trees and shrubs.
   C. French layering -
      Cornus alba 'Sibirica', and similar cvs.
      C. stolonifera
      Viburnum tomentosum and similar spp.
      V. × bodnantense
      Liquidambar (Enabling named coloured forms to be handled)
      Cotinus coggygria 'Royal Purple'
      Weigela florida 'Foliis purpureis'
      Corylus contorta
   D. Simple layering - A selection of the stool plants of *Liquidambar*, *Tilia*, *Syringa* and cultivars are simple layered to produce a larger plant in the first year.
3. Field Working. The establishment of trees from field lined stock is economic, and needs no capital apart from the stock itself. Again, no capital outlay on expensive equipment is required. Rather "less than easy" lines are looked at. Success to some limited degree has been achieved in the case of seedless chestnut - *Aesculus × carnea* 'Briotii,' on to 1-year seedlings of *Aesculus hippocastanum*.

Birch — *Betula papyrifera*, *B. pendula* 'Youngii', *B. utilis*. All these from *buds* - (chip - budding). With *Betula*, it is important to line out *small* stocks, and to bud them in late July or so. Grafting on these has not proved very successful.

Walnuts — Fruiting cultivars of walnuts have been worked in the traditional manner (grafted in early spring on to seedlings, in a closed area, using both heat and containing the plants afterwards).

Beech — Purple beech worked in the field on seedlings has proved successful.

CONCLUSION

In all, we feel that the nursery field unit at Cannington produces:

1) A lot of interest in the economic production of hardy plants.

2) A fair measure of skill in the keen student.

3) A good basic understanding of propagation by seed, layers, cuttings and grafting.

PROPAGATION OF CAULIFLOWER FROM CUTTINGS

MICHAEL FARMER

Rosewarne Experimental Horticulture Station
Cornwall

It is very difficult to grow seed from Cornish winter cauliflower (broccoli). They mature in the middle of winter, and so cannot be left to seed in the field. Transplanting to a glasshouse is rarely successful owing to their susceptibility to bacterial rots developing both in the pith of the stem and also in the middle of the curd.

To overcome this problem, various methods have been tried to propagate vegetative shoots. These vegetative shoots can be grown under glass to produce plants with relatively thin stems and small heads which are not susceptible to bacterial rots and which can produce high yields of seed.

Some research work in Edinburgh about fifty years ago demonstrated that pieces of cauliflower curd could be propagated successfully. Following this, at Seale Hayne College it was found that when rooted pieces of curd were grown on in a warm glasshouse, the flower buds aborted and vegetative shoots developed on the inflorescence.

This technique has given quite useful results but it needs very strict attention to hygiene at all stages. Also it has the disadvantage of a long delay in development of shoots and the late cultivars may fail to seed in the following year if there is a delay in planting.

In the course of this propagation work it was noticed that some plants formed adventitious shoots at the base of the stem. Such shoots were much more suitable, but not all plants produced them. Some French visitors to Rosewarne E.H.S. noted these basal shoots and made further experiments which have

Beech — Purple beech worked in the field on seedlings has proved successful.

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In the course of this propagation work it was noticed that some plants formed adventitious shoots at the base of the stem. Such shoots were much more suitable, but not all plants produced them. Some French visitors to Rosewarne E.H.S. noted these basal shoots and made further experiments which have developed into a very successful technique which is far superior to the use of curd cuttings.

The mother stock plants are selected in the field. When they have developed enough to make sure that they have no serious faults, the heads are cut off and the leaves are trimmed to the stem. The stumps are dug up and washed free of soil. They may also be dipped, as a precaution against disease, in permanganate or thiram or Benlate.

In Brittany, large plastic tunnels are used for seed production and one of these is used for the stumps and the soil is first covered with a 3 inch layer of calcareous sand (very similar to Hayle sand). About half the roots are covered in the sand; the rest left exposed. The stumps are planted at an angle of about 45 degrees so that the exposed roots are pointed upwards.

Adventitious shoots develop in a month or six weeks generally. Some of these are basal shoots from the stems and others grow from the exposed roots. Twenty or more shoots per plant are usually obtained. These shoots can be cut off as they develop and will root easily under mist or in a propagating case. Alternatively, sand can be ridged up around the stumps so that the roots may develop naturally but fewer cuttings are obtained by this method.

This technique is so simple that growers themselves can obtain seed from their very best plants. Any keen grower should be able to select plants which are suited to his own soil, climate and market requirements. With a medium sized plastic tunnel he should be able to grow 20 or 30 lbs of seed.

There are perhaps two points of interest from the propagator's angle:

1. *Apical Dominance.* The cauliflower appears to have very strongly developed apical dominance so that no shoots can be obtained until the head is removed. Experiments have been made with hormone treatments to break this dominance but they have not been very successful so far.

2. *Root Shoots.* The number and vigour of these shoots is quite remarkable and possibly it would be interesting to know if there are other plants which would respond in a similar way.

GRAFTING CERTAIN CLIMBING PLANTS

TOM ALLEN

James Coles & Sons, Thurnby, Leics.

CLEMATIS

Stocks. One can produce one's own or buy them in. If the latter, order them early the year before, in June or July. Stock plants should be set aside early and potted on into large pots around Christmas time and placed in a warm house, 50 to 60°F. The first scions should be ready in February.

Method: Side Graft. Plants then potted on into 2-1/2" pots and placed in closed cases, at a temperature of 70-75°F. Benlate is widely used on all clematis crops in order to combat *Botrytis* and, on growing plants, for mildew; application is every two weeks. Grafted plants should start to grow within the next month. They are removed from the case when buds are 1/8" high and placed on an open bench. They are staked with 12" splits when ready and moved into a cooler house. They should be ready for potting by the end of May/early June and will make good plants in flower by the middle to end of August.

PARTHENOCISSUS TRICUSPIDATA 'VEITCHII'

Stocks. Bought or grown from hardwood cuttings. *Parthenocissus quinquifolia* stocks are lifted as required. Scions are also gathered as required.

Grafting. This starts early in January. A side or cleft graft is used. Grafted plants are potted into 2-1/2" pots and then into a closed case, bottom heat: 70 to 75°F. Root action is very quick. Callus soon forms on top of the stocks and the buds soon start to swell. When runners start the plants can be removed to an open bench. We have found it good policy to stake the plants as soon as the runners are about 6" long. Plants are potted into selling pots in June and will make good size for selling by August.

PROPAGATION OF *ACER PLATANOIDES* WALDERSII

IVAN R. DICKINGS

Notcutts Nurseries Ltd.
Woodbridge, Suffolk

This cultivar is similar to *Acer pseudoplatanus* 'Brilliantissimum' with young leaves opening out to a shrimp pink but more lacey in appearance. The leaves then turn to a creamy white, veined and speckled with green.

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Preparation. Established pot grown stocks of *Acer platanoides* are brought into a cool, airy house 4 to 6 weeks prior to grafting. When they are suitably dried off, grafting can commence which takes place in late January.

Operation. The stocks are cut back to within 2" to 3" of the soil. The type of graft used is a side whip and is tied with thin rubber strips. The scion wood used is 6" long terminal shoots.

Aftercare. When grafted, the plants are plunged into moist peat with the union covered in a closed case with 65°F bottom heat. In about three weeks callus is visible and top growth begins. At this stage air is gradually applied and watering can take place. After hardening off, the plants are stood on an open shaded bench and, when weather permits, the plants are planted into a cold frame.

TOP GRAFTING OF *ACER PSEUDOPLATANUS* 'BRILLIANTISSIMUM'

LESLIE MORGAN

H. Merryweather and Sons Ltd.
Southwell, Notts.

In 1975 I was asked to produce a small quantity of *Acer pseudoplatanus* 'Brilliantissimum' trees by the management for their retail outlet.

Understocks. I had no potted *Acer pseudoplatanus* understocks available at the time so I had to use three-year-old seedlings dug straight from the field, prior to grafting.

Scion Material. My scion material was in short supply, mainly because this tree had always been bought in before. I had one 10-year-old tree available at the nursery and had also found a much older specimen in a nearby village. The scion material was one-year-old wood and it was treated in two different ways. Material off the young plant was cut in mid-winter and heeled-in in peat and sand in an outside open frame. Material off the older plant was cut just before grafting.

Grafting Procedure. I grafted *Acer pseudoplatanus* 'Brilliantissimum' in mid-February. The method I used was the splice graft. This is a very simple graft — just like the whip and tongue without the tongue. First the understock was dug and then brought under cover, all side shoots were trimmed up and then the stocks were cut off at the appropriate grafting height. They were then grafted with 15 cm scions. These were tied in with Rapidex ties. The resulting grafts were not waxed, but were covered with a 20 cm square clear polythene bag. This was tied with another Rapidex tie. The resulting grafted trees

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Aftercare. The grafted trees were watered regularly and any understock suckers rubbed off. After 4 to 6 weeks callus formation could be seen on the grafts, but I left the polythene bags on until I saw the scions bursting into growth — the polythene bags were then removed. The Rapidex ties were left tied around the graft as long as possible in order to create a good union and were finally removed three months after grafting. An overall grafting take of 85% was achieved. The young trees were left inside to form a good head; when this was achieved they were taken outside.

Observations. There seems to be no need to have established potted understocks as long as the understocks from outside are grafted and potted while fresh. The difference between heeled-in and fresh scions is insignificant, so fresh-cut scions can be used for *Acer pseudoplatanus* 'Brilliantissimum' as long as the timing of grafting is right. I have continued this basic grafting method in 1976 and 1977 with a few slight variations in that I have tried two-year-old stems and also inside scion material. The younger stems form a much better match with the scion material so forming a good graft union. Inside scion material has much stronger growth and the takes seem just as good with this material.

HARDWOOD CUTTINGS — FIELD PRODUCTION

NAT CLAYTON and JOHN RICHARDSON

E.R. Johnson (Nurseries) Limited
Whixley, York.

Production Lists. These are made up bearing in mind what we think we can sell, what we need for growing on, and the amount of land available. Four lists are made — two for office records and one each for the propagator and planting foreman. There has been an increased demand for *Sambucus*, *Symphoricarpos*, bush *Salix*, and *Populus* over the last few years for screening and planting industrial sites. Land has now become our most limiting factor against increased production.

Cuttings. Cuttings are taken from stock hedges or any other source available. They are made approximately 6″ long of one year wood, the material being no thinner than a pencil. Thicker material makes the better plants eventually. We start with *Sambucus* as soon as possible in late October and November as these cuttings are from hedges which will be cut by a contractor as soon as the sugar beets have been harvested. The *Sambucus* were potted immediately and then taken to a cold greenhouse and watered in.

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The number of cuttings produced daily varies with cultivars from 700 *Sambucus* to 1200 *Salix* per person per day. We know that these figures can be improved upon but so far have not developed the right machine.

Land. A suitable area is selected as early as possible; the land must be clean and free from perennial weeds, old tree roots, etc. All our land is a light sandy loam. Sometimes, depending on the previous crop, a light dressing of F.Y.M., is given at 20 tons per acre and then ploughed and left until the February/March planting time. The land is rotovated twice and run up into beds using the tractor wheels to mark the beds; it is then left to settle. We plant four rows to the bed with rows at 12″, with cuttings 3″ apart in the rows, giving 90,000 cuttings per acre. The planting machine, which is homemade, cuts four slits with knife coulters which close up immediately, but they push stones, etc., out of the way so that there is a mark, and cuttings can be inserted easily to the depth of the coulter. The machine requires four persons — two abreast, and plants 6,000 cuttings per hour. Cuttings are lifted from sand beds into black Dale trays which can be carried on the machine. Cuttings are pushed in as deep as possible until only 1″ is showing. Fluffiness of the soil does not seem to have any adverse effect and we have found no firming necessary. Labelling is done at the time of planting.

Aftercare. Cuttings are sprayed as soon as possible with 1-1/2 lbs Gesatop (3/4 lb active simazine). We sidehoe when necessary, usually about twice, then all that is needed is a walk over to take the odd weeds from the rows. We apply 3 cwt - (12.8.18) fertilizer in May when the cuttings have rooted and are growing away.

Lifting. An Egadal type bed-lifter behind a David Brown 995 tractor on high clearance is used for undercutting. We lift and grade as orders are required and, later, all the remaining plants are removed and replanted making good big plants the following year.

Comments. We are gradually increasing the number of shrubs propagated in this way as we find the cultivars which can root easily and the cutting material becomes available. We get a good plant in one year which is often up to and above the specification required for landscape contracting work and the smaller plants are much better liners than ones from soft or semi-hardwood cuttings. So far we are having success with cultivars from the following genera: *Cornus*, *Forsythia*, *Philadelphus*, *Ribes*, *Sambucus canadenis* (or *nigra*?) 'aurea' and *S. racemosa*, *Spirea*, *Weigela* and *Privet*.

Economics. The economics of nursery stock has always baffled us, as every cost assumed to be constant seems to change immediately it is used. No doubt this is why we are still in business, as those with true business acumen have found easier ways of making money. In deciding to expand the production of hardwood cuttings, we have made a comparison with other nursery crops, not only on the return per plant or per acre, but on the labour requirement, both in number of hours, and the time of year, the use of existing equipment, the present sales demand, and the sales potential.

However attractive a crop appears to be to grow, it cannot be an economic proposition if the labour requirements of the crop clash with other tasks already employing all available labour, and it is unlikely that mechanization can entirely overcome the problem.

The cultivars of cuttings being produced are based on three factors: will it root, does it sell, or can we make it sell? Secondary factors to consider have been the availability of stock plants, who should make the cuttings, the propagator as a routine, or should the work be saved as a bad weather job? Should the cuttings be made at the site of the stock plant or prepared indoors and how should they be bundled? Should they be layed in outdoors or indoors, in soil or in sand? All these points are labour intensive, and other work may suffer if production increases quickly.

It would appear from our own experience that mechanized planting is an advantage where more than 50,000 cuttings are to be lined out, though this figure may well be higher if a suitable machine has to be purchased. We have not considered that planting machines have been successful in the past, as the soil is left comparatively loose around the cutting and the base is not firmly in contact with the bottom of trench which, rightly or wrongly, we have considered to be of major importance.

Efficient use of labour is now essential, and it is interesting to consider that in 1976, cuttings were inserted at the rate of 10,000 per short day by three women and, in 1977, four women and a tractor driver were planting 30,000 cuttings per short day and enjoying it!!

We have ignored ground preparation in comparative costings as this is similar for most crops, but it has become obvious that production from hardwoods is still the most economic way of producing many plants, and when we have improved the system of producing cutting material and improved the speed at which cuttings are made, by machine cutting, together with a change of attitude by the propagators so that they no longer look upon each cutting as an individual, then we can consider further expansion in cutting production with confidence.

We have seen increasing interest in tenders for shrubs in the 45 to 60 cm size and, by selecting cuttings, it should be quite possible to supply strong sturdy shrubs of this size in one year. We have not yet overcome the difficulty of producing two-year transplants of willows, poplars, etc., with a central leader but only 45 to 60 cm high, which is a specification often quoted in the North, and any suggestions would be appreciated.

EFFECT OF SPACING ON THE ROOTING OF *CHAMAECYPARIS*

J.C. KELLY

Kinsealy Research Centre, Agricultural Institute
Malahide Road, Dublin 5, Ireland

Abstract. In an attempt to maximize production from a given area of heated propagation bench, it is common practice for plant propagators to space cuttings densely. The close spacing of cuttings of cultivars of *Chamaecyparis lawsoniana* reduced rooting and the results show that this was wasteful of labour and propagating material. Less densely placed cuttings showed satisfactory rooting and a lower death rate.

MATERIALS AND METHODS

In two randomized factorial experiments carried out at Kinsealy Research Centre, the effect of spacing of *Chamaecyparis lawsoniana* cultivar cuttings in the propagation bench was studied. In 1969, basal cuttings (i.e. those removed from the parent plant by cutting through the junction of the new and older wood) of cultivars 'Fraseri' and 'Pottenii' were prepared for propagation. The cuttings were immersed in a solution of captan (3 gm per litre of water). After being allowed to dry, the bases of the cuttings were dipped in a proprietary powder containing 0.8% indolebutyric acid (IBA).

The cuttings were inserted in propagation trays containing a mixture of two parts moss peat to one of sand and placed in a mist unit. Heat was applied to the bases of the cuttings by and a tractor driver were planting 30,000 cuttings per short day and enjoying it!!

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The cuttings were inserted in propagation trays containing a mixture of two parts moss peat to one of sand and placed in a mist unit. Heat was applied to the bases of the cuttings by means of soil warming cables and a temperature of 21° to 24°C was maintained thermostatically. The minimum air temperature was 15°C.

The cuttings, inserted on January 5 and recorded for rooting on April 10, were at two densities — 20 and 40 per 450 cm^2. Table 1 shows the rooting response to density. The figures in parenthesis indicate numbers ball-rooted (i.e. with numerous roots so that they lifted with a ball of rooting medium adhering).

Table 1. Effect of two spacings[1] on rooting of cuttings of *Chamaecyparis lawsoniana* cvs.

Cultivar	Spacing	Total number rooted	Percentage rooted
'Fraseri'	Wide	51 (17) N.S.	64
	Narrow	40 (0)	24
'Pottenii'	Wide	71 (29)*	89
	Narrow	108 (37)	68

N.S. = not significant
* = significant at 1% level
[1] = four replicates fully randomized, with guard rows

A further randomized factorial experiment was carried out in 1977 to test the effect on rooting of spacing densities using the cultivars, 'Allumii' and 'Drummondii'. The former represents a cultivar which has proven relatively easy to root and the latter, a cultivar found more difficult to root under conditions at Kinsealy. Stem cuttings (i.e. cuttings removed from the parent plant by cutting above the joint of new and old wood) were prepared in the same manner as above described and were propagated under similar conditions. There were three densities of cutting insertion — 25, 50 and 100 per 750 cm^2. The date of insertion was February 8 and the cuttings were recorded for rooting on May 6. The results are shown in Table 2. Figures in parenthesis indicate numbers ball-rooted.

Table 2. Effect of three spacings[1] in rooting cuttings of *Chamaecyparis lawsoniana* cvs.

Cultivar	Spacing	Total number rooted		Percentage rooted
'Allumii'	Wide	78 (63)	N.S.	78
	Medium	82 (67)		41
	Narrow	74 (50)		18.5
'Drummondii'	Wide	45 (20)	N.S.	45
	Medium	70 (23)		35
	Narrow	56 (30)		14

[1] = four replicates fully randomized.
N.S. = not significant.

RESULTS

The trial in which *C. lawsoniana* 'Fraseri' and *C. lawsoniana* 'Pottenii' were tested indicated little difference in numbers between the two spacing densities and in number of plantlets with a large root system. It was particularly noticeable that the cuttings at the perimeter of the propagating boxes were very well rooted irrespective of spacing and this suggests the importance of light for successful rooting during the winter. With *C. lawsoniana* 'Fraseri' there was no significant difference among the treatments in numbers rooted, but with *C. lawsoniana* 'Pottenii' (a very easy-to-root cultivar) there were higher numbers rooted in the narrow spacing. This indicates that for the easy rooting cultivars, spacing is less important than for difficult-to-root cultivars.

Where *C. lawsoniana* 'Allumii' and *C. lawsoniana* 'Drummondii' were tested, very high numbers of cuttings died due to basal and foliage rot at the medium and narrow spacings. The total numbers of cuttings inserted at the medium and narrow spacings were 200 and 400 respectively and of *C. lawsoniana* 'Allumii', 126 and 319 died, and of *C. lawsoniana* 'Drummondii', 126 and 342 cuttings died whereas at the wide spacing 15 and 38, respectively, died. There was no significant difference in numbers rooted among spacings within each cultivar.

DISCUSSION

To obtain optimum rooting in a given area of heated propagating bench the results show the risk of overcrowding cuttings. This is especially true of the difficult-to-root types of *Chamaecyparis lawsoniana*. An exception would appear to be those cultivars which are easily rooted, as demonstrated by the experiment with *C. lawsoniana* 'Pottenii'.

SCALE PROPAGATION OF LILIES WITH CONTROLLED TEMPERATURE STORAGE

J. EATON

Rosewarne Experimental Horticulture Station
Cornwall

Lily bulbs are produced on a field scale at Rosewarne Experimental Horticulture Station, Cambourne, Cornwall. As the large bulbs are sold off, small bulbs must be raised each year for replanting and the best method is by scaling. Any lily grower, large or small, can use this simple method which is both fascinating and offers the means of rapidly increasing your stock of bulbs. The method is as follows:

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Do the scaling in September or October. Select only the largest bulbs for scaling as these are the most likely to be healthy. Pull away the outer scales snapping them away from the bulb near the base. Discard any damaged or diseased scales and you can replant the center portion of the old bulb. Treat the scales with fungicide by soaking for 1/2 hour in Benlate (4 grams/litre) or in Captafol if Benlate-resistant penicilliums are likely to be present. Drain off and mix scales with an equal quantity of damp vermiculite or peat and seal up in a polythene bag. Use not more than about 2 bulbs per bag; large quantities of scales in one bag do not obtain sufficient oxygen and rot. Damp (not wet) vermiculite is important. Store the bags for about 2 months at a temperature of 70 - 75°F (the bottom of the airing cupboard is about right) until nice little pea-size bulblets have grown on the scales.

Harden off slightly by storing for a further month at about 60 to 65°F before opening the bags and planting out the scales together with the attached bulblets in 2 inch deep drills in an open frame or bed in December or January. Avoid deep planting since few of the scales bulbils will produce foliage the first year. We then cover the bed with 1 inch of sand and peat, this mulches the young plants and saves a lot of weeding.

Keep well hand-weeded, kill any greenfly, and bait regularly against slugs and you will have a large number of nice medium sized bulbs for planting out next year.

We have propagated Asiatic, Aurelian, and Oriental Section hybrids very successfully by this method. I did not have satisfactory results with one attempt with *Lilium superbum*, and the American hybrids may not be so successful. *L. testaceum* is satisfactory but, as it makes only basal leaves the first year, it must be planted very shallowly and sprayed regularly against *Botrytis*.

DOUBLE TUNNEL PROPAGATION

S. WARD

Horticultural Centre, Loughgall
Co. Armagh, N. Ireland

Recent increases in oil and electricity prices have considerably raised the production costs of shrubs using traditional techniques. Glasshouse management, especially programmes involving the use of intermittent mist, have had to be reviewed in economic terms so that maximum returns can be achieved. Any alternative techniques requiring lower capital investment

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At Loughgall our interest turned to polythene as an acceptable alternative in terms of economic attractiveness. As a result of many variations on the theme we developed a simple and cheap method using the basic concept of small "inner" tunnels constructed inside a large tunnel giving the Double Tunnel effect. Over a number of seasons several combinations of milky and clear UVI polythene have been tried. Experience and results gained at Loughgall made it possible for a propagation programme to be recommended. Local growers adopted this technique with considerable commercial success. Subjects suitable for this technique are generally the wide range of popular shrubs produced from summer cuttings or traditionally rooted over-winter in a cold frame. However, following original recommendations, growers using this system have successfully rooted a range of subjects previously propagated with mist, e.g. conifers and some semi-hardy shrubs. Consequently any increase in propagating capacity has been through the use of this system.

Facilities. The main requirement is a ventilated walk-through polythene structure 5.0 m (16½ ft) wide clad in clear UVI 500 gauge (125 μ) polythene. Correct siting is an essential feature both for ventilation and protection of the structure. Preference should be given to a site with a slight slope (1 in 50) protected from extreme weather conditions yet allowing through ventilation at all times of the year. Flexibility in ventilation may be achieved by using door frames with the lower half covered in polythene to prevent damage from low level draughts and the top half with an open mesh type windbreak material. Inside the outer tunnel three rooting beds, each 1.2 m (4 ft) wide × 152 mm (6 in), are constructed using treated timber 152 × 38 mm (6 in × 1½ in). These beds are lined with 500 gauge (125 μ) builders grade polythene to isolate the rooting medium from the soil and also to minimize watering. The liner is turned up at the sides and attached either by timber lathes or tacked in place using an industrial tacking machine. Free drainage is ensured by leaving the liner flat at the lower end of the beds. Hoops of high tensile galvanized wire are spaced at one metre intervals over the beds. They may be pushed into the ground or attached to the timber, preferably on the inside of the beds. Spacing can be stabilized centrally using polypropylene string and the ends strengthened by inclining two hoops together. Hoop profiles must be 'D' shaped providing an average height across the beds between the rooting medium and cover of 356 mm (14 in). The beds are either filled to a depth of 125 mm (5 in) with the recommended rooting compost, or with loose moist peat if containers (pots, trays etc.) are to be used. A sheet 1.83 m (6 ft) wide of either clear UVI or 'milky' 250 gauge (65 μ) polythene depending on the season is laid over the hoops to form low inner tunnels. When the sheet is laid loosely over a correctly constructed bed, there should be an overlap of 150 mm (6 in) which is essential to make a condensation seal to maintain humidity. At each hoop, polypropylene string loops over the tunnel will prevent excess movement. Access and ventilation are gained from the side by sliding the polythene cover upwards on the hoops.

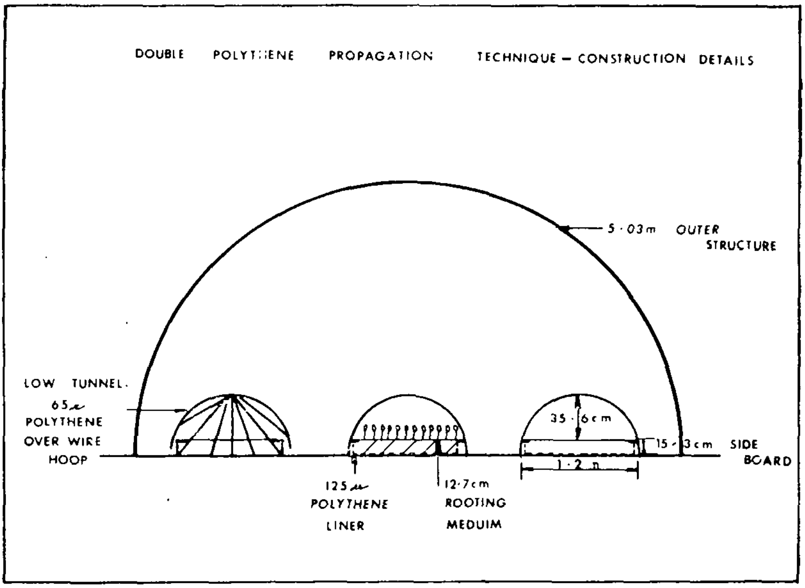

Figure 1. Diagram showing construction of "double tunnel".

Propagation material. Cuttings taken from vigorous juvenile current season's growth should be an average of 100 to 150 mm (4 to 6 in) long after any soft tip growth has been removed. In this technique the bases of the summer cuttings should be semi-ripe i.e., lignification having commenced. The cuttings are larger and more robust than mist type material so that the use of stock plants or hedges is recommended. Winter cuttings can also be rooted using this technique but material should be at a semi-hard to hardwood stage, i.e., lignification advanced. Growth has normally ceased and bud dormancy, especially on evergreen species, is established.

Preparation of cuttings. The majority of species are prepared as nodal cuttings. Foliage removal is minimal and only shallow insertion is required. Material must be collected and trimmed as quickly as possible to reduce loss of turgidity before insertion. If delays are likely to occur then cuttings can be stored at 3 to 4°C in polythene bags. Storage time however should not exceed two days for maximum success.

Insertion. Cuttings can either be inserted directly into the prepared moistened rooting medium or into containers depending on the growing system employed on the nursery. In order to achieve and maintain the correct microclimate within the inner tunnels frequent hand sprayings to maintain humidity are recommended. Initially inner tunnels, once prepared and covered, must only be opened to allow access for insertion. In this way the inner microclimate is preserved and no internal watering equipment should be necessary.

Density and Microclimate. Shallow insertion should be employed for all species. Cuttings should be spaced with foliage just touching in and between rows. No standard spacing recommendation can be given as leaf size varies widely. Failure to insert at the correct spacing will result in slower rooting and possible disease problems. The desired microclimate within the inner tunnel is obtained only if foliage is present from the surface of the rooting medium upwards thus leaving no dry areas. The outer tunnel during the rooting period is ventilated freely except for bottom draught exclusion.

Programme. The rooting medium and inner tunnel coverage will depend on the season, type of cutting and species. Over a number of years it was found that it should be practicable to root two batches of summer cuttings in early July and mid-August. No hormone treatment is necessary if material has been correctly selected and trimmed. A third batch of hardwood cuttings of a more limited range of species may be inserted in Sept-Nov. This type of material will generally need treatment with 0.8% IBA or its equivalent. Summer propagation is normally carried out in a rooting medium of 3:1 peat/sand, as a result of media comparisons. The inner tunnels are covered with 'milky' polythene to prevent scorching. Results from the other three combinations of clear and white inner and outer tunnels showed either reduced rooting under low light conditions or scorch damage in higher light conditions with double clear coverage. Rooting the summer batches will take approximately 3 to 4 weeks. A slow increase in ventilation of the inner tunnels allows rooted material to be weaned off and subsequently containerized or lined out. Winter propagation requires a more open compost of equal parts of peat and grit (coarse 3mm). Other media tried, including pure peat, sand and peat/sand mixtures, reduced rooting markedly. Unlike summer batches, clear inner tunnels have proved most effective. High light intensity was found to be desirable as rooting is slower at this time and callus develops before rooting commences in early spring. The outer tunnel is always kept ventilated to avoid temperature inversion due to radiation frosts.

Management. If adequate moisture has been provided in the initial medium, little additional attention is necessary other than an occasional light spray. Maintenance of humidity in this technique is a key factor and depends on the propagator's skill replacing the automatic but expensive control of misting. In summer, maximum humidity must be maintained. This should be a simple process with the "canopy" effect of foliage creating the microclimate and maintained by the "sealing" effect of condensation on the inner polythene tunnel. Lower levels of humidity are required during the winter period.

Good hygiene requires removal of any soft or dead material such as flowers, buds and leaves before and after insertion which may lead to problems with *Botrytis cinerea* (grey mould). Preventative fungicidal sprays can be applied at regular intervals if necessary.

Weaning in summer must commence immediately after maximum rooting to avoid "drawing" of the plants as new growth occurs. The type of root system produced is fine and fibrous while winter cuttings have rooted over a longer period with hormone treatment produce a more fleshy brittle root system.

Removal of summer rooted material means employing some method of growing on either by lining out, containerizing, or "rolling" in polythene rolls and overwintering under protection. This will produce "liners", field or pot grown, the following spring. Winter batches in a similar way will produce autumn "liners", saleable size container-grown material or bare root shrubs for the following season, depending on species.

Conclusion. It is possible to insert an average of 15 to 20,000 cuttings per bed size 16.15 × 1.2 m (53 × 4 ft). This simple system can handle large quantities of propagating material in a small intensive area. Costings of this technique compare favorably with traditional mist propagation under glass. Initial expenditure on the "Double Tunnel" system (one tunnel 5.0 × 16.5 m (16½ × 54 ft) containing three beds) is £7.78 per square metre compared to £67.50 per square metre for mist propagation. The "Double Tunnel' system has proved popular with growers because it conveniently fits the existing management pattern on the holding. This system although not recommended for use with high value shrubs, e.g. *Magnolia*, *Camellia*, *Rhododendron* (including azalea), etc. appears, however, to fill a definite propagation need. Therefore, if this simple technique can be applied in the production of the popular shrub range then the more highly capitalized systems can be put to more efficient use in the propagation of high value "difficult" subjects.

SEEDLING OAK PRODUCTION IN CONTAINERS

PETE WELLS

E.F.G. (Nurseries) Limited
Fordham, Cambridgeshire

Species of oak grown are: *Quercus robur* (Common oak or Pedunculate oak) 80%; *Quercus petraea* (Sessile oak) 5%; *Quercus rubra* (Red oak) 5%; *Quercus ilex* (Evergreen oak) 5%; *Quercus cerris* (Turkey oak) 5%.

WHY GROW THEM?

To fulfill the demand. E.F.G. produces up to 100,000 units per annum; there is little promotion of the product and I am sure there is scope for further development.

REASONS FOR THE DEMAND.

Vegetational Climax. The planners are attempting to recreate the vegetational climax of which the oak is the classic example in Great Britain. The Sessile oak being dominant on the acid soils in the west and north and the Pedunculate oak dominating the vegetation on the basic soil of the south and east. Sessile and Common oak interbreed freely and there are numerous hybrids occurring naturally throughout Great Britain. One interesting fact about oak trees which supports the planners choice is that 287 different species of invertebrates are dependent upon the oak tree at some stage in their life cycle. This diversity demonstrates the longevity of the oak as the dominant tree species in the environment and also serves to indicate the stability which it lends to a woodland habitat. Some oaks live to a great age, with a typical hedgerow specimen reaching 200 years and pollarded trees reaching an age of 300 to 400 years. Most oak trees in the U.K. are approximately 70 years old. This means that the oak trees in Britain are now middle aged and also that no plantings of oak have taken place over the last century.

In natural woodland, e.g. the New Forest, the average density of standard oak trees is 1-1/2 trees per acre. So relatively low numbers of mature trees are required for the oak to exert its dominant influence over a landscape. The best site for oak would support, on average, 25 standard trees per acre. However, it should be pointed out that good sites for oak trees are also nique can be applied in the production of the popular shrub range then the more highly capitalized systems can be put to more efficient use in the propagation of high value "difficult" subjects.

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REASONS FOR THE DEMAND.

Vegetational Climax. The planners are attempting to re-create the vegetational climax of which the oak is the classic example in Great Britain. The Sessile oak being dominant on the acid soils in the west and north and the Pedunculate oak dominating the vegetation on the basic soil of the south and east. Sessile and Common oak interbreed freely and there are numerous hybrids occurring naturally throughout Great Britain. One interesting fact about oak trees which supports the planners choice is that 287 different species of invertebrates are dependent upon the oak tree at some stage in their life cycle. This diversity demonstrates the longevity of the oak as the dominant tree species in the environment and also serves to indicate the stability which it lends to a woodland habitat. Some oaks live to a great age, with a typical hedgerow specimen reaching 200 years and pollarded trees reaching an age of 300 to 400 years. Most oak trees in the U.K. are approximately 70 years old. This means that the oak trees in Britain are now middle aged and also that no plantings of oak have taken place over the last century.

In natural woodland, e.g. the New Forest, the average density of standard oak trees is 1-1/2 trees per acre. So relatively low numbers of mature trees are required for the oak to exert its dominant influence over a landscape. The best site for oak would support, on average, 25 standard trees per acre. However, it should be pointed out that good sites for oak trees are also good sites for arable farming and have long since been converted to that use.

Romantic attractions. Oaks have a romantic attraction in the minds of Englishmen in a similar manner to the rose. This traditional appeal goes back to the first Elizabethan Age when England's navy, which ruled the seas, was built from "Hearts of Oak".

These two factors, the *Vegetational Climax*, and the *Romantic attraction* combine to motivate present day landscape planners towards planting oak in the hopes of achieving a long lasting effect on the British landscape.

Import Restrictions. Oak plants are a prohibited import to the United Kingdom. Over the past 50 odd years Continental nurseries have been a major source of hardy nursery stock for the U.K. market. Therefore, import restrictions effectively removed it from the reservoirs of planting material available to landscapers.

Fir Trees. In the minds of most people E.F.G. nurseries and fir trees are synonymous. Therefore, it was a positive decision to grow a classical hardwood and what could be a better choice for E.F.G. to grow than the oak tree?

WHY POT GROWN?

Reliability of establishment. Oaks are notoriously bad transplanters with frequent high losses from bare root material. This poor establishment can be attributed mainly to: Bad planting — either the wrong site, wrong soil conditions or unskilled labour; poor plant care; and slow root regeneration.

Increased value. Bare root oak seedlings are relatively cheap and easy to produce. E.F.G. seeks to add value by potting such a product. The pot and compost should be thought of as packaging and wrapping, but packaging which adds the benefits of protection and reliability to an otherwise unreliable product.

ALTERNATIVES TO POT GROWN OAK

Bare root transplants. These are relatively cheap but are subject to heavy losses due to the various factors mentioned previously.

Sow acorns. This practice has been carried out in the past but there is little evidence *today* of it being a successful operation. This lack of success is most probably due to grazing animals. Acorns themselves are a valuable food source for birds and small mammals. Any acorns which survive and produce young seedlings are then subject to grazing by caterpillars, small mammals and even deer. That acorn eaters and seedling grazers can have such a drastic effect on oak populations is probably due to the fact that, in turn, their predators have largely been eliminated by zealous game-keeping.

Oak seedlings are intolerant of shading. Modern woodland management strives to achieve a closed canopy condition which effectively shades out oak seedlings. There are one or two recorded instances of oak effectively invading railway embankments adjacent to oak woods, this success being largely attributed to exposure and lack of shade.

WHO BUYS POT GROWN TRANSPLANTS?

Private forestry. Where the recreational and sporting values of the woodland are considered as well as, or in spite of, the volume of timber grown per acre.

Local authorities currently use pot grown oaks on reclamation and rehabilitation schemes, motorway and trunk road landscaping, country parks and environment woodland schemes in urban areas.

PRODUCTION DETAILS.

When to Sow. Ideally acorns should be sown as soon as collected, or if buying in, as soon as delivered. The operation should be completed in November/December and January. Seed should be graded for size — the biggest yielding the biggest seedlings. E.F.G. acorns are sown in Finnish peat pots but sweet pea or Japanese paper pots would be just as practical. The Fin pots are then placed approximately 100 at a time in polystyrene handling trays. Germination and early growth takes place in a poly tunnel — no heat being provided but fan cooling is available if required to limit abnormally high temperatures. The acorns are germinated in a peat compost, no fertilizers being necessary at this stage. In April/May when seedlings are approximately 6-9″ tall the first cultural operation takes place. This entails pruning the tap root, grading, potting into 4 × 7″ whalehides, standing 20 plants to a polystyrene handling tray and subsequently placing this package on the normal container sandbeds. Outside during the growing season plants usually flush three times and grade out at the end of the season as 18-24″ and 24-30″ transplants.

SEED SOURCES.

Home Collections — this method is by far the best source of seed; it allows sowing to be made at the optimum time. Seed should be graded according to size - the rule of thumb being that big acorns produce big seedlings. Weevil-infected acorns can be eliminated by a simple flotation test, the ones which float being infected, the ones which sink being the sound seed.

U.K. sources. Acorns bought from United Kingdom sources are as good as any. They have been selected over 4 to 5 generations. A registered source is the Crown Commission Estate in Windsor.

Continental sources — Holland is probably the best source for *Quercus robur* and *Quercus rubra*. These are collected from roadside trees and have had two to three generations of selection. Germany, in particular Spessart, is regarded as the best source for *Quercus petraea* and is also good for *Quercus rubra*.

SHORT TERM STORAGE

The best advice is to sow when collected and thus avoid the problems of storage.

If immediate sowing is out of the question then the important storage criteria are that the seed should be cool and moist. Avoid stacking sacks of acorns as these will overheat and ruin the seed.

A PERSONAL VIEW OF THE ROLE OF A PROPAGATION RESEARCH WORKER

B.H. HOWARD

East Malling Research Station
Kent, England

Within the limits of their terms of reference the attitudes of research workers to applied research topics are coloured partly by their interest in the science of their subject and partly by their interest in the problems of the industry they serve. It does not follow that a science bias or an industry bias or even a middle of the road approach is necessarily best, but it is inescapable that the research worker serves two masters. His scientist overlords will assess his work on its scientific content and hopefully also will judge its value in the horticultural context. Nurserymen are exceptional if they concern themselves with the underlying science, understandably they want a technique which can be explained in precise terms so as to be able to judge its usefulness against the wide range of other interacting factors in nursery management, but they are prepared to leave the collecting of the relevant data and its interpretation to the scientist.

Division of labour. Horticulture is a co-ordinating science requiring knowledge of plant behaviour, soil science, chemistry, physics and so forth, with an ever present appreciation of the commercial background against which innovations and improved techniques will be measured. Within horticulture, propagation similarly draws on a wide range of knowledge and skills. A propagation research worker could legitimately study topics such as nursery soil sickness and specific replant disease tions. A registered source is the Crown Commission Estate in Windsor.

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Division of labour. Horticulture is a co-ordinating science requiring knowledge of plant behaviour, soil science, chemistry, physics and so forth, with an ever present appreciation of the commercial background against which innovations and improved techniques will be measured. Within horticulture, propagation similarly draws on a wide range of knowledge and skills. A propagation research worker could legitimately study topics such as nursery soil sickness and specific replant disease (the province of the pathologist and soil scientist), factors affecting regularity of seed supplies for seedling rootstock production (the province of the reproduction plant physiologist), defoliation (the province of the abscission physiologist) as well as basic vegetative propagation. Thus the demands on his time can be enormous, with the result that he either skims the surface of many problems or deals with a few in depth to the exclusion of others. Rule number one is that if among your colleagues there are specialists working in topics relevant to nursery problems try to interest them in giving some of their time to your problem because they will contribute from a depth of knowledge which the co-ordinator does not have. At East Malling specific replant disease, fungal, bacterial and virus diseases, defoliation and chemical shoot control studies relevant to propagation are dealt with by specialists outside the Propagation Department.

Propagation objectives. There are three main objectives, namely relevance, reliability and speed of propagation.

"Relevance" is the reason for undertaking a research investigation. It was relevant recently to study problems in the budding of fruit trees because fruit growers were, and still are, demanding larger, more uniform and better feathered trees than in the past, to carry early crops and give earlier returns on highly capitalized intensive orchards. The outcome of the investigation was to discover that conventional T budding was an inefficient piece of carpentry with respect to matching the cambium of scion and stock and the introduction of chip budding on a wide scale resulted. Awareness of what is relevant is important because the opportunity to make progress may arrive unexpectedly. The initial reason for studying chip budding was to follow-up a pathologist's hunch that apple stem cankers caused by *Nectria galligena* could be caused by spores carried on budwood and that chip budding would minimize the risk, which proved to be the case.

"Reliability" is an essential component of all horticultural techniques, but especially in propagation where there is often no compromise; buds may either fail or grow, cuttings either die or survive, these differences usually being more important that the quality of growth of the survivors. Reliability can often be studied best by stepping outside the role of nurserymen and questioning all aspects of current practice. In the hormone treatment of cuttings concentration of the hormone in the powder or liquid formulation in the past has been considered as the main or even the only important variable. In fact dosage, which determines the rooting response, is determined in leafless hardwood cuttings by duration of dipping, how long the cutting has been removed from the stock plant, the depth to which it is dipped and the angle at which it is left to dry, the last two components being linked to the run-off from the epidermis and absorption through the cutting base of excess liquid. Any one of these factors will markedly affect the concentration response of the hormone. Another example of needing to question conventional practice is the discovery that in stoolbed management of the popular M.9 apple rootstock the best quality plants cannot be creamed-off for budding leaving the smaller ones to be used for extending the stoolbed, as has often been done in the past on the assumption that they will 'make-up'. In fact, productivity is severely reduced each year by establishing beds with inferior material.

"Speed" is basic to nursery production. Cuttings progressively deteriorate under mist and the most successful subjects propagated by this technique are fast rooting plants. Hardwood cuttings which are propagated at the slow-to-root time of year (midwinter), or of difficult clones, expend too much carbohydrate which cannot be replaced in the absence of leaves, and have insufficient reserves left for establishment later in the field. Speed is also essential in the management of research and the introduction of new material to the industry. Where propagation research is coupled to the development of improved plants such as new clonal fruit rootstocks, both the research workers testing their performance and the nurserymen planting up new stock beds require sufficient plants at one time to meet their purpose.

Inherent rooting ability. After a few years' researching into difficult-to-root subjects it becomes obvious that the knowledge available to the researcher does not match up to the size of the problem and that a dual approach is necessary; to improve the technique and search for plants which have easy propagating characteristics. There is every reason to enlist the help of mother nature and with the help of the plant breeder this is becoming increasingly effective. New apple rootstocks are being bred which propagate far more readily from large hardwood cuttings than their predecessors which were raised by stooling, and a cherry rootstock (Colt) is now available which produces preformed roots on many of its shoots by the end of the current growing season, requiring only to be cut off the parent bush and planted. It can be shown also that among a small population of seedlings grown up as individual stock plants for cuttings of, for example, *Tilia cordata*, there exists a wide range of rootability, giving the opportunity to vegetatively propagate species hitherto raised only by seed.

Systems. It is both uneconomic to do too little or too much towards propagating plants by cuttings and it is necessary to identify relevant characteristics of the plant to be propagated and to match the propagating procedure accordingly. For example, the proportion of cuttings of Colt which do not exhibit preformed roots by the autumn, perhaps surprisingly, require inputs of bottom heat and rooting hormone to ensure a high level of establishment despite growing on the same bush adjacent to pre-rooted cuttings. The early leafing Quince C rootstock for pears can be propagated in the autumn by direct planting without the benefit of bottom heat, in midwinter bottom heat is essential, and in February it is too late to obtain many established cuttings with or without bottom heat.

Mechanisms and principles. Underlying the successful application of improved propagation techniques is an understanding of the mechanisms and principles of propagation. While not essential for the introduction of a new technique this deeper understanding is desirable for three reasons. Firstly, it allows extrapolation to situations and species which have not been the subject of the actual experiment, an impossible objective in view of the many thousands of woody plants in cultivation. Secondly, an understanding of the mechanism will suggest new ways to tackle a problem; to understand the mechanism of seasonal fluctuations in rooting ability of cuttings may lead to chemicals being applied to the cutting to make-up for internal deficiencies or, more likely, suggest ways of growing stock plants which ensure high endogenous levels of the active substance. Thirdly, an understanding of the mechanism assists in the forceful promotion of a new technique. There is no doubt that the explanation of relative efficiency of union formation helped to introduce chip budding into commercial nursery production in place of T budding.

Spin-off. It is impossible to research into all the species that nurserymen propagate and priorites are determined in relation to their economic importance and the feasibility of a research study. Research effort can be conserved by linking the applied studies on a number of species to more basic work necessarily carried out with only one or two subjects. It is sensible, and in fact the only practical approach with current restrictions on staffing and equipment, to apply spin-off wherever possible. Chip budding has possibly had a greater impact in ornamental nurseries than in fruit nurseries because in the former both bud-take and tree quality is improved in difficult-to-bud species. An investigation of factors which might influence the success of chip budding in *Acer platanoides* 'Crimson King' showed that the basic techniqe worked out for apples was entirely relevant and no modifications were needed. In fruit tree propagation the experimenter is handling clonal material and his experiments will be more sensitive and show treatment effects better than with heterogeneous populations of cuttings from seedling ornamental understocks, even though results may apply to the latter.

It is likely that differences in cutting response due to the method of applying auxin, or factors associated with poor field establishment through depletion of carbohydrate will apply equally to a wide range of woody plants; it is important that the in-depth investigation is carried out with a reliable subject and that spin-off is applied to those subjects of interest to nurserymen but less suitable as research tools. Many ornamental species, including clonal forms, have such a low level of response to propagation treatments that they are unsuitable for research. Investigations cannot easily be made with subjects which, for example, already root from cuttings at 90% or at zero per cent. Those with intermediate performance offer the best chance for understanding the essential processes and many clonal fruit plants are in this category.

A current example of useful spin-off is the development of clones of *Prunus avium* × *P. pseudocerasus* hybrids with the ease of rooting from cuttings already described for Colt. These are primarily intended to produce smaller sweet cherry trees in orchards to facilitate picking and protection from birds. Their value as easy-to-propagate rootstocks which induce good growth and profuse flowering in ornamental cherries suggests that a major advantage will accrue to non-fruit nurserymen, by giving them an opportunity to become less dependent on imported *P. avium* seedlings for the production of flowering cherries.

Development. New techniques arising from research often fail because of simple horticultural malpractice. Planting hardwood cuttings in bins of over-wet compost, planting them into the field as bare root cuttings when shoots have begun to grow in spring and planting them too shallowly so they desiccate are typical examples. This underlines the need for development to follow research either under the direction of the experimenter or with his collaboration if another agency is involved. At East Malling the presence of a commercial scale nursery for the production of plants for research and for the nursery industry gives an ideal opportunity for ironing out snags and for ensuring that the technical inputs are balanced by sensible horticulture.

Because growing methods differ so much between nurseries, and because important background factors such as labour availability, proportion of skilled labour, land availability and so forth are different on each holding, research workers are rarely in a position to actually recommend that a certain technique is taken up, because they have no guarantee that it will be carried out to the letter and with the necessary background management. Modern techniques derived from research are usually the result of a series of experiments, each giving one clearly defined answer to be fed into the final recipe. Frequently, success at one stage depends on having met previous conditions correctly, and often the importance of this is ignored. It seems that the best objective for the research worker is to ensure to his satisfaction that the technique is workable on a field scale, to emphasize important conditions, and to offer a number of different approaches to nurserymen in the knowledge that their organization will not always be geared to one particular technique.

RECENT DEVELOPMENTS IN GREENHOUSE COOLING, VENTILATION, INSULATION AND AIR POLLUTION CONTROL

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Several research projects conducted at the University of California Agricultural Experiment Station at Riverside required greenhouse facilities which have reasonably narrow temperature controls and air purification systems for protecting plants against smog damage. This report describes the application of some innovative equipment, both old and new, which have not been generally used in greenhouse facilities but which appear to be superior to "standard" greenhouse components.

Greenhouse Cooling. Cooling is essential at Riverside where summer dry bulb temperatures exceed 100°F several days per year. The standard evaporative cooling system available from greenhouse manufacturers utilize vertical excelsior pads and exhaust fans. Disadvantages of the vertical (upright) pad systems are:

1. After a few months use, voids develop in the pads which allow uncooled air to move into the greenhouse, thereby reducing the cooling efficiency of the system.
2. To maintain reasonable efficiency, pads must be changed at least annually and frequently more often.

A horizontal (flat) evaporative pad system was designed by W.T. Welchert and Frank Wiersma, Agricultural Engineers at the University of Arizona at Tucson about 1970-71.

Field observation indicated the following advantages and disadvantages of the horizontal pad orientation over the vertical pad system:

Advantages are:

1. Dust accumulation in the pad is greatly reduced; hence, air flow resistance is more constant, pad cleaning time is eliminated and pad life substantially prolonged.
2. Pad sag and air leakage around the frame is eliminated.
3. Pad cost is reduced because bulk excelsior can be used instead of hand or machine packed pads.
4. Easy access simplifies pad replacement and maintenance.
5. Pad area is not limited to available vertical wall space.
6. Light control and wall closing systems are simplified.
7. Multi-level pad cabinet arrangements permit design of multi-stage cooling and winter ventilation control.

Disadvantages are:

1. Low-volume nozzles require more water filtering than drip pipes.
2. Multi-level systems may require additional baffling to prevent the pick-up of free water in the air passing up through alternate pads.

In 1975, Benham and Wiersma conducted extensive testing to compare the relative efficiency of the two systems (2). The testing showed that the horizontally oriented evaporative pads were from 10% to 20% more efficient.

We have incorporated the horizontal pad design into several of our greenhouses and have been highly satisfied with the reliability of the system, the low maintenance and the extended period between pad changes.

Air Purification. A second requirement for our research greenhouse is a system of air filtration for the removal of the plant damaging components of "smog." Without activated carbon filters, we can experience a complete loss of such crops as tomatoes, due to smog. The removal of photochemical, phytotoxic air pollutants is accomplished by using horizontal trays of activated carbon. Either activated coke carbon or coconut hull charcoal may be used.

Manufacturered carbon filters available through trade sources are quite expensive. The horizontal tray is less costly and is the best solution to reliable prevention of smog injury to sensitive plants.

The first application of activated carbon filters to purify incoming greenhouse air was made at Cal Tech's Earhart Plant Research Laboratory in 1951. A second such installation was made in one of the greenhouses at U.C. Berkeley in 1969. U.C. Riverside now has three greenhouses with this type of air filters installed. No smog damage has occurred since their installation.

Basic design for carbon filters are:

1. Thickness of activated carbon bed: 1" to 1-1/4".
2. Pounds of activated carbon per 1,000 CfM of air flow: 60.
3. Face velocity of air through carbon bed: 50 ft. per minute, which provides air contact with activated carbon of 0.10 to 0.13 seconds.

Horizontal evaporative cooling pads and carbon filter trays can be constructed in a serial arrangement in an "air conditioning chamber" to provide purified cool air to a greenhouse operation.

Reducing Heat Losses. Reducing heat losses in greenhouses has become an important economic consideration as fuel costs have increased. The research by Simpkins and Roberts (3) on the use of curtains to reduce heat loss from double-filmed air-inflated polyethylene greenhouses indicate that substantial heat savings can be obtained. Their data suggest savings of up to 50% of the total heat requirement could be achieved by certain curtain materials and installation techniques.

Tests were conducted on a small greenhouse, 3.3 m wide × 4.9 m long × 1.8 m high, at the eaves, with a 6:12 roof pitch. Although the data developed from the small greenhouse may not apply to a full size operating greenhouse, their results do provide a basis for predicting possible heat savings.

The small greenhouse was completely covered, roof and walls, with an air inflated double film of 6 mil, Monsanto 602 polyethylene. Various curtain materials and installation techniques were compared for heat conservation characteristics.

Prior research had established that the double, air-inflated roof and walls reduce fuel consumption by approximately 30% compared to single wall polyethylene or fiberglass.

The reduction in heat loss reported by Simpkin and Roberts was in addition to that saved by the double layered cover. A portion of their data is tabulated in Table 1.

Curtain materials consisted of clear polyethylene film, black polyethylene film and aluminized mylar film. In addition, fiberglass insulation and condensation were evaluated.

Installation techniques compared were:

1. Curtains installed under and parallel to the roof surface.
2. Curtains attached at edges but not sealed.
3. Curtains from gutter to gutter to create "attic" space.
4. Curtains sealed at edges.
5. Curtains installed so they were in contact with the convex surface of the inflated roof or walls at the highest point of the bulge. This conformation was compared to installing the curtain with a 10 cm separation from the inflated cover, thereby creating an air space between cover and curtain.

Some generalizations which can be drawn from Simpkins and Roberts tests are:

1. Aluminized mylar is superior to black and clear polyethylene.
2. Black polyethylene is better than clear.
3. Sealing the edges is superior to unsealed.
4. Providing a dead air space of 10 cm between outer walls and curtain is better than curtain in partial contact at the bulge of inflated outer cover.

Table 1. Comparison of curtain materials and installation techniques on heat savings.

Curtain Material	Installation Techniques	Heat Savings, %
	Side Walls Only	
Fiberglass Insulation	On walls only	11
Black Polyethylene	Sealed at top	12
Clear Polyethylene	10 cm from wall - not sealed	13
Clear Polyethylene	In partial contact with wall - not sealed	21
Clear Polyethylene	10 cm from walls - sealed all sides	31
	Roof - 6:12 Slope	
Black Polyethylene	In partial contact with roof - not sealed at edges	20 - 25
Aluminized Mylar	In partial contact with roof - not sealed at edges	48
	Horizontal Roof	
Black Polyethylene	In partial contact with roof - not sealed at edges	28
Aluminized Mylar	In partial contact - not sealed at edges	55
	Ceiling Only	
Clear polyethylene	Gutter to gutter	37
Aluminized Mylar plus Clear Polyethylene	Gutter to gutter	44
	Roof Plus Sidewalls	
Black Polyethylene	Roof and sidewalls	12
Condensation only	No curtains	14
Black Polyethylene plus Aluminized Mylar	Roof and sidewalls	43
	Ceiling Plus Sidewalls	
Fiberglass Insulation Black Polyethylene	Fiberglass insulation on walls Black Polyethylene eave to eave	52
Fiberglass Insulation Clear Polyethylene in Curtain	Fiberglass insulation on walls Clear Polyethylene curtain eave to eave	57
Fiberglass Insulation walls, clear polyethylene plus aluminized Mylar	Fiberglass insulation on walls. Clear polyethylene, aluminized Mylar eave to eave	70

5. Ceiling curtains from gutter to gutter are better than curtains under and parallel to roof surface.

Opaque curtains such as black polyethylene or aluminized mylar must have mechanisms to extend them at night and roll them in during the day. Such mechanisms are used by chrysanthemum growers using black cloth application.

Clear polyethylene may be installed permanently at appreciably less cost. Although less effective than opaque curtains, clear polyethylene curtains can reduce heat loss by approximately 50%.

A review of fuel saving techniques being used by greenhouse operators in both the USA and Europe is in the October, 1976, issue of Growers Talks (1).

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SANITATION IN PLANT PROPAGATION

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In 1957, the *U.C. Manual 23, U.C. System for Producing Healthy Container-Grown Plants* (1) was published. It cost one dollar and was reprinted at least once. It is now out of print and in need of revision because of changes in pesticide registrations and other changes. But the information about plant diseases has not changed significantly. One section, "A Nursery Sanitation Code" by Kenneth Baker, is as good a guide now as it was 20 years ago. I would like to discuss this section explaining and commenting on the code which appears on pages 22 and 23.

There are two main sources of plant-disease causal organisms: infected plant parts, and infested soil. Reproductive or survival units (spores, sclerotia, etc.), referred to as inoculum, may be present in soil or produced on diseased plants. The inoculum can spread or be disseminated (transported) in various ways. A knowledge of the various dissemination methods will help the propagator understand the need for sanitation practices.

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Methods of Dissemination	Sanitation Procedures
Equipment: Shovels, hoes, tractors, hoses, etc. Structures: Stakes, wires	Remove soil; running water is effective. Disinfect with formalin 37%, diluted 1:18.
Hands	Wash with soap and water.
Clothing, shoes	Brush clean or wash. Keep shoes off plant beds, etc. Rubber boots can be treated with formalin.
Water: irrigation	Well and municipal water are not contamination sources. Filtration and chlorination of ditch water may be necessary in some cases.
Water: rain and moisture from the atmosphere; drainage water	Bacteria and fungus spores are spread in splashing water from infected tissue. Drainage water can transport soil and microbes.
Wind	Many types of spores, particularly rusts, mildews, and some leaf-spotting fungi, are airborne. It is possible to filter greenhouse air, but it is not often practiced.
Plant containers	Remove clinging soil, and steam or chemically treat. Formalin can be used for plastic.
Animals: Dogs, cats, birds, mice	Exclude them from propagation areas.
Insects and mites	Besides transmitting viruses, some insects spread bacteria and fungus spores. Fungus gnats can carry *Rhizoctonia solani* and *Pythium* species. Flies spread bacteria.
Nematodes	Plant-parasitic nematodes cause disease and some transmit plant viruses.
Fungi	Some root-infecting fungi (*Olpidium* species) can spread certain viruses.
Plants: vegetative reproduction (cuttings, bulbs, corms); seeds; pollen (a few viruses are transmitted by pollen)	Infected plant parts are a common means of introducing or perpetuating many kinds of diseases. Pathogen-free material can be developed in most cases. Bulbs and seeds can be treated with fungicides and by heat treatment in some cases.

DISINFECTANTS

There are several different types of disinfectants used to control plant diseases. Most are used in sanitation to prevent diseases of man. The choice of disinfectant depends on the disease and plant.

Disinfectant	Use	Disadvantages
Bleach (sodium hypochlorite, calcium hypochlorite) (5.25%, diluted 1:9)	Surface disinfectant. Effective against small microbes such as viruses, bacteria, and fungus spores. Surfaces should be visibly clean before they are wiped or dipped in solutions.	Poor penetration; no residual action; corrosive to iron. Solutions rapidly lose activity, especially in light or in presence of organic matter. Not effective in killing fungus sclerotia or other resting structures (*Verticillium*, *Sclerotinia*, *Macrophomina*, *Fusarium*, *Pythium*).
Formalin (37%, diluted 1:18)	General disinfectant for tools, flats, and soil. Good keeping quantities.	Fumes are irritating to people and plants. Porous materials like wood and soil must be kept damp until all fumes have dissipated, or plant damage may result. Not effective against viruses.
Phenols (Amphyl®, Lysol®, LF-10®, CM-19®) Usually contain surfactants and alcohol.	Effective against bacteria and fungus spores. Residual action. Solutions retain activity for some time.	Not effective against fungus sclerotia or viruses.
Alcohol (ethyl or methyl alcohol and others)	Disinfectant of tools and tree wounds. Not generally recommended for use in plant disease control.	Not effective against sclerotia, viruses, and some bacteria. No residual action.
Quaternary ammonium compounds (example: alkyldimethylbenzyl ammonium chloride)	May be useful in controlling bacterial contamination. Good algicide.	Not effective against fungus sclerotia.
Copper naphthenate	Used on wooden surfaces to provide a self-disinfecting surface. Helps control algae, fungi, and bacteria.	Not useful for tools. Toxic to plant roots that contact treated surfaces.

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DECOMPOSITION RATE OF VARIOUS ORGANIC MATERIALS IN SOIL

ROY L. BRANSON, JAMES P. MARTIN and WILLIAM A. DOST[1]

INTRODUCTION

From an ecological viewpoint, it is important that organic materials decompose in soils. Elements such as nitrogen, phosphorus, and carbon are released in forms that can be used by new generations of living things (1,5). Also, some products of decomposition have value in improving structure of some soils by aggregation of fine particles into larger crumb-like units that facilitate water movement and exchange of oxygen, carbon dioxide, and other gases, between soil and the air above it (6,7).

From the viewpoint of growers of ornamentals, however, who rely on synthetic soils, or soil mixes, organic materials used in preparing these media should be relatively resistant to decomposition. If not, there can be several undesirable effects: shrinkage of mix volume, changes in soil porosity that affect aeration, rapid utilization of oxygen by microorganisms making anaerobic conditions possible especially after irrigation, and nutrient upsets by competition of microorganisms with plants. Thus, in soil mixes longevity of organic materials used in preparing them is important.

The usefulness of peat moss in mixes is due in large part to its resistance to decomposition. Other organic materials have been substituted for peat moss in mixes mainly because of economic factors. Redwood sawdust is a notable example. The cost of locally available organic waste products often makes them attractive as substitutes. In considering their suitability, one of the important factors, in addition to cost, is rate of decomposition.

Recently, the decomposition rates of a large number of organic materials have been measured in laboratory research at the University of California, Riverside. Some of these materials will be reported on here. Among these materials is a group of woods and barks from several types of trees grown in California. These forest byproducts were supplied by William Dost, Extension Forest Products Specialist, University of California, Berkeley.

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EXPERIMENTAL PROCEDURE

Decomposition rate was measured over a period of more than six months. A fertile top soil, Greenfield sandy loam, was used for the decomposition tests. It was obtained fresh from the field, air dried, sieved and placed in 100 g portions in 250 ml Erlenmeyer flasks. This soil had a pH of 7.0 to 7.2, an exchange capacity of 11 me/100 g, and an organic matter content of about 1.5 to 1.8 percent. The organic materials were mixed with the soil at concentrations of 0.1 to 0.5 per cent.

The soil was moistened to 60 percent of capacity (about 1/3 bar), connected to a closed system, and constantly aerated with CO_2-free, moist air at an incubation temperature of 22°C. The CO_2 evolved from the mixtures was collected in KOH solution and determined by titration after the addition of $BaCl_2$. The percentage of the applied carbon evolved as CO_2 was calculated after substracting the CO_2 from the unamended soil.

RESULTS AND DISCUSSIONS

The decomposition percentage of various organic materials during the 30-week incubation period are presented in the following table.

DECOMPOSITION OF ORGANIC MATERIALS IN GREENFIELD SANDY LOAM SOIL

Product	Percentage Decomposition After Weeks					
	1	6	12	18	25	30
German Peat Moss	< 1	3	6	13	18	18
Canadian Peat Moss	< 1	5	6	8	9	11
Redwood Sawdust	0	0	1	5	9	10
Redwood Shavings	< 1	< 2	4	10	17	19
Redwood Bark	< 1	2	8	22	35	38
White Fir Sawdust	< 1	4	8	16	24	28
White Fir Shavings	0	4	8	14	23	27
White Fir Bark	0	1	6	8	12	15
Douglas Fir Sawdust	< 1	3	8	21	31	35
Douglas Fir Shavings	< 1	3	9	14	20	25
Douglas Fir Bark	2	3	6	8	9	10
Ponderosa Pine Sawdust	< 1	4	16	23	27	29
Ponderosa Pine Shavings	2	7	14	24	33	37
Ponderosa Pine Bark	1	8	10	11	12	12
Sugar Pine Sawdust	< 1	4	7	12	14	15
Sugar Pine Shavings	1	5	10	13	16	17
Incense Cedar Shavings	< 1	< 1	1	2	3	4
Worm Manure (castings)	2	5	6	11	11	11
Rice Hulls	9	19	24	31	35	35
Oat Straw	21	55	73	75		

The slowest to decompose was incense cedar shavings (4 percent in 30 weeks); the fastest was oat straw (75 percent in 18 weeks). Organic materials that are high in polysaccharides and low in lignin decompose rapidly in soils. Those with higher lignin contents are degraded more slowly. It should be emphasized that the percentages listed in the preceding table are particle-size dependent; the smaller the particle size, the more rapid the decomposition. The sawdust and bark samples tested had particles 16-32 millimeters (1/16-1/8 inch). The other materials were ground to pass a 2-millimeter sieve.

Decomposition rates for Canadian and German peat moss were similar, between 10 and 20 percent. Redwood sawdust and worm castings fell into the same category. The barks, in general, also decomposed slowly. An exception was redwood bark. A greater surface area exposed by the unusual fibrous nature of the redwood bark may account for its more rapid breakdown (38 percent).

Sawdusts and shavings, as a group, (except for redwood sawdust) were intermediate, similar to the redwood bark. The range was 25-37 percent. Although rice hulls were also in this range, there was a notable difference during the first few weeks of decomposition. The rate for rice hulls during this early period was considerably higher, indicating that a fraction of the organic matter in rice hulls is readily decomposed. This suggests that composting of rice hulls prior to use in soil mixes would be a safety measure.

One should be aware that some fresh woods and barks contain resins, terpenes, tannins, and other substances which may be toxic to some plants. It may be, therefore, safer to compost these materials, too, for 30 days or longer before using them in potting media, especially if they are ground to small particle size, which accelerates their decomposition rate (2,3,4).

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HENRY ISHIDA, Moderator: We have some time now for questions for our panelists.

VOICE: Has perlite been used on a horizontal pad for evaporative cooling?

PAUL MOORE: I don't know of it being used specifically, but I know of some other aggregates that have. However, I think that aspen wool is one of the best materials for evaporative pads. It doesn't last as long as some of the mineral types but the water and film distribution and evaporation rates are among the tops of any materials that could be used. Aspen wool is cheap, and with a horizontal pad, you can use it for three years; the cost per year is really not great.

VOICE: If you use plastic to enclose greenhouses for heat conservation, does that interfere with air flow?

PAUL MOORE: It may if it is completely sealed. In our houses, we have tube doors at one end which we close up at night. Then I have exhaust fans, so during the daytime we do have air flow. There are shutters on the fans, which close it off, but the fan wall is completely enclosed otherwise with polyethylene film. There is an appreciable savings. In other words, you can conceive methods in which you can have your mechanical air flow, or if you use tube doors, for instance, conventional convection cooling will still work. The tubes in themselves are a dead air space when they are inflated. When they are collapsed, you have air flow during the day or any other time they are collapsed.

ESTHER LAWYER: We formerly used methyl bromide for fumigating our cold storage facilities. This year, on the recommendation of another nursery, we burned sulfur. Would Dr. McCain comment on this?

ART McCAIN: Sulfur burning couldn't approach what methyl bromide will do. I don't think that you can even compare them. Methyl bromide, as a fumigant, kills weed seeds, fungi, bacteria, and other things. It depends on what the problem is in your cold storage. It may be that methyl bromide was more than was really necessary. Another material you could use in lieu of methyl bromide is formaldehyde gas. All these are quite hazardous to use, however. It may be that you don't really need methyl bromide to fumigate your storage. This would be plant material for sale, or you may be concerned about *Botrytis*, and some other airborne types of spores. One of the things that is used to control *Botrytis* is thermal dusting with chlorophthalanil. This might suffice for airborne pathogens, although sulfur may also take care of some of these.

VOICE: Has there been any research done on microwave ovens for sterilizing?

ART McCAIN: Yes, there has. In fact, Ken Baker has done a lot of work on this; apparently it is primarily a heating phenomenon but it is an expensive way to heat soil. For a commercial venture you have to have quite a large machine. There is a publication describing this. I could probably get you a copy if you will let me have your name and address. It is perfectly feasible; primarily though you have to get the soil up to the required temperature for a certain length of time. The common practice now is to kill most plant pathogens at 140°F for 30 minutes. Microwaves can be used for heating soil but it is very expensive for heating large quantities.

VOICE: Has any work been done on sugar cane residue in soil mixes?

ROY BRANSON: Sugar cane residue wasn't included in our studies. I know of no work that has been done with it, but that is no indication it hasn't been done. I expect it would decompose quite rapidly because of its high content of cellulose and other rapidly decomposable carbohydrates.

ART McCAIN: I can answer the sugar cane question. There is quite a bit in Hawaii. People like to use it but sugar cane bagasse is not a very satisfactory material; it breaks down rapidly and you get water drainage problems.

BRUCE BRIGGS: At the Eastern Plant Propagators' Meeting last winter, to conserve heat they took white poly and painted it with aluminum paint. They got quite a resistance. Do you have any data on the efficiency of this combination?

PAUL MOORE: No, but the aluminizing of the material gives reflective insulation against radiant heat loss. Much of the heat loss through polyethylene is through radiation. Our data on aluminized mylar should be applicable to aluminized polyethylene as well.

VOICE: In your soil mix, when you use peat moss, is there any difference between using real fine grades and the greenhouse grade?

ROY BRANSON: There is a difference. I didn't show you the data, but we used fine, medium, and coarse peat moss. Decomposition was somewhat more rapid with the finer material. This is true of any organic material. The data you saw were for coarse grade peat mosses.

ART McCAIN: Most peat that you buy has some plant pathogens in it. Despite the fact that the label states that it is disease-free and all that, it may contain plant pathogens. This work was done by some Pennsylvania plant pathologists; they found *Pythium* species and other fungi in it. If you have no problems, don't worry about it. But it is a source of infection and, with particularly valuable propagating material, you should consider treating the peat that you buy. It is scraped up off the ground, put in bales, and handled in various ways. There are several commercial potting mixes but I don't know if these have been tested. It is not easy to test; you just can't run it through the usual tests because the population of organisms is very low — but peat moss can be a source of contamination.

VOICE: Can you comment on the introduction of beneficial bacteria or other microorganisms in soil that has been sterilized?

ART McCAIN: This is a very interesting area and there is something to it. However, there are fraudulent products on the market that claim they contain beneficial organisms. You probably know the term mycorrhiza. This means "fungus root". Pines, for example, have mycorrhizal associations with higher fungi. Many plants have a beneficial association between certain fungi and their roots which increases the efficiency of nutrient uptake. In fact, citrus is quite dependent on a group of mycorrhizal fungi. When we treat soil, heat it, we kill the mycorrhizal fungi. If you plant clean stock, like I am preaching to you, you may have to add more fertilizer. The important thing is that mycorrhizae reduce the consumption of fertilizers and nutrients by effectively increasing the root surface. The mycorrhizal fungi grow out from the roots. It is the rule to have mycorrhizal infection in nature. Almost any plant you pull up will have it but you can't see it because they are microorganisms. They invade the roots but without any particular disruption.

How can we introduce mycorrhizal fungi into soil? There are interested companies. Abbott Laboratories is one; they are producing these fungi, but they are not commercialized yet. What they are going to cost, we don't know. There are publications in the literature; one I am familiar with is on poinsettias. You can usually demonstrate the value of this beneficial fungus, but it has to be done with a nutrient-deficient soil. From a practical standpoint today, it is much cheaper just to add more fertilizer. Fumigation kills the mycorrhizal fungi. There are beneficial bacteria also. We all know about nitrogen-fixing bacteria in nodules in legumes but there are some others; exactly what is going on we don't know. There are bacteria you can treat potatoes with — increasing growth and yields, possibly an antagonistic situation. There is definitely a microorganism antagonist of the crown gall bacteria. This thing works as a prevention. During propagation you may have a lot of trouble with crown gall, for instance, on euonymus. But if you treat the cuttings to introduce the antagonist, it will prevent crown gall development. The antagonistic bacteria is being commercialized and tested. If you read *California Agriculture*,[1] you saw an article in there about prevention of crown gall. We have tried this procedure on a number of ornamental plants; it doesn't always work. It seems there are certain strains of the crown gall bacterium and certain strains of the antagonistic bacterium.

But what I would like to caution you about is the phony products. Many are fraudulent, but there are good ones coming along. Look at the data. Have the data published been criticized, or are the claims based just on testimonials? If the promoters can't supply you with confirming literature from some reputable scientific journal, beware. Even in your own organization, someone may present a talk and show you the data; it is open to criticism, and that is good. But most of the promotion we see is supported only by testimonials. Some of the people are very sincere in promoting their products. They believe it, but they are ignorant.

VOICE: In large greenhouses, where you may have several hundred feet span, you may have cooling pads, fans, etc. You may get a heat buildup with 30°F difference from one end to the other. Have you ever heard of installing another set of pads in the center of the house?

PAUL MOORE: Usually the length from pad to fan should not exceed 120 feet; some do, but heat rise is a function of the distance between pad and fan. It may not work on larger greenhouses but the pressurized system, where you are introducing cool air through tubes, eliminates this high differential. We can keep the differential in our house to within two degrees.

[1] University of California, Division of Agricultural Sciences monthly publication, Berkeley, Calif.

PROPAGATION OF CACTUS

FRANK T. FIELDING

Fielding's Cactus Gardens
El Monte, California 91732

Cactus are propagated by three major methods: seed, offsets, and cuttings.

SEED PROPAGATION

The majority of cactus species are propagated by seed. The seed is acquired from nursery stock or imported from Latin America. Seed propagation is the slowest method as most species are ready for market in not less than 14 months.

Special conditions must be met to be successful in seed germination:

Soil. A light soil mix that drains quickly is best. A commercial planting mix is preferred as it supplies all necessary nutrients as well as being of constant makeup.

Heat. Under-bench heating is needed to keep the soil temperature in the optimum range of 70° to 75°F. The greenhouse temperature should not exceed 100°F or drop below 46°F.

Benches. The benches must be sterile. Most any disinfectant can be used but longer lasting results are obtained by the use of copper compounds.

Shade. A greenhouse shade of approximately 50% is suitable for most cactus species.

Planting Method. Sterile flats are filled with sterile soil mix to 1/2 inch from top. The mix is then watered thoroughly, preferably the day before the seed is to be sown.

When flats are ready 2000 to 2500 seeds per flat are planted. Even distribution of seed is obtained by mixing the seed with gravel of equal consistency as the seed and applying this mixture to the flat with a shaker. The seed is then covered lightly with #10 gravel. All flats are then treated with a solution of Captan to further reduce possible damping-off problems.

Watering. Uniform soil mixture is the single most important factor for even seed germination. Seed flats should be watered 3 to 4 times daily or as needed to keep the soil moist.

Germination. When the proper growing conditions are met viable seed should germinate between 3 and 21 days. Fresh seed is important as seed of some cactus species lose viability within 2 to 3 weeks after harvesting.

OFFSETS AND CUTTINGS

The difference between offsets and cuttings is that offsets are broken at natural points from the parent plants while cuttings are cut to a desired length. It is important that all cuttings are taken with a sterile knife.

Soil, light, and heat. Both offsets and cuttings require a very light, well-drained soil. They both need about 50% shade and a greenhouse temperature of 56° to 100°F, preferably on the warm side.

Healing. Healing is required on both offsets and cuttings to greatly reduce possible loss to fungus. Offsets require 2 to 4 days to heal while cuttings need 2 to 3 weeks.

Rooting. Offsets and cuttings can be rooted in the same manner although offsets have an additional method that can be employed.

1. General rooting of offsets and cuttings: Healed plants are planted directly into flats. The soil should then be kept damp but not wet.

2. Air rooting of offsets: The offsets are stood in a flat, side by side and left until air roots form. They're then planted and watered lightly, increasing the water as roots develop.

PESTS AND DISEASES

Insects. Spine mealy and root mealy bugs are the major insect problems of seedlings, offsets and cuttings. Treatment consists of 1 tbsp/gal of 50% Malathion. Offsets and cuttings taken *from the field must be watched carefully for scale.*

Damping-off. Nearly all cactus are very susceptable to damping-off fungi, particularly as seedlings and when rooting. Damping-off is treated by reducing drastically the amount of water the plants receive and applying a suitable fungicide. Captain, Benlate, and Truban are effective choices of fungicides.

PROPAGATION AT MONROVIA NURSERY COMPANY: SANITATION

DENNIS CONNOR

Monrovia Nursery Company
Azusa, California 91702

CUTTING PROPAGATION

At Monrovia Nursery, we employ specific sanitation procedures in our propagation department to produce as healthy a plant as possible. I will discuss the propagation department at Monrovia with emphasis on our disease control program.

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Most of our plants are grown from cuttings which are obtained from our own container grown stock or from planted out stock. Any pruning or cutting wood collecting of disease prone plants such as euonymus, *pyracantha*, Nerium, etc. must be sprayed 24 hours in advance with 200 ppm Physan. This is accomplished with the use of our spray trucks or portable hose proportioners, depending upon the size of the area to be sprayed.

Cutting wood is collected by a crew of men and/or women, and placed in plastic bags for easy transport back to the propagation department. New plastic bags are used to collect the cutting wood of disease prone plants. Bags that are re-used must be washed in 30 ppm chlorinated water prior to use. The bags can easily be cleaned at the chlorine sinks located in the propagation department. Pruning shears are dipped with every few cuts in 200 ppm Physan, also.

As the cutting wood is being collected, it is wet down with water in the bags, and hauled by truck to storage refrigerators in the propagation dept. The refrigerators are cleaned weekly of debris and washed down with 200 ppm Physan.

As the cutting wood is needed, it is taken from the refrigerators and dispersed to the women who will make the cuttings in the cutting shed. The cuttings are prepared with the women's shears or knives, which are dipped every few cuts into 1000 ppm Physan. As each cutting is made, it is stored in the woman's own individual moist plastic tub until she has prepared enough cuttings to stick several flats at one time. Before flatting, however, the cuttings must be rinsed in a solution of 5 ppm chlorine. This is accomplished by putting the cuttings into a wire basket and immersing them into the chlorinated water sinks. The chlorination rinse is a continuously flowing setup with diaphrams connected to a chlorine tank. The amount of chlorine in the water can be regulated if desired. Holes in the back of each sink allow the water to flow continuously, forcing debris out and down the drain. This keeps the chlorine rinse water relatively clean and minimized, totally draining the sinks, and replenishing them. The continuous flow system also keeps the chlorine at its proper concentration as organic debris in the water is minimal. The chlorine will break down quickly if too much organic matter is present.

From the chlorine rinse, the cuttings are immediately rinsed in a Physan solution in adjoining sinks. We do not use chlorine or Physan on azaleas, as it tends to burn them. A 600 ppm solution is used on euonymus, pyracantha, *nerium*, etc. as their disease prevelence is higher. Most cuttings will be rinsed in 200 ppm, however. The Physan sinks have to be drained and replenished as needed during the work day. Physan does not break down as quickly as chlorine. We are not using a continuous flow system with Physan due to its cost, where as chlorine is relatively cheap and economical. But, Physan is a better pathogen fighter than chlorine.

After the chlorine and Physan dips, the cuttings can now be dipped in hormone and stuck in our propagation media. The hormone we use is indolebutyric acid (IBA). Our IBA contains a methanol alcohol volume of 55%. We use a 1000 ppm, 3000 ppm, and a 6000 ppm IBA, depending on the type of wood to be dipped. The alcohol in the hormone aids in killing pathogens that could still be on the cuttings.

The propagation medium is 90% coarse perlite and 10% fine peatmoss. It is mixed by tractor with the use of a shredding machine. As mixing occurs, calculated amounts of gypsum are added to each cubic yard of medium, to supply enough calcium for callus and root formation.

Once the medium is mixed, it is put into new plastic flats by a flat filling machine. No pasteurized media is used as long as the peat and perlite are clean.

Now that the cuttings have been collected, prepared, washed, hormone-treated, stuck, and labeled properly, they are taken by vehicle to a waiting mist area located indoors and outdoors. The cutting shed is cleaned nightly of debris, and washed down with 30 ppm chlorine. All utensils, such as gloves, aprons, plastic tubs, etc. must be scrubbed as needed, including rinsing them in chlorine solutions and Physan solutions.

The mist propagating areas must be treated before new cutting flats can be set down on them. As rooted cuttings are removed to our hardening off area, beds and benches are cleaned before use again. Outside cement or gravel mist beds are cleaned of dirt and debris by washing them down with water, or by using rakes. Then 200 ppm Physan is sprayed on with hose proportioners. After that, a solution of Citcop 4E is applied. We use sprinkling cans and broadcast it across the surface of the mist beds. Citcop is a copper salt fungicide of fatty and resin acids, metallic copper, and inert substances. Cuprous oxide can also be used. Copper sulfate is good to control algae on walkways, as is chlorine.

Glasshouse mist benches are washed down with a steam cleaner. Monrovia's machine produces 500 pounds of pressure and heats water to 210°F. It will remove algae and slime from benches, walls, and mist lines. After steam cleaning is finished, the walls and benches are sprayed with 200 ppm Physan and copper naphthenate. New and existing wooden benches in all glasshouses receive a paint job of copper naphthenate also. We use 1 part copper naphthenate to 5 parts paint thinner. The thinner will soak into the wood, taking the copper with it. Parafin is melted into the copper thinner mixture to somewhat seal the copper into the wood.

POTTING DEPARTMENT

When cuttings are rooted, they are taken to the hardening-off area. This is also treated with Physan and Citcop. After the cuttings have been hardened off for at least 7 days, they are ready to pot. Most potting is done in our potting shed. Flats of rooted cuttings are loaded onto rack trailers in the hardening-off area, and then hauled by jeep to the potting shed. Here a separate crew of women pull the cuttings from the flats. Top growth and roots are pruned; pruning shears are kept in containers of 75% isopropyl alcohol and 25% water. New plastic flats are used to hold the pulled cuttings until they are potted by another crew of women. Pots must be new, or used ones must be fumigated. We use 45 pounds of methyl bromide in a 2365 cu.ft. fumigation chamber. Potting soils are also fumigated with 99.5% methyl bromide (with 5% chloropicrin included as an indicator) for 24 hours. The potting shed is washed down nightly of debris, and sprayed down once a week with 200 ppm Physan. Newly potted liners are taken to glasshouses or lath house. Lathhouse liner beds are treated with Physan at 200 ppm and Citcop also.

GRAFTING DEPARTMENT

Most of our grafting is done during the winter months. Almost all of the benches in the glasshouses are converted to grafting tents, made of new 4 mil plastic. The benches are treated with copper naphthenate before wax paper and a moist peat moss base is laid down. Captan is used when the peat moss is being mixed, and applied again on the surface of the peat moss after it is put into the tents. The tents are used mainly to graft junipers and Southern magnolias. Grafting knives are dipped every few cuts in Physan of 200 ppm and in isopropyl alcohol, 75% full strength. Scionwood is collected in the field, put into clean bags and kept refrigerated. Before use, the scionwood must be rinsed in 5 ppm chlorine water and in 200 ppm Physan. Grafting tents that are filled with grafted material are opened every morning and checked for disease, and to promote air circulation. Large fans and cooling pads are used also to circulate air in the grafting houses and most other propagation houses, as well as controlling the air temperature.

FERN PROPAGATION

Except for a few cultivars, our ferns are grown from spores. New wood or plastic flats, are filled with spaghnum moss then steam pressurized at 180°F for two hours. The spaohnum flats are then placed on Physan-treated benches and planted immediately with the spores. They are then covered with plastic lids to keep moisture in and minimize the settling of air-born fungal and bacterial spores on the surface. All potting soils in fern propagation are fumigated with methyl bromide, and only new or fumigated pots are used. Ferns grown from plantlets, as *Asplenium bulbiferum*, must have the plantlets washed in 5 ppm chlorine and 200 ppm Physan before planting.

SEED PROPAGATION

Most of our seeds are bought from other companies but any seed that we collect is cleaned and inspected for disease. All seeds, whether bought in or collected, are surface-treated before planting with Thylate, a fungicide. The seed planting medium is put into wood flats and steam pasteurized at 145°F for two hours. After the seeds have been planted, a thin layer of silica sand is put over the surface of the flat. The sand, being inorganic and quick drying when the flats are watered, minimizes surface fungal growth.

CONCLUSIONS

Monrovia is continuously researching new and better ways to control disease throughout the nursery. Insect control is important also, as insects may carry pathogens from plant to plant. Future research projects for the propagation department include a chlorinated mist system. Disease prone plants may have to be kept continuously immersed in Physan solutions from the time they are collected in the field to the flatting of the prepared cutting in the cutting shed.

NEW VISTAS IN PLANT PROPAGATION

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The plant propagator and the nursery industry are in the most fortunate position of being able to benefit from the result of research in many disciplines and many applied fields.

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FERN PROPAGATION

Except for a few cultivars, our ferns are grown from spores. New wood or plastic flats, are filled with spaghnum moss then steam pressurized at 180°F for two hours. The spaohnum flats are then placed on Physan-treated benches and planted immediately with the spores. They are then covered with plastic lids to keep moisture in and minimize the settling of air-born fungal and bacterial spores on the surface. All potting soils in fern propagation are fumigated with methyl bromide, and only new or fumigated pots are used. Ferns grown from plantlets, as *Asplenium bulbiferum*, must have the plantlets washed in 5 ppm chlorine and 200 ppm Physan before planting.

SEED PROPAGATION

Most of our seeds are bought from other companies but any seed that we collect is cleaned and inspected for disease. All seeds, whether bought in or collected, are surface-treated before planting with Thylate, a fungicide. The seed planting medium is put into wood flats and steam pasteurized at 145°F for two hours. After the seeds have been planted, a thin layer of silica sand is put over the surface of the flat. The sand, being inorganic and quick drying when the flats are watered, minimizes surface fungal growth.

CONCLUSIONS

Monrovia is continuously researching new and better ways to control disease throughout the nursery. Insect control is important also, as insects may carry pathogens from plant to plant. Future research projects for the propagation department include a chlorinated mist system. Disease prone plants may have to be kept continuously immersed in Physan solutions from the time they are collected in the field to the flatting of the prepared cutting in the cutting shed.

NEW VISTAS IN PLANT PROPAGATION

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The plant propagator and the nursery industry are in the most fortunate position of being able to benefit from the result of research in many disciplines and many applied fields.

Plant breeders are continually developing new plant material, some of which eventually becomes important in the nursery trade. Plant introduction programs and arboreta often bring in valuable new germplasm to be used directly, or as a gene source for introducing, by plant breeding, new characteristics into present plant material. The biochemists, plant physiologists, and botanists develop new growth regulators, herbicides, fertilizers, and such new techniques as tissue culture. They also study plant structure, adaptation to the environment, and plant functions, to give us a better understanding of plant behavior. Entomologists and plant pathologists develop new chemicals and new techniques for controlling insects and diseases, while the engineers design new propagation facilities and equipment used for such things as greenhouse heating and cooling, container growing, and aerated steam soil pasturization.

The big challenge to the plant propagator is to become aware of new developments in all these areas and to make use of them. It is a major task just to keep up with the literature and new developments in all these fields. Much ongoing research, which eventually becomes of great value in plant propagation, is not directed toward solving nursery problems, but is a spin-off from other projects. So the plant propagator, in order to make significant steps forward in reproducing plant material must continually be on the lookout for advancements in all these related fields and tie into those new developments which can be of value to him.

Looking back at the history of plant propagation there is a series of major milestones which have created great leaps forward.

Early prehistoric man had undoubtedly learned to propagate woody food producing plants vegetatively by hardwood cuttings and by layering so as to perpetuate the best selections available to him. Some of the most ancient fruit crops are among those easiest to propagate by hardwood cuttings — grapes, figs, olives, pomegranates, and mulberries. Cultivar selections of superior forms were, no doubt, being made and propagated by early man. Possibly some early hunter, chasing an animal, stuck his sharpened spear into the ground and later found it growing. Thus propagation by hardwood cuttings was born.

Grafting was an art well-know to early civilizations and is shown in their pictures and writings. It is interesting to speculate how the first grafting operation may have occurred. Perhaps the hunter, chasing an animal, missed and stuck his sharpened spear into a tree. If the spear was of living wood, and stuck just at the right angle into the cambium area of the tree and, if the two were compatible, then perhaps his spear would have started to grow — thus the art of grafting was born.

Later, through the centuries, the invention of glass permitted lighted, high humidity enclosures which enabled propagation by leafy cuttings — which was certainly a big step forward. In the 1930's plant propagation received a big boost through the study of auxin physiology and the finding that such materials as the synthetic auxins — indolebutyric and naphthaleneacetic acid — had the ability to stimulate adventitious roots on stem tissue.

Mist propagation, starting in the 1940's and 1950's, the widespread use of polyethylene sheeting in the 1960's, and container growing gradually becoming more widespread during the 1950's, 60's, and 70's, have been major events in plant propagation history.

The most recent major development in plant propagation, of course, and one we are standing in the middle of right now, is the use of aseptic tissue culture techniques for large scale reproduction of plants. Many nurseries right now have established tissue culture laboratories and are propagating commercially plant material such as chrysanthemums, orchids, Boston ferns, *Dracaena*, *Cordyline*, and *Diffenbachia*. Tremendous quantities can be produced in a short time; for example, techniques have been refined to the point where 100,000 lily plants can be produced in 6 months starting with one medium sized bulb (3). Tissue culture in Araliaceae can result in 5 million transplantable plants for each 3 to 5 mm explant within one year (10).

If we turn and look toward the future in plant propagation, what do we see? Immediately, we see explosive developments in the field of plant tissue culture. Looking through recent issues of the IPPS Proceedings, one is impressed by the increasing numbers of articles dealing with tissue culture methodology and the increasing numbers of plant species that are being successfully reproduced by these techniques. Similar articles are also appearing in most other plant science journals.

Articles and books are being written dealing with tissue culture techniques for the plant propagator. Murashige's review (11) in the Annual Review of Plant Physiology entitled, "Plant Propagation through Tissue Cultures", stated the progress made in this area as of 1974.

In 1976, deFossard published an excellent 400 page book entitled, "Tissue Culture for Plant Propagators" (5). It can be ordered from: The Department of Continuing Education, University of New England, Armidale, N.S.W., Australia, for $10.00 Australian, plus postage.

The book, "Plant Tissue Culture Methods" by O.L. Gamborg and L.R. Wetter, contains easy-to-read instructions on the techniques of tissue culture. It is available from the National Research Council, Ottawa, Ontario, Canada K1A OR6, for $6.00.

Organizations directed toward the promotion of tissue culture techniques include the International Association for Plant Tissue Culture, which was organized in 1971. Application forms for membership are available from the National Correspondent for the U.S.A.[1] This group is holding its Fourth International Congress of Plant Tissue and Cell Culture at Calgary, Canada, August 20 to 25, 1978. This meeting is open to all interested persons. The IAPTC also publishes a quarterly Newsletter containing articles and news on developments in plant tissue culture.

The Tissue Culture Association[2] is concerned with aseptic cell, tissue, and organ culture of both animals and plants. It owns and operates an educational and research facility — The W. Alton Jones Cell Science Center in Lake Placid, New York. Membership in this organization is open to scientists and technicians active in the field of tissue culture, who have the B.S. degree or its equivalent. The Plant Division of the Tissue Culture Association gives short courses at Lake Placid, entitled "Tissue Culture Techniques for Plant Propagators". The next scheduled courses are September 25 to 30, 1978. The TCA also publishes a monthly journal, *In Vitro*, and a quarterly *TCA Report*. An annual meeting is held by the TCA in which papers dealing with both animal and plant tissue culture are presented.

An International Congress on Tissue Culture sponsored by the International Society for Horticultural Science was held in Belgium in September, 1977, and during this same month at Ohio State University a symposium entitled, "Plant Cell and Tissues Culture: Principles and Applications", was held. The papers presented at the ISHS Belgium meeting will be available in an issue of *Acta Horticulturae*.

In the past, propagation by tissue culture techniques seems to have been limited to herbaceous plants, but articles are now appearing describing propagation of such woody plant species as *Malus* (1,6), *Tsuga* (4), *Ficus* (9), and *Tupidanthus* (10).

Obviously, nurseries wanting to stay on the front line of new propagation techniques must watch developments in the field of tissue culture and fit in where they can. Aseptic laboratories, equipment and trained technicians to do this type of work are required.

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[1] Dr. Donald K. Dougall, National Correspondent, U.S.A., W. Alton Jones Cell Science Center, P.O. Box 631, Lake Placid, New York 12946.

[2] TCA Business Office, 12111 Parklawn Drive, Rockville, MD 20852.

Where are there other opportunities for productive developments in plant propagation? The juvenility influence on production of adventitious roots in cuttings has been known for many centuries, yet the mechanism involved is little understood. If we knew what rooting promoter(s) occur in cuttings taken from young seedling plants (but not found in more mature plants), or what rooting inhibitor is produced as the plant ages (12) — or some combination of the two — this could have great implications in propagation by cuttings of difficult-to-root clones and would be a real step forward.

Considerable interest has been shown in the past few years in increasing research activities on juvenility in woody perennials, not only in understanding the mechanisms involved, but in learning better how to make use of this phenomenon in rooting cuttings and in bringing seedlings through the juvenility period faster to aid plant breeders in evaluating their seedling selections.

In 1975 two symposia on juvenility in woody perennials were held, the North American symposium at College Park, Maryland, and the European symposium in West Berlin, Germany. The papers presented in these two symposia were published by the International Society for Horticultural Science in the *Acta Horticulturae* series (13).

At the University of California, Davis, a new research project has been established jointly by the Departments of Pomology and Environmental Horticulture to study the mechanisms involved in juvenility — from the standpoint of regeneration and of regulation.

The practice of etiolating stem tissue has long been known to cause the production of adventitious roots on stems of difficult-to-root plants, yet there is little information on the mechanisms involved. Stems held in complete darkness are much more likely to form roots than similar tissue exposed to light. Intensive research into this field could uncover some valuable leads into the biochemistry involved in the initiation of root primordia in stem tissue.

Studies (7) using Pinto bean indicate that in this plant there is photoinactivation of root promoting factor(s) by exposure to light. Treatment of bean stem tissue with a phenolic compound, 2,4-dinitrophenol caused production of adventitious roots, particularly if indoleacetic acid was also applied, provided the tissue was subsequently kept in darkness by covering with opaque tubing. When covered with transparent tubing, no roots formed. Mixing 2,4-dinitrophenol with a solution of chlorophyll and ascorbate (both occurring naturally in stem tissue) in a test tube and exposing to light caused a conversion of the 2,4-

dinitrophenol to 2-amino, 4-nitrophenol, which had no root inducing properties. If kept in darkness, this did not occur. Further studies of this nature with other kinds of plants may be of considerable value in determining if the benefits of etiolation are due the production of light sensitive rooting factors. Possible characterization of the substances involved may lead to useful materials which could substitute for the etiolation effects.

What is there in the future in the area of grafting and budding that could develop into a major breakthrough and permit wider usage of grafting technique for those kinds of plants known to be difficult to propagate by grafting or budding and, perhaps, almost impossible to propagate by other methods?

One of the basic reasons for grafting failure in these difficult plants is the lack of the all-important callus production at the graft union. Some kinds of easily grafted plants, as grapes, apples, and pears, will produce callus profusely at cut surfaces while other difficult-to-graft plants, as the oaks, are notoriously poor callus producers. Treatment of cut graft surfaces, ready to bring together to make the union, with chemical substances which would promote callus production could lead to greatly increased grafting success. Reports in the literature from aseptic tissue culture studies, aimed at causing new plant regeneration, are replete with results in which certain treatments caused only massive amounts of callus to be produced. Certain combinations of kinetin and auxin will do this. Such treatments could very well be of great value in grafting where stimulation of heavy callus production is needed. There is room for considerable research into this area and it could lead to results of great benefit in grafting and budding procedures.

What is in the future in rootstock development? With the increasing interest in smaller, compact fruit trees and woody ornamentals, often planted in high density arrangements, there is a great need for new size controlling rootstocks similar to those now available for apples, as pioneered in England for many years by the East Malling Research Station.

The activities of the International Dwarf Fruit Tree Association[3] in setting up their Rootstock Research Foundation, if successful, may lead to the development of equally useful size controlling rootstocks for other species.

The interesting work in the development of genetic dwarf plants may bring similar results by a different route. For example, in a new fruit breeding project at the University of California, Davis, a genetic dwarf peach selection, yielding 21 tons per

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[3] Executive Secretary, R.F. Carlson, Dept. of Horticulture, Michigan State University.

acre in the second year after planting the nursery trees, has been developed. Such clones are propagated by budding 18 inches high on standard peach rootstocks, such as 'Nemaguard', with various planting densities of 500 to 3,000 trees per acre being used. Dwarfness is due to very short internode length, the trees having as many leaves as full sized trees. In such high density plantings of small trees, pest and disease control, and mechanical harvesting, would be much easier than for full sized trees. In this project, fruit quality has yet to be bred into the dwarfed high yielding selections.

What may be ahead in plant growth regulators that may be useful in plant propagation? Growth regulator research received a considerable stimulation with the formation of the Plant Growth Regulator Working Group,[4] organized in 1973. Annual meetings are held and membership is open to anyone interested in research with plant growth regulators. Abstracts of the meetings are available, as is the Quarterly PGR Bulletin. A new 94 page Plant Growth Regulator Handbook (2) was published in 1977 giving information on recently released synthetic plant growth regulators.

No growth regulators useful in stimulating production of adventitious roots on cuttings that are better than the long standard indolebutyric acid and naphthaleneacetic acid are appearing. Information being developed from tissue culture studies on the effects of cytokinins may lead to more widespread use of this material in propagation by leaf and root cuttings since it is active in promoting cell division and bud and shoot development. The synthetic cytokinins, N-6 benzyladenine, 6-furfurylaminopurine, and PBA (6-benzylamino) -9- (2-tetrahydropyranyl) -9- H-purine (to be marketed by Shell Agricultural Chemical Company under the trade name "Accel") are low enough in cost to be economically useful in propagation practices.

Ethylene gas is known to stimulate roots on stem tissue and perhaps future research will show positive results in the application of ethylene releasing compounds, as ethephon, for rooting cuttings. Evidence to date, however, is somewhat conflicting.

These are some of the areas where the future holds promise of new exciting developments that may materialize into useful benefits for the plant propagator. There are others, of course. For example, there are reports (8) that adding mycorrhizae fungi, or extracts of the fungi, to the rooting medium have enhanced rooting of bearberry and huckleberry cuttings, possibly due to synergism with auxins.

[4] Dr. E.F. Sullivan, Business Manager, The Great Western Sugar Company, Agricultural Research Center, Sugar Mill Road; Longmont, Colorado 80501.

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SUBTROPICAL FRUIT TREE PRODUCTION: AVOCADO AS A CASE STUDY

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Abstract. A general description of techniques in a modern commercial avocado tree nursery and a summary of special precautions for the prevention of infections by *Phytophthora* organisms, sunblotch virus, and *Rhizoctonia* are given. Also, a description of special procedures for seed storage and a recently patented method for producing grafted avocados on clonal rootstocks in described.

INTRODUCTION

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INTRODUCTION

I have chosen avocados to discuss because, frankly, the avocado (*Persea americana*), is one of the few plants I know anything about! It is suitable as an example of subtropical horticulture for it is evergreen, frost-tender, grows well on acid soils, and is native to areas with frequent summer rains. It is a difficult plant to grow really well in California and we of the avocado nursery industry use a number of specialized techniques to achieve efficient production. One of the rewarding aspects of our work is that we produce plants for a sophisticated commercial clientele whose interest is in premium, durable, and disease-free trees which are planted in highly capitalized orchards for commercial fruit production.

Radical changes have occurred in California avocado nurseries during the past 25 years. Twenty years ago most plants were started in fields in nursery rows, budded in place, and balled in burlap. The process required from 3 to 4 years and the percentage of successfully budded trees that resulted was very low by today's standards. The first really radical commercial departure from this traditional procedure is attributed to Walter Beck, one of the pioneers and early masters of avocado propagation. Beck began propagating under greenhouse conditions and was able to produce small and tender, but healthy, containerized plants, with a then high percentage of success, in only 8 months (1). He accomplished this by utilizing bottomless cylindrical containers of building paper, which measured 5" (12.5cm) in diameter by 12" (30.5cm) tall, and by tip grafting small seedlings. Tip grafting was simply a form of whip grafting, using apical sections of stems of winter wood as scion material.

Today's standard techniques are a blend of traditional methods with techniques worked out by Beck. We utilize Beck's greenhouse discoveries to assure ourselves of reasonable propagational efficiency; we finish our trees off in the open sun to achieve sturdiness which is almost essential when the trees are transferred and planted in their permanent orchard locations, sometimes under hot and arid conditions.

BASIC GROWING PROCEDURES

At Brokaw Nursery we start most of our seeds during the fall as they are harvested. Seeds of the Mexican race are chosen because, on the average, they are most suited to our California soil and climate. We scarify the seeds by slicing thin sections from the basal and apical ends, and bed them in a peat moss-perlite blend until they germinate and demonstrate sound, healthy, seed tissue and roots. Then we transfer them to gusseted and perforated plastic bags which measure about 2-1/2" (5.3cm) in diameter by 9" (23cm) in length. The bags have been previously filled with the peat moss-perlite blend. This type of packaging furnishes us with a very concentrated grouping of small seedlings which reach grafting stage about 6 weeks after scarification and bedding of the seeds.

For grafting we depart from Beck's whiplike procedures, for our propagators can work most efficiently with less exacting techniques. We first cut off the seedling squarely, about 4 in. above the bag. Then we cut a vertical slit in the small stock (now about 3/16" to 1/4" (.5-.65cm) in diameter) and insert a scion, the butt end of which has been sliced on two opposite sides to form a wedge at the points of cambial contact. The diameter of the scion is relatively unimportant as we merely slice off one edge if it is oversized, so as to make an acceptably neat juncture. The area of union is then wrapped with rubber, and asphalt grafting emulsion is applied to the wounds. Some of our grafters have reached high success rates in this work. We employ ladies who graft close to 100 per hour much of the time, and achieve success in a good 90% of their production.

Assuming that one chooses suitable graftwood, and handles it properly, dessication is the greatest hazard for successful "take" of avocado grafts. We avoid this problem by watering our plants just before grafting and placing them in special high humidity chambers immediately following grafting. They remain in the chambers for about 10 days. We believe that this procedure produces more uniform graft development, as well as increased success in grafting yields.

After removal from the humidity chambers, the young grafts are transferred to standard greenhouse conditions for a period of approximately three weeks. They are then sorted for size, transferred to benches under 50% shade for at least 5 days, and subsequently transferred to open sun pallets, and then to the field containers any time after 10 days from leaving the greenhouse.

A good aspect of this procedure is that up to this point we've been able to pack the plants together much of the time at a density of about 25 per square foot ($250/m^2$), and they've been in the greenhouse for an optimum total of eleven weeks. During this brief period they have been bedded, planted, grafted, and established — all of this for an eventually large, woody, sensitive tree! Of course our efficiency is not always up to this standard; our plant densities fall off from time to time as we sort, cull, and box plants for readiness, but generally it is concentrated, efficient production.

Before proceeding to the field planting of the small grafted liners (our term for the plant at this stage) it is appropriate to describe the greenhouse conditions. Our choice for the greenhouse environment is not scientifically based. We simply try to approximate the atmospheric conditions one would expect during an ideal coastal southern California April. Accordingly, we run a nighttime temperature of about 55°F (13°C) and a daytime temperature of about 72°F (22°C). We keep the relative humidity in excess of 55%. Our night temperatures are allowed to fall, principally, because low night temperatures aid in developing a suitable girth/height ratio in our plants. We believe this is important because it facilitates grafting, minimizes shading under crowded conditions and, we believe, affects the eventual girth/height ratio of the saleable tree. It is a ratio which we seek to maximize.

Transplanting of the grafted liners to field containers generally is done in the spring after the worst danger of frost has passed. For field containers we use open-ended flexible polyethylene sleeves of 10 mil material (.001·inches, or .025mm, thick), that measure 7″ (18cm) in diameter by 17″ (43cm) in height, when filled with field container soil. They are placed in rows that are two containers wide, the rows being on 38″ centers, and then filled in place by hand with the aid of a special portable frame. We use open-bottomed containers for two reasons: first, they are cheap and simple to fill and, second, the intimate contact between container soil and the underlying earth assures efficient drainage of the container growing medium.

Field container soil is for us a compromise. To achieve efficient drainage and aeration we use 50%, by volume, of sawdust, 10% mushroom compost, and 20% sand. To achieve a certain degree of cohesiveness in our ball of soil, so that it may be transplated efficiently, we include 20% clay-bearing loam soil. The clay component helps, too, with its ability to retain moisture.

Grafted liners are planted into the permanent field containers by slitting and stripping the plastic bags away from the young root systems (taking care to slice off any curled roots) and lowering the small balls into holes previously bored in the upper surfaces of the field containers. Success of transplanting is about 98%. The grafted liners needn't be large for this operation; 1/2″ (150mm) of healthy scion growth is sufficient.

We have traced the small grafted liners' history now, from the fall of one year to the following spring, when they are transplated to field containers. The trees will be ready for orchard planting the following late summer (10 months from seeding) or, more suitably, the following spring (15 months from seeding).

Field growing is conventional. The young plants are irrigated two or three times per week with a spaghetti-type drip system under a constant feed program. They are staked and tied. Staking occurs as late as practicable since the later the staking, the higher the girth/height ratio that results. Mature, saleable trees are two feet (60cm) tall minimally, they average about three feet (90cm).

DISEASE CONTROL

Avocado nursery diseases can be partitioned into two groups; 1) those whose presence we can't tolerate on saleable plants, and 2) those that threaten our producton efficiency. The first group may not encumber our production efficiency but may raise havoc in a commercial orchard. The second group presents economic and marketing problems for the nursery by reducing yield and stunting the plants.

The first and most important disease that we cannot tolerate in a saleable tree is avocado rootrot, cause by *Phytophthora cinnamonii*. The fungus must be *absolutely* banned from our growing grounds. This is *extremely* important, as the fungus is readily communicable and kills mature orchard trees, often in a very short period of time. We, and many other nurseries, operate under a California State Certification program which stipulates many of the precautions we must take to avoid contamination of the trees. Among our precautions and, in addition to other conventional disinfecting and prevention procedures, are the following:

A. Preplanting heat treatment of all seeds in a hot water bath for 30 minutes @ 120-122°F (49°-50°C).
B. Fumigation of all soils, peat moss, and other soil amendments, @ 800lb/A (900Kg/Ha) or 3 lb./$100ft^3$ (48 g/m^3).
C. Dry copper sulfate (plus flocculent) step basins to be used by all entering foot traffic.
D. Entrance water vats for wheel traffic, charged daily with formaldehyde.
E. Weekly copper sulfate sprays on all greenhouse floor areas and bench legs, and on areas where outside traffic approaches our entrance areas.
F. Sodium hypochlorite-bearing high pressure spray to sweep clean and disinfect the beds of all trucks before they pick up trees.
G. Planting of susceptible indicator plants (*Persea indica*) among our regular outside field stock.

A second disease that we try to avoid spreading in nursery stock is sunblotch, a yellow and/or pinking streaking of stems and fruit in bearing trees. It is a systemic disease, thought to be viral in nature, which is transmitted through seeds and scionwood. To avoid it, we are more and more using Registered sources of seeds and graftwood. These sources are the direct descendants of trees that have been indexed for detection of the disease under the supervision of the California Department of Agriculture and the University of California at Riverside. This disease is not nearly so important as avocado rootrot since it doesn't spread rapidly to otherwise clean fruit-bearing trees.

A minor parasite that we control is Latania scale. When passed on to orchards it tends to thrive on and girdle young tree trunks that are enclosed in poly-coated sun shields. We control the pest quite effectively with trimonthly field applications of malathion.

Our principal nursery pest (not of known major importance from the standpoint of spreading to orchard sites) is *Rhizoctonia* organisms. These destroy seeds and young seedlings and stunt root systems. They make liabilities of otherwise efficient operations in short order. We fight such potential infection intensely. In addition to other conventional disinfecting techniques we do the following:

A. Treat all seeds, after heat treatment, serially, with sodium hypochlorite and a Benlate dip.
B. Drench all bedding soil with Benlate and Terraclor.
C. Treat all graftwood with Benlate.
D. Drench all greenhouse planting media with Terraclor at time of planting, and all greenhouse media and grafted liners as a matter of course on a trimonthly schedule.
E. Often in winter and spring, we drench the large field containers with Terraclor as the grafted liners are planted.

Our practices have functioned very well with regard to *Rhizoctonia*. Even in our susceptible fumigated soil we are troubled very little by it.

EXPERIMENTAL WORK

As any commercial nurseryman knows, experimentation with new techniques is expensive and it usually fails, yet it is absolutely essential if the nurseryman wants to be among the industry's leaders. Also, it's one of the true joys in our work.

I will report a couple of items which may be new and useful. The first deals with seed storage and the second, a commercial method for clonal rooting of the difficult-to-root avocado rootstocks.

We tried for several years, with very poor and variable results, to store large quantities of avocado seeds under refrigerated conditions in polyethylene bags. The University of California could do it in small amounts, a few nurserymen we knew of could do it in small batches, but neither we nor any of our colleagues could dependably store large quantities of avocado seeds for many consecutive months. We noticed that entire bags of seeds died as if they were poisoned by their own respiration products. Therefore, we tried a form of periodic air exchanges. We inserted two stoppered tubes in the mouth of each bag, each extending from depths of the bag to the atmosphere. Monthly thereafter, we circulated atmospheric air through the bags with the aid of an air compressor, via the temporarily unstoppered tubing. In addition, we used thin plastic (1-1/2 mil) for bagging material. Since we began this practice, we have not experienced the death of any entire bags of seeds, and the viability rate has remained very high (90%+) for 6 months. We still don't know the limit of such storage, as 6 months is the longest period we've tried to date.

One of the most exciting projects we've worked on at Brokaw Nursery is the development of techniques to commercially produce clonal avocado rootstocks. This task became important some years ago when Dr. George Zentmyer, of the University of California at Riverside, discovered that certain clones, used as rootstocks, demonstrated significant resistance (or tolerance) to *Phytophthora cinnamomi*.

The most significant early work in the clonal rooting of avocados was done by Ted Frolich at UCLA (2). Frolich used the etiolation of potential rooting tissue as a powerful tool, new to avocado propagation. Basically, he grafted seedlings with bud-bearing stem tissue from a clone to be rooted, raised the grafted shoot to about a six inch height (15cm) in moist darkness, and enclosed the etiolated stem in a rooting medium, with the seedling still attached. After leaves had developed on the stem (now extending above the rooting medium) he severed the etiolated graft from the seedling and rooted the resultant cutting by conventional rooting procedures in vermiculite within a humidity chamber. After the rooted cutting had been established in a new container, he grafted it with a fruiting scion. Thusly he grew a grafted avocado tree of certain genetic identity in both rootstock and scion portions.

With this technique, Frolich was able to raise thousands of clonally stocked trees for Zentmyer's very important work on rootrot resistance. The commercial difficulty with the technique was that no commercial nurserymen could use it to produce large quantities of trees and, at the same time, make a profit. It was too slow, required too much space, and there were many failures.

Three years ago Brokaw Nursery hired Burton Silva, a recent graduate of Cal-Poly, Pomona, among other things, to administer a program to produce clonal avocado rootstocks. As a result of Silva's work we were able to employ a method which is an extension of techniques previously worked out by Frolich, with an added twist.

The method departs from Frolich's at his cutting stage, at which he severs the new potential stock from the seedling. We have substituted a "weaning" process at this point to avoid shock to the plant and to utilize the vigor of the nurse seedling as long as possible. Our steps are the following:

1. Graft a seedling in the greenhouse with a bud-bearing stem scion of the clone to be rooted. (Frolich's procedure.)
2. Etiolate (grow in the dark) the rootstock stem to a height of 5-6" (13-15cm). (Also Frolich's procedure.)
3. Slip a wide metal collar, about 1/4" (64cm) in diameter, loosely over the etiolated stem to a point immediately above the graft union. (This metal band is called the *weaning girdle*.)
4. Extend the growing medium (now the rooting medium) nearly to the apex of the etiolated shoot.
5. Allow the grafted shoot (whose lower portion is etiolated) to develop to a graftable stage.
6. Graft a fruiting scion onto the clonal rootstock shoot.
7. Transplant the three stage plant in its entirety into a larger container for development to a maturity suitable for orchard planting. During the process the new rootstock is automatically weaned from its nurse seedling, which dies.

Rooting takes place in the above process sometime during stages 4-6, depending upon the girth of the plant. Silva's raw data suggests that over 90% of all etiolated stems have rooted after reaching a diameter of 7mm, one inch above the rooting medium.

The steps above are amenable to minor changes. Certain plastics may be substituted for the metal collar, but this is a detail only. We prefer metal because it girdles the stem very assuredly with less chance of the girdle's "callusing over" than with corresponding widths of plastic. We have never seen incomplete girdling where our metal bands were used.

In step three it is important not to rupture the cortex of the etiolated shoot. If the shoot is damaged in avocados it may callus to the point of bridging the girdle.

This procedure is currently protected by a Method Patent for avócados. It is now used commercially by Brokaw Nursery in the United States and (by special exclusive licensing agreement) by Getzler Nurseries in Israel. The method may be applied freely to difficult-to-root species other than avocado and perhaps has some usefulness among them. It is similar to a method described by Hartmann and Kester (3), but the published technique does not dependably serve for avocados.

FUTURE AVOCADO RESEARCH

I believe that in the future our research efforts will be directed toward the search for other avocado rootstock clones for a variety of specific purposes. We need rootstocks, for instance, with better rootrot resistance, rootstocks with dwarfing tendencies, and stocks that withstand salty soil and water, and for calcareous soil conditions. Techniques for economic, commercial, clonal rooting, are now in operation, and these will be surpassed in the future. We now need to find suitable stocks for special problem areas so that we can truly match special conditions with special plants — tailored from top to bottom.

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JIM POORBAUGH, Moderator: Do we have any questions for our speakers at this time?

BRIAN GAGE: It was stated that Monrovia Nursery brought quantities of peat moss into the grafting house. What was the peat moss used for? I assume it was for plunging containers.

DENNIS CONNOR: We are bringing in peat moss that has been wetted down and treated with captan into the grafting tents to supply the humidity for the grafts once they have been prepared and put in the tent.

ED SCHULTZ: Mr. Connor, do you use bottom heat on your juniper cuttings when you put them outdoors for rooting?

DENNIS CONNOR: Yes, we do. We are starting out at about 65°F bottom heat for most of the conifers that we produce. In about a 6-week period we are upping that to about 70° to 72°F. However, we have been doing a lot of experimenting in the past few years trying to get away from the use of bottom heat; this seems to be O.K. on certain kinds of conifers that even do better without bottom heat. For example, some of the "spreaders," like Bar Harbour, will root a little slower but just as well without bottom heat. It is a space problem for us at Monrovia with the amount of junipers we cut. We don't always have the bottom heat space to put the plants in we would like to. So when we plan our production of junipers for the year, we try to arrange them so that the kinds that have to have bottom heat will go on the bottom heat beds, while the plants that can do without it will go on beds without bottom heat.

VOICE: What type of wood are you using to prepare conifer cuttings?

DENNIS CONNOR: Basically it is semi-hardwood. This is true for all the conifers we produce.

ARDA BERRYHILL: What is the rooting mixture you use?

DENNIS CONNOR: We use a 90% perlite and 10% peat, which is standard for our entire cutting operation. We use that mixture for just about everything that we propagate, with a few exceptions; for example, on azaleas we use a little more perlite of a finer grade. A few kinds of plants we propagate in sand. But basically the perlite-peat mix is used for everything we propagate.

HOWARD BROWN: A question for Mr. Fielding. What would you consider the best source of seed for cactus propagation?

MR. FIELDING: You can't find cactus seed listed in the usual seed catalog. It is a specialty, of course. There are cactus growers who make a business of doing nothing but growing plants and collecting the seed. The average type of seed will run $2.50 per thousand, but some is $1.00 per thousand. The growers in Fallbrook, California, raise a lot of cactus seed. Seed that is collected from Mexico to South America is harder to come by but there are people there who specialize in cactus seed. New Mexico Research collects seed from all over the world. They have a catalog and you can buy seed from them. You can also buy seed from Germany and England that is collected all over the world.

BILL NELSON: I would like to ask Mr. Brokaw about his experiences with dwarfed types of avocados, genetic or otherwise.

WILLIAM BROKAW: Dr. Hartmann, in his talk, mentioned the genetic dwarfs; we have these in avocado — several types which tend to be dwarfed. We are trying to find dwarfing rootstocks, but we haven't run into one yet. The problem is in recognizing them because what we are necessarily working with most of the time are seedlings which often look like they are dwarfed. They are dwarfed seedlings all right, but when we graft a fruiting scion on them they get big. We have a standing inquiry out to the industry to let us know if anyone finds a tree of a standard cultivar on good soil which is small and bears well. We would sure like to force roots out from the rootstock shoots and duplicate the trees, thus obtaining a dwarfing rootstock for avocadoes.

BRIAN GAGE: Is there any research being done on inducing hardiness in avocado by the rootstock?

WILLIAM BROKAW: There is no evidence that rootstocks have anything to do with the cold hardiness of the fruiting scion of an avocado tree, I am sorry to say. We have some fairly hardy strains, such as Yama, which are suitable in the San Joaquin Valley of California. This one doesn't bear too well but does stand quite a lot of frost.

FRANK EVANS: Question for Mr. Brokaw. Does the Mexican avocado seed require treatment from the Department of Agriculture before you get it?

WILLIAM BROKAW: No, but as a matter of course, we are more and more using seeds which are from registered sources which has to do with the sun blotch that I mentioned; then as part of the certification program, we must be supervised in the heat treatment of the seeds before we put them into certified nursery locations.

LES CLAY: Question for Dr. Hartmann. I would like to know if he has any record of what work is going on in tissue culture in England.

HUDSON HARTMANN: There is considerable work on tissue culture being done in England. *Malus* (apple) has been propagated in England in this manner. I can send you a copy of the reprint describing this work if you are interested in it.

LES CLAY: My father was in England earlier this year and he came back all excited about two-year-old apple trees there with full crops of apples on them which he saw.

HUDSON HARTMANN: This is the "meadow culture" which has been developed at the Long Ashton Research Station near Bristol. They are planting the trees in an ultra-high density pattern and by the use of certain growth regulators and dwarfing rootstocks they bring the trees into bearing very early and are getting high yields. Whether this will develop into something commercial remains to be seen. But there is a lot of work in tissue culture going on in England. For example, Dr. Street in England was one of the leaders in tissue culture research. His book, *Plant Tissue and Cell Culture*,, has just been published in its 2nd edition.

VOICE: Do you know of any avocado strain where the fruit can be left on the tree for about a year and a half before it is harvested.

WILLIAM BROKAW: No, but you could certainly get full year-round production by planting two cultivars and heavy two-year production with three cultivars. I would recommend planting three trees of different cultivars in one hole.

VOICE: Where does DNA recombination fit into tissue culture research in the future and in plant hybridization.

HUDSON HARTMANN: We are going to have a talk on Friday on this subject so if you can stay until then you will, perhaps, get all your questions answered. Cell and tissue culture research is a new field but DNA recombination is probably quite a ways down the road for plant propagators, although it is something coming up in the future. Genetic engineering, where you might develop your own plant, is a fascinating idea, but it is not in the immediate future for plant propagators.

VOICE: What is the strength of the Clorox solution that you use for avocado seeds; a second question is whether or not you condition the seed before dipping in Clorox.

WILLIAM BROKAW: We use 10% of the 3% household bleach. The answer to the conditioning is essentially — no. What we have is kind of a cold water dip, then we dip them into the Clorox solution. Shortly after that we give them a Captan treatment.

VOICE: At what time, if ever, do you excise the original nurse seedling in your nurse root grafts?

WILLIAM BROKAW: Never, it is automaticaly aborted. With the nurse root graft procedure we use now the root is automatically cut off and we have never found a failure.

POTENTIAL APPLICATION OF PROTOPLASTS FOR FUTURE PLANT IMPROVEMENT

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INTRODUCTION

Traditional plant breeding methods for commercial improvement of plants are restricted to hybridizing plants that are closely related. With few exceptions, hybrids combining desired qualities derived from both parents can only be made between different species of plants. These F_1 hybrids are usually self-sterile and require doubling of the chromosomes before they can be used for further breeding purposes. Intergeneric hybrids are very rare. In recent times, some notable discoveries have come out of fundamental research on plant tissue cultures.

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Some of these discoveries have already given rise to practical applications, such as embryo cultures of seeds, which would not otherwise germinate, to obtain rare hybrids, and creation of virus-free stock and rapid vegetative propagation of rare plants. Furthermore, production of haploid plants by anther culture and subsequent doubling of the chromosomes have provided pure line materials. More recently, special attention is being focused on the potentialities of introducing new genetic information directly into protoplasts. Protoplasts are individual plant cells which have been treated to remove their outer cell walls. Without the barrier of the cell wall, a naked protoplast is vulnerable to virus infection, fusing with protoplasts of an entirely different species of plant, and taking up genetic materials such as DNA. In this brief paper, an assessment of recent progress will be made as well as the prospective value of this research in regard to future plant improvement.

Isolation and Culture of Protoplasts. Whereas numerous investigators throughout the world have made important contributions, the results emanating from Cocking's laboratory in England and Takebe's laboratory in Japan have been in the forefront. The Cocking group demonstrated the mass production of protoplasts after enzymatic treatment of cells of tomato seedlings (4). Takebe and collaborators were the first to show what conditions were necessary for protoplasts to regenerate new cell walls and then divide to form a callus of new cells from which entire plants could be created (15,23). Thanks to the previous pioneering efforts of Steward, Skoog, and their collaborators, it was already known what conditions were required to transform the undifferentiated cells of a callus tissue culture into entire plants indistinguishable from the plants that gave rise to the tissue culture cells in the first place (20,22).

The successful isolation of protoplasts has now been reported for more than 50 plant species (16). Of these, regeneration of the protoplasts back into plants have been reported for several cultivars of tobacco (*Nicotiana tabacum*), *Petunia* × *hybrida*, carrot (*Daucus carota*), etc. (26). In many plants, even though protoplasts can be formed, it has still not been possible to cause them to regenerate back into entire plants. Because of this difficulty, this is a very active field of investigation particularly in regard to regeneration of plants from protoplasts of crop plants such as soybean, rice, corn, wheat, etc.

Techniques Being Explored on How to Introduce New Genetic Information into Protoplasts. Three methods are currently under intensive investigation in various laboratories throughout the world: Fusion of protoplasts derived from two different species of plants; Introduction of nuclei or chloroplasts of one plant species into protoplasts of another; Introduction of particular genes in the form of DNA molecules isolated from one species of organism into the protoplasts of another species.

1. *Somatic hybridization through protoplast fusion.*

There are now two recorded instances of creating entirely new species of plants by fusion of protoplasts (2,19). In addition, three new cultivars of *N. tabacum* have been created by fusing protoplasts of two different cultivars (6,9,14). The first creation of completely self-fertile plants by fusion of protoplasts of *Nicotiana langsdorffii* with protoplasts of *N. glauca* by Carlson, Smith and Dearing (2) is recognized as an exciting achievement of modern plant genetics. This success came about because it was possible to select for fused protoplasts containing the *N. langsdorffii* + *N. glauca* genomes because they required non-hormones to grow as a callus culture rather than homologous fusions of either *N. langsdorfii* or *N. glauca* protoplasts alone. The further exploitation of this success by Smith, Kao and Combatti (21) came about by a discovery made by Gamborg and his associates in Canada that polyethylene glycol was a very effective agent in promotion fusion of protoplasts (10). Besides the new species of *Nicotiania*, fusion of *Petunia* × *hybrida* and *P. parodii* protoplasts have created a new species of *Petunia* (19). These successes have promoted a great deal of experimentation to see whether hybrids could be made between protoplasts belonging to different genera such as soybean and wheat with the hope of combining the soybean's nitrogen fixing capacity with wheat's capacity to form grain. There has been success in causing the fusions to occur but so far there are no published reports that the fused protoplasts will continue growth to produce a callus which is capable of regenerating a new intergeneric hybrid plant species.

In the case of the new species of *N. langsdorffii* and *N. glauca* plants, fusion of protoplasts resulted in combining the genes contained in the DNA of the nuclei of both of the species and subsequent fusion of the nuclei. Thereafter, the cells derived from the fused protoplasts contained a nucleus with one set of chromosomes derived from *N. glauca* and one set from *N. langsdorffii*. This permitted the new hybrid to become self-fertile because during meiosis, the *N. glauca* chromosomes could pair with each other and the *N. langsdorffii* chromosomes with themselves and both sets undergo an independent, but a normal reduction division which would result in fertile eggs and pollen. In addition to the genetic information contained in the genes of the chromosomes of nuclei, there also exists genetic information contained in the DNA found in chloroplasts and mitochondria. It is this extranuclear genetic information which is the basis of cytoplasmic inheritance. The genetic factors in cytoplasmic inheritance can have profound effects on the expression of nuclear genes. Also the genetic factors of cytoplasm can, in most cases, only be inherited by the maternal line. They are therefore not subject to change by the conventional breeding techniques whereby genes in nuclei can be manipulated more or less at the convenience of the plant breeder.

Fusion of protoplasts would seem to offer the promise whereby plant breeders could begin to control the cytoplasmic factors. However, in the *N. langsdorffii* + *N. glauca* case, there is a difference in cytoplasmic factors between the two species of plants. but it is a disappointment so far that in all of the hybrid plants created, there has been no evident mixing of the genetic information in the cytoplasms as compared to the complete mixing of the nuclear genetic information. The new hybrids contain cytoplasms either of the *N. glauca* or the *N. langsdorffii* type, but not both (3). Consequently, more research will have to be done before the plant breeder can expect to control the genetic factors in cytoplasm.

2. *Transfer of the genetic information contained in chloroplasts and mitochondria of one species into protoplasts of another species.*

This approach is being tried as one possibility of overcoming the barrier in changing the genetic information in cytoplasms. The idea is to use the chloroplast or mitochondrion as the vehicle to place new cytoplasmic genetic information in a protoplast. Experimentation has advanced to the point where it can be demonstrated that isolated chloroplasts can be caused to be absorbed into the interior of protoplasts (1,18). While the chloroplasts appear to survive after mitosis of protoplasts resumes, there has been only one report of a plant regenerated containing chloroplasts identical to those introduced into the protoplast (11). Efforts to duplicate this finding have so far been unsuccessful (Uchimiya, H., unpublished data). There are many problems to solve such as whether the DNA of the chloroplasts survives in the protoplasts and, if so, what causes it not to function in forming new chloroplasts of its own type.

The practical importance of being able to change the genetic information in cytoplasm is illustrated by recent experience in hybrid corn production. Practically the entire hybrid corn agriculture of the U.S. was based on a high yielding corn containing a particular cytoplasm known as Texas cytoplasm. However, in recent times, this type of hybrid corn was destroyed by a fungus. The ability of the fungus to attack this corn was directly traced to the presence of the Texas cytoplasm and it is believed that the fungus secretes a toxin which interferes with activity of the mitochondria in the Texas cytoplasm (13). It is probable that nothing can be done about this problem until it can be learned how to introduce new mitochondria resistant to the fungal toxin.

3. *Uptake of DNA as a means of introducing new genetic information into protoplasts.*

There are a few reports that a foreign DNA applied to callus, roots or seeds has produced changes in the plant that could only be attributed as having come from the genetic information contained in the foreign DNA (7,12,24). However, repetition of these various experiments has not occurred with enough frequency to encourage their use as a means for improving plants.

Another possible means of unconventional altering the genetic make-up of plants involves the uptake of foreign DNA itself by protoplasts (5,8,17). The hope would be that the foreign DNA could integrate with the host DNA and use the host's mechanism to get the new genetic information expressed and create a change in the plant phenotype. Conditions have been established whereby protoplasts have taken up as much as 10% of a foreign DNA supplied them (25). It could be shown that some of the foreign DNA survived for a prolonged period of time within the host protoplasts (25). It remains to be seen, however, whether the genetic information in a foreign DNA is ever expressed in plants regenerated from protoplasts. It is also clear that a great deal more experimentation will be required before any easily reproducible transformation of a plant's phenotype by treatment with a foreign DNA will be attained.

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TISSUE CULTURE OF FOLIAGE CROPS

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Tissue culture is a scientific extension of the foliage grower's propagation house. Many foliage items can utilize the rapid multiplication of the tissue culture laboratory at an economical and feasible expense.

The expense of tissue culture is very critical in certain types of foliage propagation. Certain items still may be grown cheaper and just as well in mother blocks in the greenhouse. These items then, even though may be technically possible in the lab, may not be economically feasible; i.e., we have found African violets to be cheaper to produce outside the laboratory.

Many of these non-economic, feasible laboratory propagations may be done in the lab for other reasons. One is to have pathogen-free stock to put out in greenhouse mother blocks. Another reason would be a new cultivar to multiply in the lab to gain sufficient numbers to build up a large mother stock block then take cuttings from the greenhouse stock.

We have found that most ferns are economically feasible to reproduce in the lab due to the rapid multiplication. The stock is also available on a year round basis. Sometimes this is impossible from spore sowings.

Availability on a continuing basis is another reason for tissue culture in the lab. Many times during winter months, rooting material in a propagation house may become scarce, but with tissue culture in a controlled environment, production can be maintained on a rather steady schedule.

Another reason for using the tissue culture lab is that certain plants, such as various begonias, are fuller in foliage in a finished pot from tissue culture than from various types of cuttings, particularly leaf cuttings. The reason is that with tissue culture, the plants are started very small — just as a seedling would start with far more breaks — and thus become a fuller plant.

I have not dealt with any specific formulations for the various foliage plants in that there are prepared media available and there is much research needed for the correct formula, even for different cultivars within the same species. Also, sometimes the various hormones are not sufficient to induce adequate multiplication and actual, physical cutting and planting of the small plants in the flasks is required. Each lab has its own techniques and these are developed over years of trial and error along with help from various universities that are doing continuing research in this area.

Lab space and layout is another important aspect. One point that might be made is that there never seems to be enough space, even though initially the projected layout seems adequate.

CONIFER TISSUE CULTURE

ZACHARY S. WOCHOK and MOSTAFA ABO EL-NIL

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Abstract. Significant progress has been made during the last five years (1972-1977) in the commercial implementation of plant tissue culture technology; larger commercial nurseries have pioneered the application of this technology. More recently, several forest products industries have shown an interest in plant tissue culture. The current status of these forestry programs in conifer tissue culture, and some recent advances in basic technology, are reviewed.

TECHNOLOGY

Almost three decades have passed since the first experiments in plant tissue culture were reported (15), demonstrating the potential for vegetative propagation of selected plant tissues. This early work has been refined and extended to many plant species; among the most intensively studied has been the carrot and tobacco systems. At the time the original reports of these studies were being published, few in forestry could envision a significant impact in the field of domesticating forest trees. While this domestication is still under debate, many forest products companies have accepted tissue culture as a viable alternative to traditional reforestation practices (10).

The *in vitro* culture of conifer tissues has considerable significance for the forest products industry. Provided an effective tissue culture system is available, the technology can be implemented for mass propagation. *In vitro* vegetative propagation may be used to supplement an existing or planned program such as grafts or rooted cuttings. Similar to horticultural applications, tissue culture may be used as a tool in the forest products industry to eliminate pathogens from mother plants, or to augment an existing breeding program.

Tissue culture laboratories are now in existence at, or being planned by, Weyerhaeuser Company, International Paper Company, Crown Zellerbach, ITT-Rayonier and St. Regis. The first techniques and these are developed over years of trial and error along with help from various universities that are doing continuing research in this area.

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Tissue culture laboratories are now in existence at, or being planned by, Weyerhaeuser Company, International Paper Company, Crown Zellerbach, ITT-Rayonier and St. Regis. The first two companies have the largest tissue culture programs at this time.

This paper will review some of the recent progress made in conifer tissue culture and discuss some results from our laboratory.

REVIEW OF LITERATURE

Conifer embryos were first cultured in sterile conditions by A. Schmidt in 1924 (14). For the next 40 years various researchers succeeded in culturing embryos, cambial tissue, megagametophytes, mature pollen, shoot tips, roots, and the callus derived from many of these explants. A detailed atlas of gymnosperms cultured *in vitro* from 1924-1974 provides considerable information on the subject (4).

Adventitious buds have differentiated in sterile culture from embryos of pine and Douglas-fir (5,11,13,16,17,18), cotyledons of Douglas-fir and western hemlock (7,8), buds of Douglas-fir (2,3), young shoots of balsam fir (1) and hypocotyls of white spruce (6). In many cases the induced buds developed into shoots which could be rooted.

Shoots have also differentiated from cotyledon-derived callus, subcultured needle callus and callus from seedling stem explants of Douglas-fir (18). All of the investigators reported low rooting percentages of tissue culture-derived shoots. In 1976 Boulay found that resting buds and shoot apices taken from trees two-years-old or less could regenerate viable shoots that would root (3).

The usefulness of plant tissue culture in tree improvement programs has been cited (9). The diverse applications of this technology to such programs include freeze preservation of gene pools, production of homozygous specimens, study of host-parasite relations, production of disease-free specimens and prediction of phenotypic expression. Others have cautioned against the over-emphasis on the use of this technology solely for the purpose of mass propagation. Two criteria are of foremost importance: 1) consistent differentiation of buds and roots, embryoids or plantlets must be achieved with a minimum of time to reduce the incidence of genetic change under artificial cultural conditions; 2) subsequent generations of plantlets or propagules must be easily attained for mass production of desirable genotypes. These criteria have not been met for optimizing commercial production (5).

MATERIALS AND METHODS

Douglas-fir seeds, obtained from Weyerhaeuser Company's seed production facility in Rochester, Washington, were germinated and 2- to-4-week-old seedlings were harvested. The seedling tops were then surface sterilized in 10 percent Clorox for 6 minutes and washed three times in sterile deionized water. The cotyledons were cut into 2-to-4-mm pieces and placed on nutrient media described by Cheng (8). In some experiments cotyledon explants from individual seedlings were distributed uniformly on different culture media; each group of media containing explants from the same seedling will be referred to as a set.

Plantlets were obtained by placing the shoots in a nutrient medium containing 0.05 mg/L NAA solidified with agar. The root tips were then prepared histologically by the squash technique and acetocarmine staining for chromosomal analysis.

Growing shoot tips were removed from an 11-year-old grafted superior Douglas-fir tree during the period March through July; the original graft was taken from a 53-year-old tree. Denuded shoot tips, 3-5 cm long, were sterilized and placed on the same media in culturing the cotyledons. Leaves from these actively growing shoots were cultured separately.

RESULTS AND DISCUSSION

Somatic tissues exhibited organogenesis by forming bud-like outgrowths on the surface of the cotyledons after 2-4 weeks in culture. In most cases, these buds differentiated leaf primordia after 4-6 weeks on the initial medium (Figure 1) followed by shoot elongation (Figure 2). Alternatively, callus may develop from the same tissues which responded organogenetically, or callus growth may persist without any organized development. Shoots developed from cotyledon explants were excised, separated, and cultured on a medium lacking hormones to promote further growth. These were later transferred to solidified rooting medium, with only 2-3 mm of the basal end embedded in the medium. We have obtained, in six treatments including 3,300 shoots, a range of rooting response from 3 to 11 percent with an average of 5 percent (Figure 3).

Root tips from plantlets differentiated from somatic cells, were found to contain the diploid chromosome number ($2n = 26$), indicating chromosomal stability of these cells (Figure 4).

There is evidence that considerable variability exists in wild seedling material as demonstrated by the wide range of responses in bud development. When 10 sets of cotyledons from wild seedlings were tested on five different media the response of each set was found to be highly variable. The number of bud primordia produced ranged from 21 to 264 with an average of 97.6 per seedling. These data indicate a high level of genetic variance in terms of *in vitro* morphogenetic potential. In comparing overall response to the five media there was a slightly greater than two-fold difference between the medium effecting the least and most production of buds (Table 1).

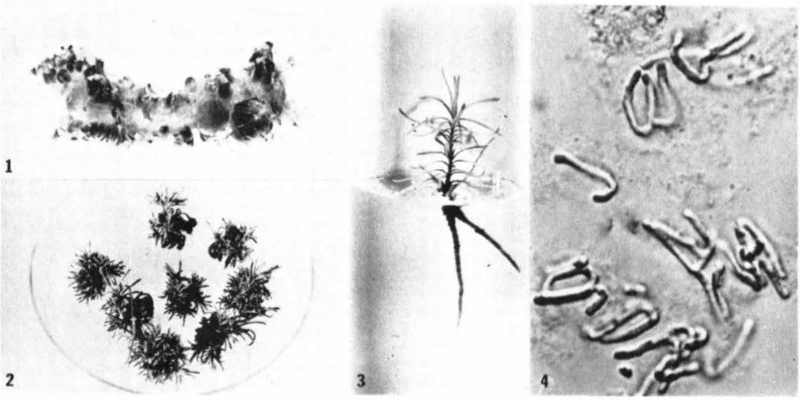

Figure 1. Cultured cotyledon explant of Douglas-fir showing adventitious bud formation (after 5 weeks of incubation). **Figure 2.** Large number of expanded shoots on the cotyledon explants. **Figure 3.** Douglas-fir plantlet produced *in vitro* after root induction and growth on agar rooting medium. **Figure 4.** Chromosome configuration ($2n = 26$) in root-tip cells of *in vitro* produced plantlets.

Table 1. Differentiation of bud primordia on Douglas-fir cotyledon explants *in vitro* as a function of wild seedling responses to 5 media.

	Seedling Number										
Medium	1	2	3	4	5	6	7	8	9	10	Total
3	71	54	3	18	0	32	32	34	18	0	208
4	38	0	14	0	76	7	43	31	25	0	234
5	45	11	0	0	4	11	17	15	7	2	112
6	61	15	9	1	6	0	25	38	17	10	182
7	49	28	15	4	24	55	30	16	10	9	240
Total	264	54	41	23	110	106	147	134	77	21	

We have also found that relative age of the tissue selected for culture is critical as was established with other tissue culture systems (12). Our data showed that there is a diminished responsiveness *in vitro* of cotyledons selected from 2- to 4-week-old and 7- to 8-week-old seedlings. Mature cotyledon tissue is far less responsive than immature tissue for both wild seedlings and genetically selected seedling stock (Table 2).

Results similar to that of Boulay (3) have been obtained with shoot tips of actively expanding spring growth of Douglas-fir. Removing the needles causes activation of axillary bud growth (Figure 5) and in certain media, the development of adventitious buds (Figures 6 and 7). Leaves from mature trees have also formed buds and shoots (Figure 8), but aging of the host explant tissue resulted in degeneration of these shoots. Still, this represents a significant achievement toward propagation of somatic tissue from older, genetically improved forest trees.

Table 2. Percent bud induction on young (Y) and mature (M) Douglas-fir cotyledons from wild and selected seedlings after 6 to 8 weeks in culture.

	3 × 76		28 × 88		53 × 71		Wild	
Medium	Y	M	Y	M	Y	M	Y	M
2	51	9	89	13	59	15	43	10
3	61	4	85	4	54	1	6	1
4	50	9	97	7	45	2	—	—
5	54	2	49	5	77	2	86	—
6	63	4	83	6	68	7	26	1

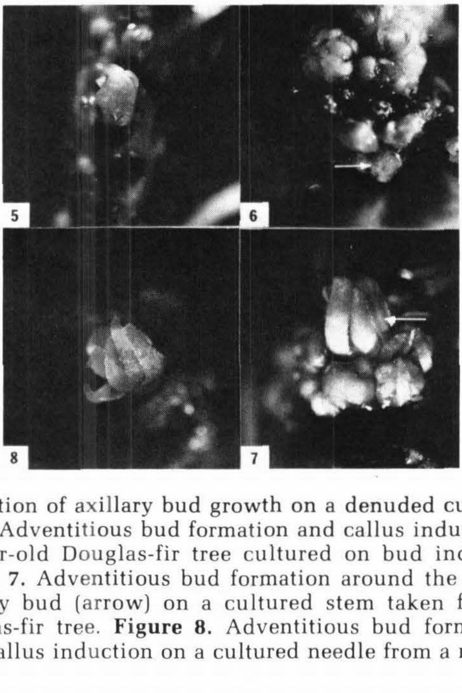

Figure 5. Activation of axillary bud growth on a denuded cultured stem. **Figure 6.** Adventitious bud formation and callus induction (arrow) of a 64-year-old Douglas-fir tree cultured on bud induction medium. **Figure 7.** Adventitious bud formation around the actively growing axillary bud (arrow) on a cultured stem taken from a flowering Douglas-fir tree. **Figure 8.** Adventitious bud formation associated with callus induction on a cultured needle from a mature tree.

CONCLUSION

When perfected, conifer tissue culture techniques will aid genetic tree improvement research and reforestation programs.

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DICK MAIRE, Moderator: We have time now for several questions for our speakers.

WES HUMPHREY: Dr. Uchimiya, part of the reason for asking you to come is because of the great amount of controversy that we see concerning DNA type of research in the newspapers. So much of it seems to be negative. Would you like to comment a bit on positive aspects of DNA type research?

HIRO UCHIMIYA: Much of what we know about genetic engineering at this moment is particularly for bacterial systems.

People are worrying about biological hazards such as transfer of cancer virus into bacterial systems, which is DNA taken outside of bacterial chromosome and can replicate in tremendous amounts, about 3,000 copies in only one night. So far this can only work only in the bacterial system. Nobody has shown that the same system works in animal or plant tissue. So people try to jump from lower organisms, such as bacteria, to higher plants or animals. Recently we are organizing some guidelines for the use of genetic engineering techniques, especially for plant systems. There is the idea of transfer of nitrogen fixation genes from soybean to rice or wheat; but we don't know if the techniques are hazardous or not. There is still much research to be done. I can only say that at this moment we can see some new ideas coming in several years.

BRUCE BRIGGS: Dr. Wochok, we know that juvenile shoots will root better than mature shoots. Do you have any ideas of techniques, whether physical or chemical, of getting plant material to revert back into juvenile wood. The second question is on your various tissue culture media. Was the variability in salinity or in hormones?

ZACHARY WOCHOK: Second one, first; the five media differed only in hormone composition. First question. We were having difficulty, as I understand, in vegetative propagation up to just recently with rooting adult Douglas fir cuttings and, as I understand it now, that has been overcome. The rooting percentages are very high. One method of vegetative propagation would be to establish hedging stock plants to maintain young material. This is being looked at in our work and, of course that information won't be coming out very soon because it takes a while to establish a hedging orchard. Now with woody material, I guess I didn't quite understand your question. Maybe you could be more specific.

BRUCE BRIGGS: We know that cuttings from wood in a juvenile stage root better than adult wood. Just because wood is young on a plant doesn't make it juvenile wood. That is the reason I was concerned. We know that you can have juvenile wood and adult wood all on the same plant. Is there some way it can all be converted back into juvenile wood? I noticed yesterday on the tour, seeing the eucalyptus which had mature wood on the tops, but near the root system there was juvenile wood, whose leaves were nice and blue.

ZACHARY WOCHOK: On the slide which I showed you, which is from 63-year-old material, the shoots which were regenerated in that instance must be considered juvenile material. That they are coming from mature tissue makes them mature, I don't hold to that. The fact of the matter is, the regenerative process in and of itself would indicate that you are not carrying mature gene material into the new cells. There is no transmission of age into that material. Now one gets into this controversy of a meristem on a mature tree — is that considered juvenile? Some people will say, no, because it is a part of the mature tissue. Now strictly speaking the meristem is juvenile by definition. It can be influenced, however by the sub-tending cells. If you have older tissue that is now putting out a new flush of growth, that meristem can be influenced by the physiological conditions of the tissue of which it is a part. Hence, in a seedling, that meristem on the shoot tip or the leader is going to be different certainly than the meristem on the lateral branch.

VOICE: I have heard of embryo culture of certain palm species, I wonder if meristem culture or tissue culture has been applied to any of the palm species.

GARY GALLUP: We have tried applying tissue culture to several palm species. Keeline-Wilcox has done some work on this too. I don't know what their success has been. Palms are very slow in all stages of development; there has been work done but I don't know how far it has gone.

ESTHER LAWYER: Could you comment on any tissue culture media which you think would be especially good to promote formation of callus, which is necessary for formation of the graft union.

ZACHARY WOCHOK: I can't speak to the technique of grafting, but if you want to induce callus, the auxins, or auxins in combination with cytokinins, are the best way to do it. They could be applied in a paste, or what have you.

ESTHER LAWYER: We tried dipping our scions and our rootstock in various solutions to promote callus. One thing that we tried was vitamin C and we had positive results with this.

ZACHARY WOCHOK: What is the problem?

ESTHER LAWYER: The problem is to promote graft formation of callus for healing of the grafted materials.

ZACHARY WOCHOK: Then I would suggest you use auxins and cytokinins. Vitamin C then would possibly counter any problems you might have with browning or aging of the tissue, or building up of phenol compounds. That, together with the auxins, should do the trick. I think what you want to do is to screen compounds and probably the best ones to go with are indolebutyric acid or naphthaleneacetic acid; probably indolebutyric acid would be the first that I would use.

VOICE: I have two questions. The first to Mr. Gallup: What is the reason for reversion to original type in ferns; the second one is for Dr. Wochok: What briefly is the method by which you are able to root the conifer cuttings.

GARY GALLUP: THe reason for the reversion back to the original type of fern is the same reason that it has "sported" to begin with. It is usually a chimera; a different tissue covers the meristematic tissue and you damage this through cutting and things of this sort. It reverts back to the original tissue or it will "sport" again into something entirely different, maybe better or worse. It is just unstable tissue. There are a lot of ferns that are stable — you can take the tissue and go on forever without any problems. But in the very unstable ferns, the very fancy Boston types, there is a continuing problem with "sports."

VOICE: Dr. Wochok, you mentioned that there had been a recent development; that it is now possible to root mature Douglas fir cuttings. What is the procedure?

ZACHARY WOCHOK: The technical report hasn't come out yet. So I can't go into great detail, but I can say it involves the traditional method of dipping in a rooting auxin compounds. I don't think that is anything different from what you are using now. That is not the critical issue, though. The critical issue has been to prime the material, if you wish, into its biorhythmic patterns because the tissue has to get into an environmental set of conditions. The environmental conditions could be photoperiod, short-days or long-days, or whatever the plant needs. It will be different for every plant. So you have to find out what the best regimen is for the given plant that you are working with, such as the day-length versus night period, and, of course — temperature.

HUDSON HARTMANN: I want to refer back to Dr. Wochok's last response. Who is doing the work on biorhythms in rooting Douglas fir cuttings and where is it going on? Where and when will it be published?

ZACHARY WOCHOK: The work is being done in the Rochester, Washington, facility of Weyerhaeuser Co.

WEED MANAGEMENT IN CONTAINER PLANT PRODUCITON

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Production on woody ornamentals in containers, free of weeds, is not a difficult task. Weeds compete with the desired plant and are costly to control when hand-weeding is the primary method used. To develop a weed-free nursery all one needs are: *first*, a desire and *second*, a program. Assuming the first, here is the program that is needed:

(1) maintaining clean growing grounds;
(2) producing and/or purchasing liners or transplanting stock, free of weeds and weed seed; and
(3) maintaining the containers without weeds.

The last item will be focused on here.

The use of pre-emergent herbicides is a major aid in getting the job done. This is indicated by:

(1) work that has been done on pre-emergent herbicides as an aid in reducing weed populations and competition in containers;
(2) the increasing availability of registered chemicals for this use;
(3) the success of several nurserymen in using pre-emergent herbicides as a major part of their program in maintaining a nursery relatively free of weeds; and
(4) the importance of supplying the customers with a clean, quality product.

Pre-emergent herbicides are not a panacea. However, when coupled with a good program of hand-weeding, they can help get the weeding done quickly, easily and efficiently.

Devrinol® and Surflan® are the two pre-emergent herbicides registered in California for use in containers at the present. Oxadiazon (Ornamental Herbicide I® and Ronstar®) and oxyfluorfen (Goal®) are two additional chemicals that show considerable promise for container weed control use and much work is being done with them. What about Devrinol® and Surflan® and their control of some of the major problem weeds and their effects on ornamental plant species?

Bittercress (*Cardamine oligosperma*), a major problem weed, is controlled for a short term (1 to 2 months) with Surflan® and considerably reduced with Devrinol® at label rates. Spotted spurge (*Euphorbia maculata*) is controlled with Surflan®, and Devrinol® can reduce the stand at label rates. Creeping woodsorrel (*Oxalis corniculata*) is controlled with

Surflan® from seed but Devrinol® is less effective. This weed is often a problem in containers due to its presence in liners. Once established, neither of these two herbicides will control it. Common groundsel (*Senecio vulgaris*), one of the most composite weeds, which is a frequent problem in container-grown plants, is controlled from seed to a reasonable degree with Devrinol® and stunted severely or reduced with Surflan®. Both are highly effective in controlling many annual grasses. As the labels indicate, they do not control all weeds. Those weeds that escape control should be hand-pulled before any seed is produced to minimize their becoming a problem from the standpoint of competition and increase. Even if the weeds are not eradicated, they are usually stunted and much easier to remove by hand weeding.

Neither Surflan® nor Devrinol®, at suggested label rates and use directions, have caused any serious adverse effects on the ornamental species evaluated.

Pre-emergent herbicides, when properly used, are a major aid in maintaining a weed-free nursery. Supplementing them with some hand weeding can accomplish that weed-free nursery at reduced costs and provide a clean product for the customer. The label is an important guide in using pre-emergent herbicides in your program. Read it.

INSECT PEST MANAGEMENT ON NEWLY ESTABLISHED PLANTS

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The management of pest populations on propagation plants is similar to that utilized on all ornamental plants. There are characteristics of newly rooted plants that do isolate them from the control methods which are used on more established plants. One of these characteristics of the newly rooted plant is it has greater sensitivity to some chemicals because of the lack of an established root system. But basically the approach to insect and mite control is the same. The demand for insect-free and damage-free plants has resulted in the utilization of stringent control programs relying primarily on the use of chemicals. An ornamental plant is purchased by the consumer because of its aesthetic qualities and any reduction in that quality results in a

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product which is hard to market. As a result, pesticides have been the easiest and most effective tool in keeping anthropod pests in check and they will continue to play an important role in pest management in the future. Effective insecticides are not as plentiful as they were in past years and there is not a large group of new compounds setting on the horizon waiting for approval of EPA for registration. Already we have some insect pests of ornamentals which are very difficult or even impossible to control. The picture is not entirely bleak. We do have some effective materials available for most pests and there are new materials which show promise in controlling insect and mite pests of ornamentals. I do feel though that we should take advantage of everything that we know to try to maintain our plantings as free of insect and mite infestations as possible, so that our reliance on chemicals can be held to a minimum.

CULTURAL CONTROL

The first approach to pest control is good cultural and management practices which keep the chances of developing damaging pest populations to a minimum. This is especially important on propagation plantings because insect and mite populations which are present can be passed on to growers and to consumers causing control problems at a later date. By maintaining pest-free plants at this stage we can prevent spreading pests to our customers and expanding the need for control at that level.

There are several things which can be considered in maintaining a good environment and monitoring pest build up. First, pests are not present in the greenhouse or other growing area naturally, but they must gain entry to these structures to infest the plants maintained there. If we can eliminate or inhibit this entry we will greatly reduce the need for control measures. Pests gain entrance into greenhouses in many ways. Vents and doors offer the easiest access and often pests enter these access points either independently or with the aid of personnel entering the structure. For example, moths are attracted by lights at night and readily enter vents if open at this time. Man is just as guilty in the introduction of pests as the natural habits of the pest. Some pests, such as mites, will hitchhike from one area to another on the clothing of workers. Also pests are brought in on plants which are moved from one area to another or on plants exchanged between growers. It is important that propagated plants be kept clean because exchanging plants is an excellent source by which pests can be distributed among other growers who purchase these plants. In addition, pests can enter the greenhouse in the soil, mulching material, or equipment which is brought in from outdoors and care should be taken to eliminate this source.

Poor quality cutting material is another common source of pest problems. This is an important reason to keep the mother plants clean before taking cuttings. The earlier the pest control can be achieved in the growth process, the smaller the area which must be treated. Also weeds often attract pests which subsequently reproduce and build their population on weeds. If weeds are allowed to grow around the periphery of houses, pests are close at hand and take advantage of any opening to the greenhouse to extend their feeding to plants housed within. By keeping the area around the houses clean, insects and mites do not have this attraction to frequent the premises around the greenhouses. Weed control in the houses is also important; weeds and algae under greenhouse benches provide a place for insects to hide and reproduce. Once they have established on weeds under benches they can easily move up to the plants on the benches.

EARLY DETECTION

Even with the greatest of care, pests will still gain entrance to the growing area. The next area of good pest control management is early detection. If a pest is detected early before it has a chance to spread or increase in numbers it can be easier to control or be removed from the premises. It is important to be constantly conscience of the pests which frequent the particular species or cultivars being grown and to check the plants frequently to make sure they are free of pests. The success of such a program depends on a knowledge of the pests and their habits and biologies so you are aware of what to look for and know what you have once you detect the pest that is causing the problem. Pest detection could be either the sighting of the insect or mite itself or, as if often the case, the detection of injury caused by a particular pest. Very often the damage which is observed is not that easy to identify because a number of pests cause similar damage. But at least the damage will be a key to what to look for and often the pest can be discovered by more diligent searching. It should be remembered that the bottoms of the leaves should be checked. Often pests such as spider mites, can build up significantly before the stippling damage can be detected on the upper surface of the leaf.

When checking a greenhouse for possible pest infestation consider the components of the greenhouse which might result in ideal conditions for pests. Points of access should be considered. Often damage starts near a door, along the main aisle, or near vents because these were the points of entry. Consider the warmer areas of the greenhouse such as over steam pipes or under modine heaters. Also the corners of the greenhouse may be warmer and they are usually isolated. As a result, populations can reach high levels undetected in corners because conditions are ideal and workers do not frequent them. Early detection of pests can not be overemphasized because early detection not only results in easier control but also limits the amount of damage loss obtained.

CHEMICAL CONTROL

We can reduce many of our pest problems by the use of good management practices but we must still rely on chemical control to keep populations in check. During the past year we have tested insecticides and miticides on the twospotted spider mite (*Tetranychus urticae*), greenhouse whitefly (*Trialeurodes vaporariorum*), and citrus mealybug (*Planococcus citri*), which are major pests of ornamental plants. In these experiments several new compounds were tested and many were effective in controlling troublesome pests of ornamentals.

Twospotted Spider Mite. Twospotted spider mites are probably the most common pest encountered on ornamental plantings in California. They are tiny and develop on the undersides of leaves of most plants making their detection difficult. Most often, they are detected by feeding damage rather than the discovery of the mites themselves. Injury is observed as minute spotting or stippling appearing on the plant leaves.

Miticide effectiveness. Two experiments were conducted this year on the efficacy of miticides for mite control. The first was conducted at the University of California — Riverside greenhouses on *Dracaena*. Treatments consisted of single plants and were replicated five times. Plant were approximately 15 inches high and in six inch pots. Miticides were applied with a hand sprayer, at 75 psi, utilizing an 8003 nozzle. Plants were sprayed to the point of runoff. Samples were taken weekly after application by removing one leaf per plant and counting the number of mites on each leaf to determine the efficacy of each miticide (Table 1). Excellent control was achieved with all compounds for two weeks. During the third weed reinfestation was observed on the Bay KHS 0137-treated plants and numbers of mites continued to increase throughout the test period. Mites were also observed on the Pentac- and Vendex-treated plants at three weeks. In both of these cases, mite observation was a result of a large number of mites on one leaf and could be the result of poor coverage on these leaves because the counts on the following two weeks were low. DPX 3792 and PP 199 treatments were free of mites for a period of at least four weeks.

The second mite control test was conducted in Encinitas, California in a rose range. The plants treated were the 'Forever Yours' rose. Treatments consisted of blocks of six feet of bed 42 inches wide and were replicated five times. Miticides were applied with a commercial 5 gpm sprayer, at 125 psi, utilizing a 6506 nozzle. One and a half gallons of finished spray were applied to each treatment and plants were sprayed to the point of runoff. Plants were sampled weekly by removing five leaves per replication and counting the number of mites on each leaf to determine the efficacy of each miticide (Table 2).

Table 1. Control of twospotted spider mites on Dracaena in the greenhouse.

	Average Number of Mites per Leaf							
	Weeks Following Treatment							
Treatment and lb ai/100 gal	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Pentac 50WP, 0.25 lb	0	0	6.0	0.2	0.2	10.6	26.2	64.8
Vendex 50WP, 0.25 lb	0	0	7.6	0	0.4	4.6	1.2	0.4
Bay KHS 0137 50%E, 0.25 lb	0	0	4.4	12.8	21.2	27.0	13.6	34.2
DPX 3792 2E, 0.25 lb	0	0	0	0	3.8	5.0	11.8	8.2
PP 199 25%E, 0.125 lb	0	0	0	0	0	0.2	0.4	59.6
Check	14.8	20.8	24.2	25.0	18.4	19.0	39.2	42.8

Table 2. Control of twospotted spider mites on roses in the greenhouse.

	Average Number of Mites per Leaf					
		Weeks Following Treatment				
Treatment and lb ai/100 gal	**pre**	**1**	**2**	**3**	**4**	**5**
Pentac 50WP, 0.25 lb	51.2	0	0	0.1	0	0
Vendex 50WP, 0.25 lb	32.2	0	0	0	0	0
DPX 3792 2E, 0.25 lb	43.8	0	0	0	0	0
DPX 3792 2E, 0.125 lb	37.8	0	0	0	0	0
PP 199 25%E, 0.125 lb	36.3	0	0	0	0	0
Check	—	18.6	90.5	49.0	62.7	74.5

In this experiment all of the test compounds were effective in maintaining mite populations at a very low level throughout the five week test period. In this experiment the chemical treatments were separated from the untreated check plots. This reduced the amount of reinfestation from the untreated checks.

Phytotoxicity. Phytotoxicity was observed from the application of the test formulations of the numbered miticides: DPX 3792, PP 199, and KHS 0137. Damage occurred from applications of all three compounds on *Dracaena*. It was observed the first week after treatment and appeared as yellowish to brown spots on the new leaves. No damage was observed on the old growth or on subsequent new growth. The only phytotoxicity observed on roses was from DPX 3792 at the 0.25 pound rate, and then the damage was not very extensive. In some of the replications, some new shoots were distorted and curled during the first week after application. In subsequent weeks, no damage was observed on any of the treatments.

Greenhouse Whitefly. The greenhouse whitefly is a common greenhouse pest and in California it can also be found in shadehouses and outdoor plantings. California nurserymen report that the greenhouse whitefly is the hardest pest for them to control. These insects can be found on nearly every plant. They are found on the undersides of leaves and often large populations can be established before they are detected. They suck juices from the leaves of the plants, and excrete large quantities of honeydew upon which sooty mold grows. Eggs, nymphs, and pupae are at least partially resistant to most registered insecticides used for their control. As a result, efforts to control this pest results in repeated applications resulting in only partial control.

Insecticides were applied to polka-dot plants (*Hypoestes sanguinolenta*) to test their efficacy in controlling greenhouse whitefly (Table 3). Treatments were replicated eight times with one plant per replication. The plants were approximately 16 inches high in 4 inch pots maintained on raised benches in the University of California-Riverside greenhouses. Foliar sprays were applied to the point of runoff with a commercial 5 gpm sprayer, at 150 psi, utilizing an 8004 nozzle. One leaf per plant was removed weekly, following application, and the number of whitefly nymphs were counted on each leaf and recorded for five weeks after treatment.

Table 3. Control of greenhouse whiteflies on pink polka-dot in greenhouse.

	Average Number of Nymphs per Leaf				
	Weeks Following Treatment				
Treatment and lb ai/100 gal	**1**	**2**	**3**	**4**	**5**
SD 43775 2.4E, 0.1 lb	1.8	1.4	0.1	0.2	0.3
FMC 35171 1.6E, 0.1 lb	1.0	0.0	0.2	1.7	0.3
FMC 45497 0.8E, 0.1 lb	6.7	0.2	0.1	2.7	0.5
FMC 33297 3.2E, 0.1 lb	0.7	0.3	0.0	1.3	1.1
Vydate 2E, 0.5 lb	13.8	2.6	7.1	4.1	4.5
A 47171 2E, 0.5 lb	16.9	8.6	3.6	10.9	4.8
NC 6897 76WP, 1.0 lb	15.8	17.6	8.7	20.3	14.4
Orthene 75S, 0.5 lb	15.0	37.5	34.0	27.9	18.3
Drawin 775 4E, 0.75 lb	34.6	34.0	30.4	33.5	15.4
Check	31.9	68.8	50.0	39.8	62.2

Four pyrethroid compounds (SD 43775, FMC 35171, FMC 45497, and FMC 33297) were the best test compounds in controlling whitefly nymphs. Plants treated with these compounds were protected throughout the test period. Populations of whiteflies on plants treated with the other test materials were also reduced but not as low as those treated with the pyrethroids. Only one application of an insecticide was applied so subsequent applications of some compounds could have resulted in better control.

No phytotoxicity was observed from the application of any of the test materials.

Citrus Mealybug. Citrus mealybugs are important pests of ornamental plants. They and other mealybugs injure plants by sucking sap with their piercing-sucking mouthparts. Honeydew is excreted and attacts ants and serves as a medium for growth of sooty mold. This mold and also the masses of wax from the mealybug bodies and cottony egg sacs result in an unsightly and unsalable plant. Mealybugs are capable of locomotion throughout life and a good means of checking your success in controlling these pests is to examine new growth to see if they have survived and moved.

An experiment was conducted to test the efficacy of nine insecticides in controlling citrus mealybug on areca palm (*Areca*). Treatments consisted of single plants and were replicated four times. Plants were approximately 24 inches high and in six inch pots. Insecticides were applied with a hand sprayer, at 80 psi, utilizing an 8003 nozzle with the exceptions of Temik and UC 21865 treatments. Temik is a granule formulation and was applied to the soil and UC 21865 was applied as a soil drench. Observations were made weekly following application by tagging four leaflets on each plant and following the populations on these leaflets throughout the five week test period to determine the efficacy of the test compounds (Table 4).

Temik and UC 21865 were applied to the soil so it took two weeks to obtain good control because of the time required for movement of the material within the plant. After two weeks both compounds yield good results throughout the remainder of the test. Vydate, Cygon, and Orthene treatments resulted in over 90 percent control throughout the test period. Sumithion and Supracide treatments also resulted in good mealybug control throughout the test period with over 90 percent control for four weeks and over 80 percent the fifth week. A second application of some of the test materials could enhance the control of mealybugs.

No phytotoxic responses were observed on any of the plants treated.

In addition to the pests mentioned, many other pests can cause damage to propagation plants. Leaf miners, fungus flies, lepidopterous larvae, and many other pests damage ornamental plants in all stages from propagation to harvest. In every case good cultural practices can reduce the frequency of pest infestation. Early detection can increase the efficiency of control measures utilized and reduce the damage obtained. But chemicals are the main means of controlling pest populations once they are established.

Table 4. Control of citrus mealybugs on palms in the greenhouse.

	Corrected Percent Mortality				
	Weeks Following Treatment				
Treatment and lb ai/100 gal	**1**	**2**	**3**	**4**	**5**
Termik 10G, 0.2 g*	80	99	100	99	100
Vydate 2E, 0.25 lb	100	100	100	97	96
Cygon 4E, 0.5 lb	97	99	94	88	94
UC 21865 75WP, 0.5 lb	59	91	91	96	91
Orthene 75S, 0.5 lb	96	98	98	97	98
Sumithion 8E, 1.0 lb	100	91	94	92	89
Supracide 2E, 0.5 lb	99	96	91	91	82
Ambush 2E, 0.1 lb	76	88	87	78	86
SD 43775 2.4E, 0.1 lb	52	49	32	45	56
Check	—	—	—	—	—

* Grams of aldicarb per 6 inch pot.

ENTOMOLOGY IN THE PRODUCTION NURSERY

GEORGE P. GUTMAN

Hines Wholesale Nurseries, Inc.
Santa Ana, California 92705

Whether a large scale production nursery or a small ornamental plant grower, both parties should have basically the same philosophy in their approach to entomological problems. This philosophy is dictated by the economics of the ornamental plant itself. Most ornamentals are sold on one fact; their eye appeal or their beauty. Ornamental plants must be kept cosmetically clean; hence one could call the control of insect pests in the ornamental nursery cosmetic entomology. It makes little difference if you are concerned in your individual nursery with one particular insect pest or 100 different species. There are some *basic* guidelines one can follow to effect a fairly efficient control procedure which can be applied to almost every insect problem that may occur. Anyone engaged in the elimination of insect pests for an ornamental nursery probably follows the same set of principles I am about to elaborate on, although he may not have stopped to evaluate his own procedures. I have found the degree and expertise which one incorporates into these procedures depends greatly on the desire to build and maintain a pest management program. The procedures: (1) Detection of the pest. (2) Identification of the pest. (3) Analysis or research of literature (life cycles). (4) Implementation of controls. (5) Evaluation of the project.

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Detection. Detection of an insect problem is the first step in eliminating it. The sooner one can determine that there is truly an insect problem present, or that an insect problem is developing, the better. Time is of the essence. Early detection will allow some leeway for the time consuming procedures of pest identification and life cycle analysis. In a small production nursery detection of pest problems can be made by actually "walking the field". This method becomes less efficient as the size and scope of the growing area increases. Detection aids must be employed in this later case. The use of blacklights and sticky cards are two widely used aids. Blacklights provide excellent samples of adult moth pests. The detection of the adult forms is particularly desirable since one can control the next generation more effectively in many cases. Sticky cards are cards to which a commercially manufactured glue-like substance is applied which entraps the insect. These cards are placed in areas of known or suspected insect activity. The cards are specifically used for the detection of small insects such as thrips, whiteflies, adult male scale, and aphids. These cards may be used to monitor pest build ups over a period of time, freeing the inspector for other duties. The keeping of accurate records on the detection of pests will be most beneficial in simplifying your detection inspection efforts in the future. You will know what to expect and when. The incorporation of temperature and humidity as well as any other influential factors that can be gathered should also be recorded. This information may be coordinated and patterns found in the research phase.

Identification. The accurate identification of an insect pest is essential to the planning of control measures for that pest. You must know what you are dealing with before you can do anything about it. The exactness of the identification should be as near to the species taxon as possible. In many cases it will make very little difference whether you have a particular species of pest but, on the other hand, it may make all the difference. It is a good pest management principle to identify the pest accurately making the research of the life cycle possible. There are outside sources such as the county entomologist or the state taxonomy laboratory which can identify a particular pest for you if no one is available on your nursery staff who is familiar with insect systematics.

Analysis and Research. This step is where the pest management aspect is brought into perspective. After identifying the pest one can research its individual life cycle. Some of the important elements that can be learned from this research are optimum point for breaking the cycle, the stage in the life cycle you have detected, calculations on the appearance or disappearance of any stage in the cycle, and an overall estimation of the proportions of the infestation. Many facts on the duration of individual stages may be of significance in specific cases. The time one expends on this research of the literature is well worth it. The process need only be done once for each pest and is invaluable as a quick reference. This research will also lead to the knowledge of predators and parasites of your problem pest. This may or may not be of assistance to any control measures that might be undertaken. The information you derive from researching literature on an insect pest may be of significant benefit when coupled with facts on the population dynamics you acquire through your inspections. After you have found all that you can from literary sources you should consult others about any particular deviations in the population dynamics of the pest in your locality. Information from literary sources may be only valid in a particular range (locality). Cooperative Extension Services of the Universities and the State and County departments of agriculture are also good sources of information.

Implementation of controls. When you have analyzed the research information you can start to see how the pest is employing its particular dynamics in your own nursery. From your research you will have an idea of what to expect from this pest, such as alternate host, number of generations per year, flight patterns, and reproductive capacities. The absorption of this information along with the idiosyncracies of your own nursery operations must be weighted together before you can arrive at a control measure. Chemical controls must be considered for phytotoxicities as well as their effectiveness on the pest. Secondary problems of the host plants, their location in the nursery, surrounding areas, equipment available for application; all of these must be considered. Integrated controls, whereby a population of predators or parasites are released into the pest population and chemical controls are applied after the pest population is reduced sufficiently to effectively eliminate the problem may be the better solution. Whatever is decided upon, the fact still remains that ornamental plants have a very low economic damage level. So your control measures must be as effective as possible with the least amount of damage to the crop. The clearer a picture one can see of the pest problem the more effective a plan can be made to control it with respect to the present and the future.

Evaluation. When you have selected a plan of control and tried it you must evaluate it by keeping in mind a number of points. Do you really have the pest under control? Does your program have any drawbacks you didn't foresee? After seeing the program is there a better way? Better does not always mean cheaper. It does mean more effective, quicker or safer. This step is important because it reflects the fruits of your labors in the preceding steps. This evaluation may be an ongoing process over a number of generations of a pest. Long or short, this part of your overall pest management program is where anomalies can be detected and adjustments made to correct them.

The interrelationship of the steps I have outlined for controlling an insect pest is obvious. Each step is built by the preceding one yielding an overall effect. Hopefully this effect is a scientifically calculated elimination of the insect pest. In the everyday production nursery these procedures are often overlooked in favor of a quick one shot remedy. This stop gap measure must be done sometimes but it should not become a habit. In the long run this kind of control practice will only lead to more complex problems. Whenever possible, think your insect problem through. Your operation will reflect the work you have done with smoothness, efficiency and, most of all, clean insect-free plant material.

J. HAROLD CLARKE, Moderator: Do we have any questions for the speakers?

VOICE: If a pesticide is labeled for use on a particular plant can it also be used on the same plant grown in containers?

WES HUMPHREY: Let me speak to the California situation only; it is my understanding that among the regulatory people in California that if the material is to be used for container-grown plants, it is preferred that it so specify on the label. We are trying to get the chemical companies to develop the label information and to get registration so the label specifically states that it can be used on plants grown in containers.

VOICE: I am curious about any investigations of biological control that might be going on right now.

RONALD OETTING: We have some experiments going on biological control. The most recent is on control of two-spotted spider mite. We are running into problems; conditions here are not the same as they are in Europe. For some reason, we are not getting the results they obtained in Europe. For one thing, we feel that it is temperature. The first experiment that we ran was under greenhouse conditions. We did not get a buildup of the predator and as a result we didn't get the control that was anticipated. It was true that we had a reduction and we did have plants that looked a little better — a little greater growth, so there was some effect but we still had damage and still had the two-spotted spider mite population very high. We tried some other experiments under controlled conditions — one using growth chambers. We got excellent control in the growth chambers by reducing the temperature 10°F, getting a little more uniform temperature. In a matter of a week, we could almost wipe out the two-spot population. Now there are other predators and parasites which do feed on pests of ornamentals. We have not started any other programs at this time. First of all, we are going to look at this two-spot program and then expand into some others. I know there are some field programs going on for mealy bug control, with parasites and others, but these are still in the future. Right now we have the program on two-spot mite and that is it.

WES HUMPHREY: As far as I am aware, there is only one major biological control method available for weeds in containers. You are all biological entities, it seems to me. Any time you are out there using my favorite herbicide, dos maños, or have a crew using dos maños, you are going to fall very deeply into the category of biological weed control.

THE IPPS . . . WHAT IT IS

JOHN MACHEN, Moderator

Mobjack Nurseries
Mobjack, Virginia 23118

This is our first meeting — the inaugural meeting of the Southern Region of IPPS. We need members — from this group and from those who are not here today — who will join us and share their knowledge and their enthusiasm to make this Society outstanding. We would like to take a few minutes this morning to talk about IPPS — what it stands for, how it functions as an international group and how it came to be the outstanding Society that it is today. We have two eminently qualified speakers who will address themselves to the question of "What is the IPPS?"; Bill Curtis, Sherwood, Oregon, and Jim Wells, Red Bank, New Jersey. Both of these people have really been there in IPPS — they have been president and vice president of their individual Regions and president of the IPPS. Mr. Wells was one of the founding members of the IPPS and its first president. These two gentlemen are going to address us on the history of the society, the rules and the procedures of the society in a discussion format.

BILL CURTIS: I have a roommate with whom I ate dinner last night. While dining we discussed various operations in the nursery and I came away with an idea how to avoid spending $2.50 a bundle for lath to tack plastic on the house — a tape which I hadn't heard of before; the labor that I will save in putting plastic on my houses next year will more than pay for my expenses in coming out here. You will find that as you are members of this society, and as you associate with your fellow propagators, you will get tremendous benefit; you can't attend a meeting without getting some benefit out of it — maybe it will be just a little item, but it may mean many dollars to you so I would advise all of you never to miss a meeting. If you do you are going to miss something that you need in your operation. There may also be a person there that needs the information you have. It is unbelievable the amount of information that is present and available to all of us in the 170 or so people here today! So come to the meetings — don't miss any of them!

JIM WELLS: What happened way back in the beginning? There are only two people here in this room — Bill Snyder and myself — who were actually at the first meeting. Way back in the summer of 1951 I received a letter from Ed Scanlon, Commissioner of Shade Trees, Cleveland, inquiring whether or not it would be a good idea to start a plant propagators' society. I said YES! He apparently received affirmative replies from a number of people and so he called the first inaugural meeting held in the Senator Hotel in Cleveland early in December, 1951. There were between 75 and 80 people there. A number of interesting papers were given and, as far as I know, the first written paper on the propagation of rhododendrons from cuttings was given at that time. The thing that stands out in my mind most, Bill, about the meeting was that we spent the whole time arguing. There was a committee formed and it argued all night about how the Society should be organized. I wanted the organization to be called the Plant Propagator's Guild, but nobody wanted a guild — this was un-American. The arguments were really about what membership requirements should be — I wanted it to be a society in which the voting members had some knowledge. You would have to be a practicing propagator for at least 10 years. This was too long — 5 years was finally agreed upon. We also wanted to unlock the "locked greenhouse door" to guarantee a free exchange of information from one member to another.

JOHN ROLLER: Before this organization (IPPS) there was a Propagators' Society. The first Propagators' Society failed because it did not promote the free exchange of ideas. This Society now is composed of members who have a moral obligation to share their knowledge *with other members*. This is the reason why we have grown and not failed as did the first one.

JIM WELLS: We therefore required that a person should have experience, but we didn't eliminate the person without it — that was built in later with the introduction of the Junior Member, so that he or she could come along and learn, but the main structure of the Society was built around people who had knowledge and who would regularly share it. Being doubting Thomases, we wanted proof that people had, and would, share with each other; and this has been developed over the years until now we have a system whereby you are required to produce in writing three sponsors. These sponsors have to take the trouble to state on a form provided by the Society that the candidate is known to them personally and that the candidate does meet the membership requirements of the Society. This is not just a casual requirement. Where you work or where you come from has no bearing; it is you the propagator who is the important consideration — it is what you do, what your knowledge is, and how much you are willing to share your knowledge with other people that counts.

Everyone went home from the first December meeting without much having been firmly decided. A portion of that first group met the following summer in Detroit and elected Jim Wells President, commissioning him to carry out the establishment of the Society. During the next ten years or so the meetings were held at the Wade Park Manor Hotel in Cleveland. I stated during the early meetings several times, rather bluntly, that anyone who was not willing to share with each other was not welcome, and a couple of people walked out. We also had 1 or 2 people who didn't share and I had to tell them to share or get out. Anyway, it began to work. People came knowing that they would go home with more than they brought. People were charged up; they wanted to participate — they couldn't be stopped. Discussions continued after the meetings until the early hours of the morning.

It is my most happy opportunity to be associated here now with the sixth inaugural meeting of a section of this Society. I remember the atmosphere of excitement at Asilomar, California, with the Western Region, and how the whole thing picked up and started running along full steam ahead. I've seen the same thing now in England, Australia, and New Zealand, and now, happily, here. I don't think anyone can argue that the idea doesn't work, hence there is no reason why it shouldn't be a success with this new Region.

BILL CURTIS: I think all of you will find that the best step you ever made was when you became a member. This has been an open meeting. Normally, a member will give invitations to a few selected individuals to attend the meeting. This Society is very ethical, and if you are not ethical then you will have problems finding people to recommend you. We have had a few proposed members on the West Coast who wanted to join who told their boss that they were required as members to share information freely with other members; their boss said "No, there are things we are doing which we do not want broadcast", and so these individuals could not become members. The information we have we want to share. You are going to find that one of the greatest advantages of membership is sharing your information, and as you share, the person along side of you will share with you. You will find a fellowship in this organization that you won't find anywhere else. You will go home just full of enthusiasm (mental indigestion).

JOHN ROLLER: We have been talking about membership. When this Society gets going in the mailing of the program, there will be two guest cards included. You fellows who are members, I hope you will use them wisely and invite people who have knowledge they are willing to exchange. They can attend one meeting as a guest with this card, after which they must join the Society if they wish to come back.

JIM WELLS: Membership in this Society is fundamentally by invitation; you cannot normally say "I wish to belong and I wish to apply." The only time this occurs is at a meeting such as this first open inaugural meeting of a group. Then people come here to find out what the Society is like, and whether they would like to be part of it. If they do, then they file an application conforming to the regular application procedure, which is processed by a membership committee according to the rules of the IPPS. At subsequent meetings, potential members must apply as guests who then may file an application to join.

BILL SNYDER: There are some other requirements, Jim. You must be employed in the commercial production of plants or engaged in teaching, research, or extension, or you must be a student taking a course including plant propagation. Amateurs cannot belong; there are restrictions. We want people who are seriously interested in propagation who can contribute to the Society.

BILL CURTIS: After you become a member there are certain things you must do to remain in good standing. This is a sharing organization; you can't share with your fellow members if you stay home. The meetings are moved around so you won't have too far to go all the time; you must attend one meeting every three years or give a meaningful contribution in writing to the Society on some aspect of propagation in which you are engaged and want to share with other members. This should be mailed to the Regional Secretary (Dr. Stadtherr).

JIM WELLS: This Society has grown rapidly in recent years, but we have had our problems too. There was a great deal of argument at the time over changing the name of the Society to include "International". There has also been argument over the dues structure; the International Board (President, Vice President, Secretary-Treasurer, Editor and one executive member and one director from each Region) has seen fit to give the Regions more autonomy in governing themselves — a move which will strengthen the Society. Dues go mainly toward publishing the Proceedings ($15.00) — a great buy at the price. How else could you get all the information included in it? The cost is insignificant compared to the benefits of belonging to the Society.

When I came to this country 30 years ago, I was told Rhododendrons could not be rooted from cuttings, although a few people were doing it. At the 1951 meeting, we illustrated how it could be done, and, as you know, now hardly anyone is grafting a Rhododendron. I attribute my ability to grow Rhododendrons such as the one you see here, directly to the help which I have received and help our company has received from this Society.

JOHN ROLLER: One idea which can be obtained here at the meetings can pay for all the rest of the dues and registration fees.

BILL CURTIS: The Proceedings of all the meetings are recorded and, in addition, copies of all the papers are given to the Editor and these are all bound together in one volume, so that you are getting information in this book that isn't available anywhere else in the world. That, to me, is one of the most valuable things in regard to the Society. Most members can hardly wait each year to receive their copy of the Proceedings to see what has happened in the other Regions at meetings that they might not have been able to attend. Quarterly, we also receive a newsletter, "The Plant Propagator", full of interesting articles in regard to the problems we face or new information about plant propagation.

JIM WELLS: It has been an absolutely firm rule of this Society that there shall be no commercial selling or effort at display or other attempt to commercialize upon your product or your operation while at this meeting. As far as the organized, published technical meetings of the Society and the displays at the meeting, they are never intended to sell material, but merely to inform the members as to specialized procedures or techniques in regard to plant propagation. Salesmen are not allowed unless they are also growing and propagating what they sell. A commercial man might be invited to present a paper on, say chemical weed control, or whatever, but he is not to promote his product.

WILLIAM SNYDER: There are two reasons for this — Number 1 is you are here as an individual, not as a firm. Secondly, there are enough trade meetings where there is ample opportunity to sell so that it is not necessary to commercialize this one. The commercial people in general felt that this meeting should be limited to an exchange of information about plant propagation exclusively.

JIM WELLS: We will have a short question period. If you have a question, please use the microphone so we can record your name and your question so we can have it for the Proceedings.

FLETCHER FLEMMER: I joined the Eastern Region three years ago. How is the Southern Region now going to be distinguished from the Eastern, and being in a borderline state, which states are going to be "Southern" and which are going to be in the Northern Region.

WILLIAM SNYDER: We used to separate the Eastern from the Western Region by the Rocky Mountains; however, people in border areas can become a member of the region of their choice. We have several members in Colorado, Texas, and Oklahoma who belong to the West; others who belong to the East. If the Southern Region in fact does become established, and is accepted into IPPS (which will take a full year to be accomplished), then at that time, each of the Eastern Region members who live in roughly the Kentucky, Tennessee, Virginia, and Maryland area southward, will be given the opportunity to stay in the East or to affiliate with the South. If, as a member of the Eastern Region, you decide to affiliate with the South, can you attend the Eastern Region meeting? — YES! Can you attend the Western Region meeting? — YES! and etc. Great Britain, Australia, and New Zealand? — YES! However, you can only vote in that Region in which you are a member, although you can attend any and all meetings of the Regions, as long as you are a paid up member of your Region. Current IPPS members will be given an opportunity about a year from now to indicate a preference for their affiliation — to stay with the East or to join the South.

JIM WELLS: Attendance at any regional meeting will cover your attendance obligation for that year.

WILLIAM SNYDER: Meetings are handled by the regions; the regional Secretaries will mail out programs and registration materials to their members and usually put the program into the American Nurseryman or some other industry-oriented publication which lists the programs. The Plant Propagator will always list the dates and places of the upcoming meetings for all five of the current regions. After you become a member of the Society, you have the privilege of buying back issues of the Proceedings. A few are presently out of print, but these are being reprinted now, so soon all volumes will be available to you at a fixed price. You can obtain all the benefits of the past 26 years even though you joined this year.

JIM WELLS: The Proceedings is a vast encyclopedia of knowledge about plant propagation — irreplacable. If you wanted to pay the $300-400 cost to get the complete set it would be worth it because you couldn't get anywhere a more complete and exhaustive set of information and knowledge on such a vast amount of plant material from all over the world. With the accumulated indices available now you can go back and get whatever you need.

DAVID MORGAN, Texas A&M: Those of us with universities oftentimes can't attend these types of meetings unless we present a paper. While we may desire to present one, I have not seen an invitation to do so. I wrote the secretary and inquired about this and he said that at the conclusion of every meeting a call for papers is issued. Do you have one?

JOHN ROLLER: Yes. We have a pink sheet available here now which requests information as to whether you would be willing to present a paper as well as certain other information such as your preferences for meeting topics, times, and places, as well as whether you would like to moderate a section.

DAVID MORGAN: Does that mean we would be on the program?

BRYSON JAMES: No, the program chairman plans the program and selects the speakers. The vice-president is the program chairman for the annual meeting. The vice-president usually will canvas the members for program contribution and ideas. If you have something you want to present, by all means let the program chairman know!

PROPAGATION AND LINER PRODUCTION OF AZALEAS

HUNTER H. BOULO

Cottage Hill Nursery, Inc.
Mobile, Alabama 36609

Since there are almost as many ways to root cuttings and grow plants as there are nurserymen, I will not try to tell you how it should be done, but will tell you what we do at Cottage Hill Nursery. First and foremost — whatever method one uses in propagation — sanitation and cleanliness are a must if it is to be at all successful. This begins with the stock from which the cuttings are to be taken. Stock plants must be healthy and free from disease. The clippers or knives used to make the cuttings and the baskets or boxes used to hold cuttings must be clean. The area in which the cuttings are processed, the greenhouse or area in which the cuttings are placed for rooting, the rooting medium, and the benches or containers in which the medium is placed — all of these should be disinfected and/or sprayed down with a fungicide to eliminate contamination from any residue from previous crops.

The greater part of our propagation is done under saran shade or lath shade (50-60% shade). Only in the winter do we propagate under cover, and then we use a polyethylene cover over our quonset type houses with some heat to protect from freezing. This probably sounds strange to many of you, especially since it is so easy with the plastics to make an enclosed "greenhouse". We have found that we have better success and far less disease problems with the cooler temperatures and additional air movement we get in the "open" beds.

Another matter in conflict with our old way of thinking is the time we take cuttings. It used to be that the only time we made cuttings was in the late spring and early summer — now we root cuttings at almost any time of the year. The wood must be at the proper stage of growth, however. Not just any cutting such as your preferences for meeting topics, times, and places, as well as whether you would like to moderate a section.

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Another matter in conflict with our old way of thinking is the time we take cuttings. It used to be that the only time we made cuttings was in the late spring and early summer — now we root cuttings at almost any time of the year. The wood must be at the proper stage of growth, however. Not just any cutting will do; we prefer a young tender cutting with the nutrient level fairly high. We feel that it is a waste of time and money to make cuttings of old, hard wood. It is far better to cut back the stock plants and wait for the new growth — even if it means a delay of as much as two months.

We use two methods in propagating our azalea cuttings. In the first we use plastic trays with inserts having 96 individual compartments of a little less than one inch square. A mixture of 1/3 Canadian peat, 1/3 vermiculite, and 1/3 perlite is used as a rooting medium. This medium drains very well. Cuttings rooted in this manner handle very well and there is practically no shock when transplanting. Also, after rooting, the cuttings can be held in the cell-pak for several weeks or longer if we are unable to transplant immediately when rooted.

The second method we use in our propagation is to root the cuttings directly in the pots in which we grow our liners. This has proven to be, by far, the most satisfactory method for us. By rooting directly in the pot we feel that we reduce our labor costs by at least 50%. We also save the cost of the peat, perlite, vermiculite, and the plastic trays that are not used here as in the first method.

The medium used in direct pot rooting is the same as we use to grow all of our lining out stock: 3 parts pine bark, 1 part peat moss, 1 part sawdust and 1 part sandy soil, together with fertilizer, minor elements and lime. This soil mixture provides excellent drainage, which is another absolute necessity for successful propagation.

With both methods — cell-paks and direct sticking in the pots, we use time clocks and solenoid valves to provide controlled moisture and humidity. The "mist" is set to be on for a 30 second period once ever 15 minutes at the early stage and gradually reduced to being on only once each hour. The system is operational 8-10 hours a day in the early stages, with the time on being gradually shortened until the "mist" is applied only once or twice a day before being removed entirely. By handling in this manner the cuttings are gradually hardened off after they are sufficiently rooted and can be transplanted (when using the cell-pak) with minimal shock. This is much safer than transplanting from a tight greenhouse or using bare-root cuttings.

Actually I have been using the term "mist" very loosely, since we do not actually use a mist nozzle, but mostly Ross 24-H spinners which are placed 10-12 feet apart. We have had excellent results using Rainbird #20 sprinklers. It is actually not too critical as to how you apply the moisture. Rather, it is critical that you apply it in the right amounts and at the proper time.

When going directly to pots with our cuttings, we begin by placing empty pots on a layer of shavings or sawdust. Then we fill these pots with our potting soil by hand — carrying the soil to the beds in buckets and pouring it on and into the empty pots. We rake this down with a hand rake to just cover the tops of the pots and then water it in with a garden hose to settle and thoroughly moisten the media.

Ladies and young girls do most of our cutting work. Each cuts, strips, and sticks her own cuttings, placing a label with her name on the portion done by her. This provides a little competitive spirit, and also allows us to check each person as to their productivity and quality of work.

After the soil is thoroughly watered the ladies sit on a carboard boxtop directly on the pots and slide backward on this as they stick. This may seem rather crude, but it is effective. If we have "good" cuttings — cuttings fairly easy to make and handle — five of our ladies can cut and stick 20,000 pots per 8 hour day, or 4,000 per person. This works out be about 1/2 cent per cutting for labor.

Now, back to sanitation and cleanliness. It is far better to prevent disease from entering the crop, if possible, than it is to clean it up after it becomes established. We therefore use a pre-stick soak. All of the cuttings receive a 30 minute soak of Daconil® or Polyram® as a precaution against the various root rot, stem rot, and leaf spotting disease.

Two weeks after transplanting cuttings to pots, or after the mist is off in direct rooting, we apply a thorough drench of Dexon® and Terrachlor®. We follow in about six weeks with a second drench using Banrot®, or possibly Dexon® alone. For foliage protection we like to spray the foliage at least every two weeks during the growing season with Daconil® or Benlate® or comparable fungicides as a preventative measure against leaf spot diseases.

The greatest danger to our crops, however, is not from diseases. The two things that can cause more losses than all the diseases and insects put together are OVERWATERING and OVERFERTILIZING. All the drenching and spraying in the world won't help if you do not control these two items. Use water and fertilizer with great caution and respect.

AZALEA PRODUCTION FOR THE FLORIST MARKET

ZACK WESTBROOK

Columbus Nursery Co., Inc.
Columbus, Mississippi 39701

Azaleas for the florist market are usually acquired by one of three procedures:

1. *Growing on of large well-established potted or bed-grown liners.* Cultivars are usually selected from the Belgian Indicas, Rutherfordianas, Pericats or F_1 Hybrids.

2. *Purchase of hardy types in the fall* (usually Kurumes) but including some cultivars as mentioned in number one.

3. *Growing plants from cutting or liner stage to market size in a continuous year-round cycle.* Growers of this nature usually have cold storage facilities for breaking dormancy to allow for year-round flowering. They may force the plants into bloom themselves or sell in a budded stage for forcing.

My comments today will deal primarily with the third method. To grow plants on a year-round cycle and of a quality which is acceptable to the florist industry requires some additional equipment and investment compared to acquiring them by either of the other two methods mentioned.

Growing structures. To control temperatures so as to produce desirable vegetative growth and uniform budding, greenhouses must be available for fall and winter use. Uniform, desirable budding requires night temperatures of 65°F or more. In summer, night temperatures are consequently not much of a problem in some areas of the country. However, another problem arises in summer. The high heat and light intensity in some areas can adversely affect growth as well as foliage size and quality of plants. Therefore, a suitable greenhouse for growing azaleas year-round is one in which temperatures can be maintained at desirable levels in winter by heating and in summer by application of shade materials to provide reductions in temperature and extremely high light intensities. One other desirable characteristic would be facilities for providing supplemental lighting during fall and winter months when day lengths are less than 15 hours. It is also desirable to have raised benches, since disease problems, drainage, weed control and uniform heating are more easily accomplished on benches than at ground level. Another benefit of benches is the ease of pruning or pinching, fertilization, etc., as opposed to ground bed operations.

Fertilization. Azalea growth is greatly improved by the addition of nutrients through the irrigation water at regular intervals. A good program for us has been to use a water soluble formula such as 21-7-7 or 30-10-10 analysis. The addition of 10 oz. or 8 oz., respectively, per gallon of concentrate to be used through a 1:100 injector will provide a nutrient solution of about 175 ppm N. Feeding should be done 2 out of 3 waterings in summer and 1 out of 2 in the winter. This schedule will not eliminate the need for adding basic amounts of fertilizer to soil mixtures. The constant fertilization will maintain the desired levels. An alternate method of fertilization would be to apply a long-lasting slow release form of fertilizer such as Osmocote® to the soil mixture and supplement with weekly or bi-weekly feedings through the irrigation system.

Soil mixes. Great success has been had in the past with pure peat as a growing medium. For economic reasons many growers now use mixtures containing high volumes of pine bark or other substitutes. We have had relatively good success with a mixture of 2 peat, 2 bark and 1 Birmingham slate with addition of a basic fertilizer as follows, per cubic yard:

2 lbs 12-6-6	4-6 lbs dolomitic lime
5 lbs Osmocote®	2 lbs. gypsum
4 oz minor element mix	

Any soil mixture should be porous enough to provide good drainage yet spongy enough to retain adequate moisture for the plant.

Disease and Insect Control. While many crops can be grown without occurrence of damaging insects and diseases, I believe some preventive measures are good. Usually the use of drenches containing Benlate® and Truban®, Benlate® and Dexon® or Banrot® applied at eight to ten week intervals will prevent any problems with *Cylindrocladium*, *Rhizoctonia*, *Pythium* or *Phytophthora*. A regular spray program applied at two week intervals using alternately Malathion, Diazinon or Sevin with either Thylate, Manzate or Dithane will usually control any other insect and disease pests. Morestan or Tedion will do a good job on any resistant mite infestation.

Watering. I would recommend applying water by means of overhead sprinklers. Higher humidity will be maintained in the growing area by use of sprinklers. Some additional benefits are obtained through foliar feeding if water-soluble fertilizers are used. Leaching of media can be easily accomplished if necessary. Some cooling effect occurs in summer during extremely hot and dry periods. It is wise not to keep foliage wet for long periods or not to water late in the afternoon since this can give rise to *Rhizoctonia* or leaf blights, algae growth, etc.

Growing Procedures. Liners should be grown or purchased that are in good vegetative growth when placed into the production cycle. Strive to maintain uniformity in size and budding of the finished plant. If plants are not in a good growing stage they must be allowed additional time in the production cycle until good vegetative growth is accomplished.

We usually start with growing-on liners of a 5 to 6 inch head size in 6 inch pots. The plants receive a pinch at this size. This is done by the use of a combination of hand pruning and chemical pinch using Off-Shoot-O®.

Off-Shoot-O® solutions are sprayed on the plant to pinch any soft growing shoots which will not be hand pruned. Exceptions to this are when plants have already formed flower buds. Chemical pinching is usually not effective then and the pinching must be done totally by hand or with shears. Effective concentrations of Off-Shoot-O® vary among cultivars and with time of year, temperature, drying conditions, age and maturity of shoot growth. Effective rates can range from as low as 4-5% concentrations to a high of 10%. After the chemical spraying, a good policy is to wait two or three days and then hand prune any irregular shoot growth. This will help prevent a recurrence of faster growth on the longer more mature shoots and lead to greater uniformity when the final pinch is made on the plants. It also provides a good opportunity to check the success of the chemical pinch.

At the time the head size of the plant is 5-6 inches the pot spacing should be on 12 × 12 centers. Eight weeks after the 5-6 inch size pinch a plant should have sufficient growth for another pinch. The head size should be 8-10 inches. The plant will be uniformly covered with new shoot growth if the previous pinch has been successful.

The plants are then in the optimum condition to receive a final pinch. This can be done with chemical pinching almost entirely if uniform vegetative growth has been achieved.

We allow 18 weeks following this final pinch to obtain a new flush of growth and budding of the plants. In winter and early spring, applications of B-Nine or other growth retardants are beneficial in controlling excessive shoot elongation while bud initiation is occuring. The application of retardants is made 6-8 weeks after the pinch. Usually shoot growth will be 1-1/2 to 2 inches long by then. Two applications of B-Nine at 0.25% concentration are usually required, applied one week apart. The most effective spraying can be done when foliage is dry, soil is moist and the humidity is high.

Environmental Effects. Due to several factors, bud formation can be adequate in less than 18 weeks, or may take longer. During periods of high light, bud initiation occurs at a faster rate. Higher light intensity and longer days also result in more multiple buds per shoot and more multiple flowers per bud.

Higher temperatures also encourage faster bud initiation and growth. Extremely high temperatures (90°F days) and excessive light intensity can cause adverse reactions, such as slower growth, smaller leaf size and generally less attractive plants, although bud formation during these periods is usually excellent. It is therefore desirable, if possible, to shade azaleas in high light and heat periods with 50 to 60% shade (3,000-4,000 foot candles) during the day. On the other hand, providing houses with good light penetration in winter is extremely important. Supplemental lighting of from 10 to 20 foot candles intensity and 2 to 4 hours duration to extend short day length is also desirable and is an actual necessity in northern areas and during dark and cloudy periods in the southeastern-most regions. Being able to condition plants during the last six or eight weeks of bud development by the use of blackcloth shading to provide short days would be desirable, but, in my opinion, is not imperative. I would also question the economics of the additional expense.

To grow and force azaleas to produce flower buds adequately is best accomplished when normal seasonal conditions are duplicated. This means simply: (1) duplicating late spring and early summer climatic conditions (warm long days, high light, mild nights) to initiate good growth; (2) duplicating summer conditions (hot long days, high light and warm nights) to initiate and complete bud formation and growth; (3) duplicating fall and winter conditions (cool shorter days, low light and cool or cold nights) to mature buds and break dormancy prior to forcing into bloom.

Cooling and storing azaleas with buds is done when visual examination determines that plants have buds. They can be mechanically cooled to break dormancy by providing 6 weeks of cooling in refrigerated storage at 45 to 50°F. Lighting for 12 hours/day with a minimum of 20 foot-candles is necessary to prevent foliage drop in the 45-50°F temperature storage. For natural cooling, plants can be held in a well-shaded greenhouse at temperatures ranging from just above freezing up to 50-60°F day temperatures for a minimum period of 10-12 weeks. This period depends on how many days and nights temperatures reach levels below 50°F. The accumulated effect must be approximately the same as 6 weeks at 50°F. Plants can be held in this greenhouse environment much longer than in cold storage. The limiting factor is usually the natural forcing which occurs with the warmer days of late winter and spring.

AZALEA PRODUCTION FOR THE GARDEN CENTER AND THE LANDSCAPE MARKET

FOUNT H. MAY

May Nursery
Havana, Florida 32333

We have, during the past five years, leaned our plant production towards the Garden Center and Landscape Gardener, and azaleas have been a major part of our total production.

Three types of plastic houses are used in our propagation of azaleas. Some have spray mist but most now have controlled water sprinklers. Prior to sticking the cuttings in June and July we clean the houses, then fill each house with 3 inch cups, using a medium of pine bark, peat and sand. Though the soil is sterile, we will give the filled containers a shot of fungicide before sticking, if time permits. Cuttings of abot 3-1/2 inches are then obtained, rinsed in fungicide, dipped in Hormodin#1, and stuck 2 to the cup. Azaleas produced are Kurumes and Indicas. We start our controlled water on a 3-1/2 minute to 4 second cycle. At the first sign of any roots we then lengthen to a 7 minute - 6 second cycle. With further root growth we reduce to 15, then 30 minutes, then off. During this period we spray twice weekly with fungicides, reducing this to once weekly after the cuttings have hardened off.

Until a root system begins to develop we have been using a Nachurs foliar feed. Thereafter we make GeWa applications of Peter's Azalea Special — based on our soluble salt readings which should be between 0.4 and 0.8. By October we have a well-rooted, established plant, ready for winter dormancy. We only use heat when a really hard freeze is predicted. Still they will bud and bloom and we constantly keep them pinched. This not only reduces fungus but also tends to promote growing plus early shaping.

As early in March as possible we begin to upgrade into 1 and 2 gallon containers, using a mix of 43% pine bark, 36% peat and 21% sand. We cut the root-ball 2 or 3 times at potting, helping to force new root pattern and growth. After a good watering we now go to the shaded field area, using a polypropylene of 30% shade.

We keep the plants bunched until mid-summer which conserves space until the old crop has been shipped and also gives the root system some added shade. Early prunings are made easier while plants are bunched because we can use electric shears operating off a portable generator. When the time comes to space the plants we use a marked aluminum pipe as a guide, which gives the field a neat appearance and also gives us the ability to know exactly how many plants are placed on a given bed area.

During the warm months — March through October — we maintain a liquid fertilizer program of 9-0-8. Our winter feeding of 13-6-6 granular is applied 2 or 3 times between October and February.

We try always to be on a preventive program but still get caught short. Fungicides are applied weekly and more often during rainy spells. Insecticides are usually applied on a bimonthly basis, or as needed. The same holds true for miticides. Our herbicide program revolves around the alternating use of pre-emergence herbicides. Clean field areas also help keep weed seeds from reaching the container. For us, there is no way to put a dollar value in savings created for us as a direct result of the work done by the Extension Service of the University of Florida on weed control.

At this point, the crop is in its last stage: it has been spaced and we have gotten our cuttings for the next crop. Now *all* we have to do is "fan and feed them" for the next 6 months. A percentage are ready enough for late spring sale, but only if the customer has personally seen the plant. Some customers have protective holding areas, allowing for fall shipping and the assurance of a spring bud and break for their season. A few of our larger and established nurseries in the South maintain their own holding areas farther north providing them with an ideal solution to this particular shipping problem. Other customers have us ship in the spring before the buds begin to swell — and this can get rather hectic at times. Landscapers are not as dependent upon color as Garden Centers, which makes for easier shipping schedules.

I have now completed our cycle of an azalea crop. We try constantly to change and improve our methods as we learn of new techniques or find that some of our practices can be eliminated. We may vary our propagation mix, our fertilizer program or hormone treatment. At present we contemplate eliminating the use of hormones altogether. I say "we" broadly and emphatically. I just happen to be the one up here talking. This has always been a joint venture with the combined efforts of my brother, Don, his sons and my sons. With all our heads together our efforts are multiplied, so are our mistakes.

JAMES WELLS: Hunter, would you, or any of the panel, elaborate on weed control programs for azaleas?

HUNTER BOULO: The main thing is applying the knowledge we have — we know how to kill weeds and we know how to keep them out — the main thing is doing it. We use paraquat to burn down existing weeds and Lasso as a pre-emergent herbicide. With rigorous application of these two items we have come up with a fairly good weed control. We do still have some hand weeding — some of these thngs you just can't seem to get ahead of. We really have come a long way on it, though.

FOUNT MAY: We use preemergents on our containers, alternating between Lasso, experimentally; with Treflan, with really good results, although you still have to come in and hand weed sometimes. We use Roundup and even diesel fuel around the edges of our bed areas. There are certain things though that you don't dare use Lasso on, even experimentally.

BILL COLBURN: Hunter, do you use Lasso on your liners? What is the smallest pot you use it on?

HUNTER BOULO: No, not on liners. We have made some applications on our crops but primarily we stress keeping the environment as clean of weeds as we can; I don't advocate using herbicides on the crops.

CHARLIE PARKERSON: Hunter, how do you soak your cuttings?

HUNTER BOULO: We give them a 30 minute soak (recommended by Ray Self) in baskets holding 3-7,000 cuttings at a time in bath tubs, then we dump them out to drain before the women stick them. We keep records on which portions of the beds are stuck by which women.

DICK MARSHALL: Hunter, how deep do you stick them?

HUNTER BOULO: We try to make all our cuttings about 3 inches long and stick them no more than one inch deep.

JACK AICHELE: Does anyone use growth retardants?

ZACK WESTBROOK: We use B-9 during spring and early summer; growth is not too much of a problem in late summer. There have been some comments that growth retardants on azaleas stimulate bud formation; I don't think there is much evidence for that; it seems as though fast growth or long shoot growth are inhibited with indirect stimulation of bud growth resulting.

HUNTER BOULO: If your plant is compact and full, it is just as good without B-9 as it is with B-9.

ZACK WESTBROOK: You're exactly right, Hunter. Some cultivars are better without it. You may get a little bit smaller leaves and better foliage color with less bypassing growth if you were holding them for late spring forcing.

VOICE: Zack, have you had success using chemical pinching agents on 'Gloria' or 'Dorothy Gish'?

ZACK WESTBROOK: We've used Off-Shoot-O with varying results. If there is any indication of a bud forming there it doesn't do a job; you have to get them in exactly the right vegetative stage to do a good 100% job; our results have been rather spotty with those two cultivars, but we get good results with many other cultivars — 'Redwing' and 'Alaska' respond extremely well.

JIM WELLS: Has anybody used Atrinal as a pinching agent? It is available now; we tested it this year in our nursery. It did a good job on evergreen azaleas. It works differently from Off-Shoot-O — it doesn't kill the bud, but stops it from growing and natural branching results. The whole crop does turn yellow for about three weeks and it scares me, but it comes out of it.

VOICE: What about soil sterilization?

FOUNT MAY: Our medium is naturally sterile, being composed of Canadian peat, river sand and pine bark.

ZACK WESTBROOK: We don't heat our soil, but we do use a drench — Benlate and Dexon or Banrot — although as Fount says, with those ingredients we haven't had any problems.

HUNTER BOULO: We use some sandy soil and we sterilize only that part of the mix with methyl bromide, 2 lbs/100 sq. feet.

VOICE: Fount, you use foliar fertilizer; what is the formula?

FOUNT MAY: We use Nachurs 9-18-9, but we don't use it for a very long time and may eliminate it altogether.

HOMER THOMAS: What about the people who handle the Daconil-soaked cuttings — do the women wear gloves?

HUNTER: We haven't had any problems with Daconil to my knowledge. Thylate does cause rashes, so we don't use it anymore. They don't use gloves.

CHARLIE PARKERSON: Zack, you put Benlate and other things through your irrigation system — how much water do you mix with the Benlate?

ZACK WESTBROOK: We use a 1:100 injector. Use Benlate at 8 oz/100 gal, so the stock solution is concentrated enough to give a finished product of equivalent concentration through the injector. We run it 10 to 15 minutes through the injector via overhead sprinklers. The soil should be moist; this is for drenching. If we need to spray, we do.

VOICE: What about rooting aids?

HUNTER BOULO: We use Chloromone, made from alfalfa. It's easier than a powder.

FOUNT MAY: We use Hormodin #1.

ZACK WESTBROOK: We have used both of these and agree that there is a benefit to using a rooting aid.

JOHN MACHEN: Zack, how do you keep the Benlate in solution?

ZACK WESTBROOK: We have to stir it by hand occasionally in the separate vat that we mix it in; we only have to do this for about 10 to 15 minutes.

VOICE: You will find that if you will use a wetting agent this will keep it from settling.

CHARLIE PARKERSON: With a heavy material like Benlate? What do you use?

VOICE: We use liquid Aqua Gro.

BILL GREEN: Hunter, do you soak your cuttings with any toxic insecticides?

HUNTER BOULO: No, we don't use insect infested stock plants.

JUD GERMANY: Zack, in extending your day-length with the 100 watt bulbs, what distance are they from the plants?

ZACK WESTBROOK: We normally have them about 4 to 5 feet above the plants; try to locate them so you get the best light distribution. You want to get as many foot-candles as you can with the best distribution; generally the recommendations are similar to those for chrysanthemum production — between 20 and 40 foot-candles.

VOICE: Hunter, what is the rooting percentage on your direct stuck cuttings and what about Chloromone — we burnt some cuttings with it.

HUNTER BOULO: We get close to 100% take. The instructions for Chloromone are based on using much harder wood than we use; we use very tender tip cuttings and so use it at 5 parts water to 1 part Chloromone on Kurume azaleas — with further reductions in concentration for other tender material.

BILL COLBURN: Do you heat your houses, Hunter?

HUNTER BOULO: Not with the intent of forcing growth — just to keep them from freezing.

BRYSON JAMES: Hunter, you say not to use "old wood". How old is "old" — can you describe the cuttings better?

HUNTER BOULO: We like young tender growth — just at the point where you can bend the tip and it doesn't snap — the tip 1/2 to 2/3" will droop over occasionally for the first few days after sticking.

VOICE: When should mist be eliminated?

HUNTER BOULO: After 15 days in late spring or early summer, roots are beginning to form and within 7 to 8 weeks the cuttings are able to be taken out of the mist.

VOICE: Is there any advantage to removing that top half inch or so of the cutting that droops?

HUNTER BOULO: Yes, we like to do it if we get time — to cut down on the wilting and to get a soft pinch; we have a two-inch leafy cutting. We don't remove the lower leaves either.

VOICE: Does anyone use bottom heat to root azaleas?

FOUNT MAY: No, not for azaleas.

DICK STADTHERR: Do you remove the flower bud, if it is present, on a cutting?

HUNTER BOULO: I believe it would be advantageous to do so; the flower will sap the strength of the cutting and, as I said, we try to pinch the tips off if we can.

FACTORS INFLUENCING HERBICIDAL ACTIVITY

P.L. NEEL

University of Florida
Agricultural Research Center
Ft. Lauderdale, Florida 33314

Inasmuch as we are concerned with ornamental plants or dooryard fruits rather than commercial food and fiber crops I shall limit my remarks to those factors and those herbicides of potential interest relative to their use in nursery production situations. Before I proceed further, I must point out that it is illegal to use *any* pesticide in a manner inconsistent with its label recommendations, under penalty of law. Herbicides are classified as pesticides under EPA regulations and no herbicide is currently registered for use on container-grown ornamentals, while only a few are recommended for use on certain field-grown stock or established landscape plantings. Nevertheless, there are several herbicides which have been used experimentally on many container or field-grown species safely and efficaciously. We should not, however, forget that there are other methods for effectively controlling weeds or reducing their numbers; a herbicide program should be integrated with these and not solely relied upon. These methods include frequent shallow cultivation, the use of mulches, mowing, keeping weeds down in perimeter areas to prevent reinfestations of crop areas, early removal of initial invaders to prevent their going to seed, the use of naturally weed-free media components and/or the use of sterilized media, and filtering irrigation water to re-

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The name herbicide literally means "plant killer"; their use demands respect. Proper usage requires that: 1) the dosage be correct; 2) the chemical used is the correct one for the crop and the weeds; 3) the application equipment is properly calibrated and adjusted; 4) the herbicide be applied to the proper place — the weed foliage or the soil surface; and 5) the material is applied at the proper time in the life of the weed (applying a pre-emergence herbicide *before* weed seeds germinate).

Herbicide usage may be classified as being pre-emergence or post-emergence with respect to the weeds. A preemergently used herbicide (alachlor, napropamide, trifluralin, oxadiazon, to name a few), to be effective, must be applied before weed seeds germinate. These materials act upon the very young seedlings as they pass through and emerge from the treated soil. Such herbicides may be absorbed by the roots, shoots, or seeds themselves. A post-emergently used herbicide (paraquat, glyphosate, 2,4-D, dicamba, diquat, for example) is applied to the foliage of already-growing weeds. These are absorbed through the foliage and, with some materials, also through the roots if spray enters the soil. Paraquat, glyphosate, and diquat are "tied up" (absorbed) almost immediately by organic matter, clay and other colloids in the soil and are therefore not available to roots growing in soil accidentally treated with these materials.

The very small particles of the soil mentioned above (clay, humus, colloids) have electrical charges upon their surfaces which interact with many types of herbicide molecules which are electrically charged. The cation exchange capacity (C.E.C.) of the soil, which is the measure of these colloidal materials, is thus a good indicator of the ability of the soil to "tie up" and reduce the herbicidal activity of applied chemicals. High organic content soils, such as are frequently used in container nursery production systems therefore generally require from 2 to 4 times the rate of herbicide for effectiveness as is indicated for field use. While this property might be considered to be a drawback to herbicide use, it does provide a safety factor to roots located below layers of soil which contain herbicides. It also provides a means of correcting an overdose, or of "cleaning up" a treated area. Activated charcoal applied to herbicide-treated soil at rates around 300 lbs/acre (336 Kg/ha) has been shown to effectively neutralize a number of herbicides.

Herbicides are either applied as granules to the soil surface or as liquids to foliage and/or soil. Granules generally contain from 2 to 15% active ingredient by weight, and liquids (emulsifiable concentrates, etc.) from 2 to 6 lbs active per gallon. Granules offer several advantages to the user. Applications are relatively inexpensive and the granules usually fall off the crop foliage where they could cause some damage if they remained. The use of granules on crops which have whorls of leaves which can act as funnels is to be avoided; considerable damage has been done to Dracaena crops in Florida because of granules being funneled down into the bud. Some form of directed application would have to be used with such a crop to avoid this problem. Application of herbicide granules to wet foliage can also cause the plant injury because the granules stick to the foliage.

Liquid formulations can be applied as directed sprays through precision spray equipment or through the irrigation system over the crops if the foliage is not sensitive to the material. Wetting the foliage a few minutes prior to injecting the herbicide into the irrigation system and then rinsing the foliage with pure water after the injection will minimize the amount of herbicide absorbed by the foliage from the "herbigation" water.

Numerous tests with preemergence-type herbicides on containerized plants have shown that most injury symptoms manifest themselves as reduced growth, with some shoot tip kill and/or leaf burning at excessive rates on more susceptible plants. Chlorosis may also occur with certain chemicals; if the roots of sensitive plants are examined, frequently they will be injured or appear deformed. While most preemergently used herbicides do remain held in the upper inch or so of the soil for several weeks, they will gradually be moved down through the scil profile by irrigation or rain water, and can adversely affect growth rates of sensitive species.

No herbicide will control all weed species; the spectrum of control is different for nearly every one. If one herbicide is used exclusively, it will not be long before weeds resistant to its effects become a problem. For this reason more and more investigators are beginning to look at herbicide combinations as a way to get more complete weed control. Presently a combination of alachlor and simazine is being studied in several states. Preliminary results show promise on plants tolerant to simazine.

One should not use excessive rates of a herbicide in order to achieve 100% weed control; the risk to the crop is too great. Rather, herbicide usage rates should be such that weeds are 75-95% controlled, with hand pulling or some other means providing the remainder. I know of several nurserymen who are using alachlor successfully in this way and who tell me that the number of man-hours spent on weeding in their nurseries has dropped by 80% since they began using it.

Herbicides most often receiving favorable comments by nurserymen and researchers with regards to their safety on many plants and reasonable weed control are alachlor (Lasso®), trifluralin (Treflan®), napropamide (Devrinol®), oryzalin (Surflan®), dichlobenil (Casoron®) and oxadiazon (Ronstar®). Tests by others and myself with oxadiazon have shown it to be one of the safest and most efficaceous herbicides of those most commonly evaluated. It may receive an ornamentals label in 1977.

Experimentation has shown that the effective rates of use for most of these materials fall between 2 and 8 lbs ai/A (2.2 - 9.6 Kg/ha) applied every 4 to 8 weeks. Most of the above named materials could be applied (by mistake) at double these rates with injury symptoms of sensitive species showing up mainly as reduced growth.

What makes the use of one material "safe" and another hazardous? Some materials simply do not get down into the root zone in sufficient quantities to cause damage. Other materials in the root zone might not be absorbed by the roots, or, if absorbed, they might be inactivated in the roots by chemical reactions (forming insoluble salts), or by metabolic reactions (detoxification). Even if a herbicide is absorbed by the roots, it must interfere with some vital function to be effective. Many soil-applied herbicides exert their effect in the shoot portion of the plant and must therefore be translocated into the shoots or, as in the case of a germinating seedling, the shoots must come into contact with the material. Some herbicides are not translocated from the roots of resistant plants in sufficient amounts to be herbicidally active. Then, of course, there are those sensitive species which freely absorb the material and translocate it to sensitive sites and are thus injured or killed. The exact means by which most herbicides act is known in relatively few cases at present. Some affect photosynthesis; others affect the ability of cells to divide properly, or the ability of cells to produce one or more essential metabolites or the growth hormones.

Many of you have tried herbicides; perhaps some of you got poor results or plant damage. I hope that this discussion might help you to understand some of the many factors involved in herbicide use and/or misuse. A cardinal rule for anyone wanting to use any product which is new to him is to critically try it first on a few plants of each species with conditions similar to those under which the material is intended for use. Then if it works well for you, go ahead and expand the scope of utilization if the product is registered for the use intended.

HERBICIDES FOR NON-CROP AREAS

CHARLES H. PARKERSON

Lancaster Farms, Inc.
Suffolk, Virginia 23435

Weeds in the aisles, along edges of growing beds, around buildings, and along fence rows are unnecessary and detrimental. The immediate effect is an unsightly appearance of uncleanliness; weeds cost money, harbor insects and diseases, and are a wonderful source of seed for your container stock.

Our nusery is similar to yours in many ways but vitally different in many respects. What I am about to share with you works for us, in our particular micro-climate. What I do may work for you . . . but it may *not*, so check it out first. I am sure that most of you are in the same position that we are in . . . everything that you own is sitting out in the field, so run your own trials before spraying a chemical that you have heard or read about. The herbicides we use only work when applied in a timely and accurate manner. In general we use the following chemicals for weed control in noncrop areas: Pramitol 25E, Paraquat CL, and Roundup.

Pramitol 25E. This chemical is a soil sterilant causing the soil to be unproductive for approximately a year or longer. This material is a non-selective herbicide that is applied with water before or after plant growth begins. Use only in areas where complete control of all vegetation is desired. Most of its activity occurs through root absorption, therefore, its effectiveness is depending on movement into the root zone. It should not be used on land that is near desirable trees or shrubs because plant injury will occur. One year I treated next to a poly house containing 1 gallon pyracantha. Roots came out of the bottom of the pots and entered the treated area; next summer the plants were killed. We apply Pramitol with a watering can at the rate of 1 pt/3 gal of water, which covers about 200 sq. ft.

Paraquat CL. I am sure that everyone has had experience with this contact herbicide. It kills both broad-leaf and narrow-blade weeds; in fact it is our experience that it burns back anything if it is green and growing. The killing action is unique in that it interferes with photosynthesis. Once a plant cell is contacted there is cell collapse, and death is very rapid. The roots of plants are not affected because the chemical deactivates on contact with soil. There is no soil sterilization. When you are spraying, weeds should be covered uniformly, not drenched. Spraying under windy conditions should be avoided because a little drift will burn adjacent desirable foliage. Paraquat is mixed at the rate of 1 qt/50 gal of clear water. A good spreader at the rate of 4 ozs/50 gal is added.

For spraying we use a tractor-mounted PTO roller pump set at no more than 40 psi, to deliver material to a Tee Jet 8004 flat spray tip nozzle. Our man simply drives the tractor along and sprays using a hand wand.

Paraquat seems to work best when applications start early in the spring and are kept up during the growing season. In order for us to keep bermuda grass under control we must spray every two weeks from spring to fall.

We do like Paraquat but the need for repeat applications is very time consuming and costly.

Roundup. If you have not yet had a chance to try this herbicide get some. I know that you will like what you see. We are more and more impressed each time we use this chemical.

Roundup is a foliar-applied systemic herbicide. When properly applied, Roundup controls a wide variety of annual and perennial weeds. This chemical is translocated from the actively growing leaf and stem surfaces of the weed and travels down the stem to the root or rhizome. Roundup circulates throughout an entire plant, killing it and preventing any regeneration from plant parts below the soil surface.

As effective as Roundup is on weeds, it has no activity in the soil. There is no residual soil activity.

We use Roundup at the rate of 2 qts/50 gal of clean water. No additional surfactant is added since the formulation contains the proper amount of wetting agent. For best results spray coverage should be uniform and complete. You must cover the weed to get control almost to the point of runoff. The same equipment is used as for Paraquat application.

The label of this material is quite extensive and I will not try to cover it all in this paper . . . BEFORE USING, READ THE LABEL . . . ALL OF IT.

Roundup spray solutions should be mixed, stored, and applied only in stainless steel, aluminum, fiberglass, plastic or plastic-lined steel containers. Do not use galvanized steel or unlined steel containers or spray tanks. Roundup spray solution may react with such containers and tanks to produce hydrogen gas which forms a highly combustible gas mixture that could explode.

Roundup is specific for grass control, but we have had good luck with the herbicide on broad-leaf, hard-to-kill weeds. Around our irrigation ponds we had a problem with Swamp willow (*Salix* sp.) that defied our every effort to control. Two applications of Roundup at the above rate gave us complete control of this pest.

Roundup costs a little more than Paraquat but the long lasting effects and the less frequent applications make this herbicide a more economical material for our operation.

Some research has been done on using dilute amounts of Roundup over the tops of established plants to clean up weeds. Self (1,2) and Whitcomb (3) have had good results with this process. We have tried to duplicate some of their work but, to date, we have not been successful. We have either killed the plants or not obtained weed control. I am sure that when rates and usage are refined, Roundup will be used quite widely in the nursery industry.

Roundup, as we see it, is one of the best new herbicides to come our way in a long time. It is a material that I am sure you will find to your liking.

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2. ________ and C.T. Pounders, Jr., 1976. Weed Control and Phytoxicity Studies on Container-Grown Ornamentals. *So. Nurs. Res. Conf. Proc.* 20:117.
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AFTER TRIALS WITH HERBICIDES, A DECISION IS MADE

CURTIS W. WILKINS and GRADY L. WADSWORTH

Greenleaf Nursery Co.
El Campo, Texas 77437

Abstract. Nine herbicides were evaluated for their effectiveness in reducing weed growth in twenty cultivars of containerized nursery stock. Alachlor at 4 lb ai/A and 6 lb ai/A and 4 lb ai/A showed generally the least amount of phytotoxicity but also demonstrated the poorest weed control of all nine herbicides evaluated. Profluralin at 6 lb ai/A and 9 lb ai/A gave fair weed control and only slight damage to the plant materials. Tests with napropamide at 6 lb ai/A and 8 lb ai/A indicated fair to poor weed control followed by moderate damage. The combination of alachlor at 4 lb ai/A and 6 lb ai/A with trifluralin at 4 lb ai/A and 6 lb ai/A, respectively, demonstrated moderately effective weed control with slight to moderate plant damage. Oxadiazon at 2 lb ai/A and 4 lb ai/A in granular, wettable powder, and emulsifiable concentrate forms showed excellent weed control, but also moderate to excessive damage to nursery stock. Alachlor at 4 lb ai/A and 6 lb ai/A combined with simazine at 1 lb ai/A and 1.5 lb ai/A, respectively, gave poor weed control with only one application during the growing season. However, with two applications, weed control was excellent, but damage was excessive.

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INTRODUCTION

With the rising costs of producing quality container nursery stock, and the increasingly competitive market, it became apparent that there was a need to decrease the production cost per unit. Until three years ago all of the container nursery stock at Greenleaf Nursery was entirely hand-weeded. It is reported that over 600 man-hours are required to hand-weed one acre of containerized nursery stock. This figure correlates to our approximate cost of $1000/A. Fretz (3) demonstrated the need for growing nearly weed-free nursery stock for quality. His research proved that the dry weight of Japanese holly (*Ilex crenata*, (Thumb.) cv. *convexa* Makino) decreased as much as 60% in a 2.4 liter container when the quantity of weeds increased. Poor quality results from slow crop growth due to competition for nutrients and moisture between the nursery stock and the weeds.

Unfortunately, there is limited information concerning herbicide usage on container nursery stock. This primarily results from lack of interest of the chemical companies due to the small nursery market for them, compared to the risks involved with labelling a product for nursery use. Since few of the available herbicides on the current market give the necessary weed control over the broad-spectrum of plant material existing in nurseries, increased interest has encouraged research both on an individual basis and with the chemical companies in this area.

For the past three years Greenleaf has conducted research into the possibilities of incorporating herbicides into the weed control program, thus reducing the production cost per unit. This year with the herbicidal research program, we have evaluated nine herbicides at various rates as listed in Table 1. This year closer attention was paid to the phytotoxic effect which may have resulted from the rates necessary to obtain the best possible weed control.

Table 1. Herbicides Evaluated in 1976.

Trade Name	Common Name	Manufacturer	Application Rates ai/A
Devrinol 10 G	Napropamide	Stauffer Chemical Co.	6-8 lbs
Lasso 15 G	Alachlor	Monsanto Co.	4-6 lbs
Princep 4 G	Simazine	CIBA-GEIGY	1-1 1/2 lbs
Ronstar 2 G	Oxadiazon	Chipman Division of Rhodia Inc.	2-4 lbs
Ronstar 25% EC	Oxadiazon	Chipman Division of Rhodia Inc.	2-4 lbs
Ronstar 75% WP	Oxadiazon	Chipman Division of Rhodia Inc.	2-4 lbs
Surflan 75% WP	Oryzalin	Elanco Products Co.	2-4 lbs
Treflan 5 G	Trifluralin	Elanco Products Co.	4-6 lbs
Tolban 2 G	Profluralin	CIBA-GEIGY	6-9 lbs

MATERIALS AND METHODS

The research for this year was established on July 1, 1976, with the twenty cultivars of plants listed in Table 2. For each cultivar 190 plants were selected for uniformity of growth from our standard beds of 120 × 6′. These liners were planted in 2.4 liter polyethylene containers and allowed to establish for a minimum of eight weeks. Each of the herbicides, and the combinations of alachlor and simazine, and alachlor and trifluralin, as listed in Table 1, were evaluated using ten plants × 2 rates × twenty cultivars, bringing each test block to a total of 400 plants per herbicide.

Table 2. Plant Material Utilized in 1976 Herbicide Research.

1. *Azalea indica* 'Formosa'	11. *Ilex cornuta* 'Burfordii'
2. *Buxus microphylla japonica*	12. *Ilex crenata* 'Helleri'
3. *Elaeagnus macrophylla* 'Ebbengi'	13. *Nerium oleander*
4. *Euonymus japonica* 'Aureo-variegata'	14. Photinia fraseri
5. *Euonymus japonica* 'Grandiflora'	15. *Pinus caribaea*
6. *Gardenia jasmininoides* 'Mystery'	16. *Pittosporum tobira* 'Variegata'
7. *Lonicera* spp.	17. *Pyracaakoidzumii* 'Victory'
8. *Juniperus horizontalis* 'Wiltonii'	18. *Viburnum suspensum*
9. *Lagerstroemia indica*	19. *Washingtonia robusta*
10. *Ligustrum Japonicum* 'Texanum'	20. *Yucca aloifolia*

The plants were grown in a highly organic mix consisting predominantly of pine bark. The granular herbicides were applied with a Gandy herbicide applicator which was carefully calibrated before each application of the herbicides. The wettable powder formulations and emulsifiable concentrates were applied with a one gallon CO_2 constant-pressure sprayer calbrated at 40 psi to deliver at 6-1/2′ band with #8003 Tee Jets at a volume of 30 gal per acre. The treatments were completed on July 2, 1976, and the containers irrigated with 1/4″ of water with overhead sprinklers to incorporate the herbicide. Each container was fertilized prior to the herbicide treatment with one teaspoon of 18-9-13 osmocote. Throughout the experiment overhead liquid fertilizer was used to maintain proper quality of plant material.

Initial weed counts and phytotoxicity symptoms were evaluated 28 days after the herbicide application. Actual weed counts were taken, with those results listed in Table 3. The predominant weeds encountered were: bittercress (*Cardamine hirsuta* L.), weeping woodsorrel (*Oxalis corniculata* L, barnyard grass (*Echinochloa crusgalli* Beauv.), and sowthistle (*Sonchus oleraceus* L.). Each cultivar was given a phytotoxicity rating. The rating system was 0 to 10.0, with 0 representing no physical damage and 10.0 representing death of every plant within the cultivar tested.

Eleven weeks after the initial treatment, an application of the individual herbicides was applied again to half of each of the 20 cultivars, using the same experimental rates as the initial application. The same precautions were utilized in calibrating the Gandy applicator and with the constant pressure CO_2

sprayer. Again, after the treatments, the herbicides were incorporated into the soil with a 1/4 inch of water.

Weed counts were taken and phytotoxicity symptoms were rated 3 weeks after the herbicide application. Those results are listed in Table 4. The results of weed counts and phytotoxicity ratings of the plant material not treated the second time are listed in Tables 5 and 6. Similarly, the same rating system: 0 to 10.0 was employed.

RESULTS AND DISCUSSION

Alachlor (LASSO®) was evaluated at 4 and 6 lb ai/A. These evaluations were made at the lower and higher rates with either one or two applications during the growing season. With no appreciable difference in damage with both rates, alachlor is still the standard for other chemicals to be measured against. Alachlor also gave fair weed control when applied at 6 lb ai/A only once without any adverse effects. Since alachlor has a short duration of weed control, it must be applied at 6-8 week intervals for acceptable weed control. However, since it is readily leachable, the phytotoxic symptoms may increase as shown in this research.

Oryzalin (SURFLAN®) at 4 and 8 lb ai/A provided excellent weed control in the previous year's research followed by severe phytotoxic effects. However, this year at 2 lb ai/A and 4 lb ai/A, oryzalin produced little or no phytotoxic effects but exhibited the poorest weed control of all nine herbicides evaluated. This data concurs with that of Whitcomb & Butler (7), which states that oryzalin appears unsuitable for container use due to rapid leachng and high potential for plant damage.

Profluralin (TOLBAN®) at 6 and 9 lb ai/A gave fair weed control with only slight damage to the plant material. Research has shown profluralin to be effective against bittercress in weed control; however, this was not the case in this year's research. Profluralin reduced the amount of weeping woodsorrel by as much as 90% when compared to the control. With bittercress there was no significant reduction in weed counts with profluralin. Profluralin may still show promise in future evaluations for good weed control without plant damage if used, possibly, at a higher rate of application.

Napropamide (DEVRINOL®) evaluated at 6 and 8 lb ai/A showed fair to poor weed control with moderate damage. Research with napropamide at higher rates of application to obtain acceptable weed control would possibly result in excessive damage to the plant material. However, it should be noted that napropamide does effectively control bittercress. Napropamide seems to be too specific for the broad spectrum of weeds that we encounter. Therefore, napropamide appears not suited for our particular micro-environment of growing conditions.

Alachlor (LASSO®) applied at 4 lb ai/A and 6 lb ai/A combined with trifluralin (TREFLAN®) at 4 lb ai/A and 6 lb at ai/A, respectively, showed moderate weed control and phytotoxic effects. Fretz (4) reported that trifluralin at 4 lb ai/A combined with alachlor at 1.5 ai/A gave excellent control of grasses but poor control of broadleaf weeds. Since most the weeds we encounter are broadleaf, this combination is not acceptable for our use.

The oxidiazon (RONSTAR®) products all provided excellent weed control, yet were highest in phytotoxicity. Initially, all three products demonstrated similar phytotoxic effects. With the second application the granular form proved to be less phytotoxic than the others. The emulsifiable concentrate was the most damaging. This could be expected with the petroleum distillate carrier in the EC form. Even with spot burn from the granular form on *Yucca aloifoilia* L., the overall effects were not as severe as with the wettable powder and emulsifiable concentrate forms. For weed control, the EC proved to be more effective than the WP and G forms when applied twice during the course of the experiment, but the G and WP forms still gave excellent weed control. However, with only one application, the EC fell behind the other oxadiazon formulations in weed control.

Despite this, oxadiazon seems very promising for weed control in container grown nursery stock. However, oxadiazon has an initial stunting effect on plant material which may or may not grow out of it. Perhaps reevaluation at lower rates or frequencies of application would suffice without sacrificing weed control. Skimina (6) recommended that oxadiazon be applied at 2.25 lb ai/A. With this year's research, this rate falls within those that we applied resulting in excellent weed control but also moderate to heavy damage. This was especialy true with *Ilex cornuta* var. *Burfordii* and *Yucca aloifolia*. All of our research has shown oxadiazon to result in excessive damage, ranging from severe stunting to 50% death of the experimental plants to these two cultivars. Since Greenleaf uses a large percentage of very porous organic material in its soil mix, this would possibly explain the severe phytotoxic effects due to the slight leaching of the chemical in the media.

Alachlor (LASSO®) at 4 lb ai/A and 6 lb ai/A combined with simazine (PRINCEP®) at 1 lb ai/A and 1.5 lb ai/A, respectively, gave poor weed control with only one application during the growing season. With two applications, alachlor and simazine gave excellent weed control but likewise resulted in excessive damage to the plant material. Dean *et al.* (2) have re-

Table 3. Effects of nine herbicides (two applications) on various weed species of 20 container-grown broadleaf ornamental shrubs.

Weed counts[1]	Rates of Appl. (lb ai/A)	*Cardamine hirsuta* L. (bittercress)	*Oxalis corniculata* L. (weeping woodsorrel)	*Sonchus oleraceus* L. (sow thistle)	*Euphorbia nutans* Lag. (spotted spurge)	*Echinochloa crus-galli* Beauv. (barnyard grass)
control	—	124	54	2	18	1
alachlor 15% G	2	3	20		2	
	4	2	3			
oxadiazon 2% G	2	1	4		3	
	4	1	3			
oxadiazon 75% WP	2	1	2			
	4	1	1			
oxadiazon 25% EC	2					
	4		2			
oryzalin 75% WP	2	31	34	5	1	
	4	12	15			
profluralin 2% G	6	60	1			
	0	31				
napropamide 10% G	6	34	4			
	8	6	31		1	
alachlor 15% G + trifluralin 5% G	4/4	17	7			
	6/6	4	5			
alachlor 15% G + simazine 4% G	4/1	2	17			
	6/1.5		6	1		

[1] Weed Counts were made 10-11-76, 93 days after the herbicide application.

Table 4. Cumulative phytotoxicity ratings with two herbicide applications.

Herbicide	Rate of Application (lb ai/A) Low Rate	High Rate	Phytoxicity Ratings Low Rate	High Rate
control	—	—	0.0	0.0
alachlor 15% G	2	4	0.30	1.05
oxadiazon 2% G	2	4	3.15	3.65
oxadiazon 75% WP	2	4	3.18	4.47
oxadiazon 25% EC	2	4	4.25	4.68
oryzalin 75% WP	2	4	0.86	1.20
profluralin 2% G	6	9	1.00	1 50
napropamide 10% G	6	8	1.40	1.40
alachlor 15% G + trifluralin 5% G	4/4	6/6	1.71	1.95
alachlor 15% G + simazine 4% G	4/1	6/1.5	2.45	2.55

Table 5. Effects of nine herbicides (1 application only) on various weed species of 20 container-grown broadleaf ornamental shrubs.

Weed counts[1]		Rates of Appl. (lb ai/A)	*Cardamine hirsuta* L. (bittercress)	*Oxalis corniculata* L. (weeping woodsorrel)	*Sonchus oleraceus* L. (sow thistle)	*Euphorbia nutans* Lag. (spotted spurge)	*Echinochloa crus-galli* Beauv. (barnyard grass)
control		—	121	76	9	3	2
alachlor 15% G		2	30	67		3	
		4	2	15			
oxadiazon 2% G		2	112	6			
		4	8	2			
oxadiazon 75% WP		2	85	9			
		4	2	14			
oxadiazon 25% EC		2	142	8			1
		4	96	1			
oryzalin 75% WP		2	161	38	1	6	
		4	79	49			
profluralin 2% G		6	108	15			
		9	85	5			
napropamide 10% G		6	68	76		2	
		8	83	33		1	
alachlor 15% G + trifluralin 5% G		4/4	91	39			
		6/6	29	19			
alachlor 15% G + simazine 4% G		4/1	28	125			
		6/1.5	29	85	1	3	

[1] Weed Counts were made 10-11-76, 93 days after the herbicide application.

Table 6. Cumulative phytotoxicity ratings with one herbicide application.

Herbicide	Rate of Application (lb ai/A) Low Rate	High Rate	Phytoxicity Ratings Low Rate	High Rate
control	—	—	0.0	0.0
alachlor 15% G	2	4	0.20	1.65
oxadiazon 2% G	2	4	1.65	2.00
oxadiazon 75% WP	2	4	1.28	1.92
oxadiazon 25% EC	2	4	1.55	2.00
oryzalin 75% WP	2	4	0.21	0.25
profluralin 2% G	6	9	0.50	0.80
napropamide 10% G	6	8	0.90	1.00
alachlor 15% G + trifluralin 5% G	4/4	6/6	1.10	1.15
alachlor 15% G + simazine 4% G	4/1	6/1.5	1.65	1.75

ported severe damage to plant materials with the second application of simazine. Further evaluation of this combination is needed to explore the possibilities of using one initial application of simazine & alachlor followed by applications of alachlor at eight-week intervals.

Using herbicides in a weed control program requires experimentation on an individual basis. A particular herbicide may be suitable for one nursery, while not for another. Growers must consider the variables of their micro-environment, such as soil mixes, amounts of irrigation, plant size, and cultivars to be grown. Fretz (5) reported that the greater the amounts of organic matter in a mix, the higher the concentration of a particular herbicide required for efficient weed control. On the other hand, Carpenter (1) stated that increased porosity of a soil mix also hastened the leaching of the herbicide material into the root zone of the plant. With this in mind, one can conclude that only experimentation is the key to using herbicides for container grown nursery stock.

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WEED CONTROL IN FIELD NURSERY STOCK

BRYSON L. JAMES[1]

McMinnville, Tennessee 37110

Successful weed control requires an aggressive program directed toward eradication, prevention and control. Emphasis should be placed on *aggressive* because anything less than an all-out attack will not subdue our weed enemy.

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Half-heartedly waging war on weeds is expensive and usually leaves our fields miserably infested with weeds. Perhaps it will help to emphasize key points in this review if we can compare tactics and terms used by the military to those needed to successfully fight weeds. Keep in mind that the object is to destroy the enemy while providing safety for your own troops.

FIELD COMMANDER

Every campaign needs a leader. One whose primary responsibility is to win the battle. This leader must not be pulled away to fight other battles such as digging balls, loading trucks, planting, fertilizing or repairing equipment. If your firm doesn't have a weed control General, get one! To fight weeds wisely requires being at the right place at the proper time with effective weapons (herbicides and equipment) that are properly maintained and used. The Company cook can't win the battle for you after supper dishes are washed. The degree of planning and organization and coordination required to wage a successful campaign against weeds deserves the undivided attention of one man.

KNOW YOUR ENEMY

Military intelligence gathering is recognized as the key to winning battles and wars. Recognizing and understanding the habits of weeds is important when planning your attack on weeds. If we will use the things we know about weeds, we can defeat them easily.

1. We know that *weeds will launch two major attacks every year*, spring and fall. By placing land mines (preemergence herbicides) in our fields in the fall before winter annuals germinate and again in the spring before summer annuals germinate, the enemy's two major attacks will be stopped.

2. We know where their *weed factories* are. Some plants have facilities both above and below ground and can survive frequent surface attacks. Elimination of weed seed factories adjacent to the battlefield greatly reduces reinforcement capabilities of our enemy. Perennial weeds such as Johnsongrass, Bermudagrass, nutgrass, artemesia and wild artichoke have extensive underground activities which should be destroyed before sending our own troops (plants) into the field.

3. We know *how weeds are transported*. Mulches and manures, wind, water (rainfall and irrigation) men and other animals and on machinery are the main systems of transportation for weeds. We can influence and/or control most of these systems. Sterilize or don't use weed infested mulches and manures. Use windbreaks to stop many wind-blow seeds. Don't irrigate from ponds and streams surrounded by weeds. Be careful

about moving B&B plants from a field with perennial weed problems to one that is weed free. Wash and thoroughly clean machinery after turning a field with perennial weeds and after mowing a weed field, before going into clean fields.

4. We know *when weeds are easiest to kill*. Annual weeds that escape the preemergence herbicide barrier should be killed when immature. Light cultivation or a weak contact herbicide will do the job. However, perennial weeds and grasses are more easily killed with Roundup (glyphosate) when they approach maturity.

KNOW YOUR OWN "TROOPS" (PLANTS)

Know which plants are most sensitive to chemicals and group similar species together for easy treatment. Avoid intermixing species or otherwise you will be forced to use your weakest herbicide on everything to prevent injury.

KNOW YOUR WEAPONS

There are many good herbicides on the market that are safe for ornamentals when used properly. Time will permit us to talk about only a few of the more widely used products for field nursery stock production. Eight herbicides are discussed at the conclusion of this paper.

Not only do we need to know what weapons to use, we also must know how, when, how much and how often to use them.

A BASIC ATTACK PLAN

After thoroughly studying the weapons (herbicides) available and considering tolerances of your troops (plants), call in your field Commander in charge of weed control and map out a basic plan of attack that will turn back the invasions that you know the enemy (weeds) launches each year. The least expensive and most effective tactic is ambush and surprise attack, so timing is important. Coordinate your efforts with planting, fertilization and cultivation forces so they will not destroy your mine fields (preemergence herbicide barriers).

A typical plan for nurseries in the mid-South is outlined below. Refer to the information at the conclusion of this paper for rates and precautions.

A. **New Plantings**

1. Eradicate perennial weeds and grasses the season before lining out stock. Roundup at 2 to 4 lbs ai/acre (2 to 4 quarts) will do the job. Use the higher rate for Bermudagrass and nutgrass.

2. Incorporate Treflan preplant at 1.5 lbs ai/acre (1.5 quarts). Rototill or disc thoroughly 2-3" deep immediately behind the sprayer. Liners may be planted immediately or delayed a few days or weeks if necessary.

3. Two to three months after planting —

a. Broadleaf evergreens and certain deciduous shrubs. Apply Lasso or Dymid or Enide or Casoron or Kerb or Surflan.

b. Conifers and many deciduous tree species. Apply Princep.

B. **Established Plantings**

1. Fall, cultivate to kill any winter annuals that may have germinated then:

a. Broadleaf evergreens and certain deciduous shrubs. Apply Lasso or Dymid or Enide or Treflan or Casoron or Kerb.

b. Conifers and many deciduous tree species. Apply Princep.

2. Spring, after fertilization and cultivation to remove any existing weed growth:

a. Broadleaf evergreens and certain deciduous shrubs. Apply Lasso or Dymid or Enide or Treflan or Surflan.

b. Conifers and many deciduous tree species. Apply Princep.

PRINCEP (SIMAZINE)

Formulations:	80% Wettable Powder 4% Granules
Toxicity:	Acute Oral LD_{50} (rat) over 5,000 mg/Kg.
Crops:	Arborvitae, Barberry, Cedar, Cotoneaster, Elm, Fir, Hemlock, Honeysuckle, Juniper, Mahonia, Maples, Oak, Oleander, Pines, Pyracantha, Russian Olive, Spruce, Taxus.
Activity:	Preemergence. Apply to weed-free soil to kill grasses and weeds as they germinate. Can be sprayed over the top without crop injury. —Perhaps the most effective herbicide that can be used with safety on the crops listed above. Controls both grasses and many broadleaf weeds. —May be combined with many other herbicides.
Precautions:	Has a long residual activity and could damage subsequent crops not tolerant to simazine. Also repeated use could cause a build-up. —Use lower rates on sandy soils and make only one application per year. —Do not apply more than two times per year on any soil type.
Rates:	When used alone, 2 lbs active/Acre (2-1/2 lbs 80W; 50 lbs 4G) on most soils. Use less on very sandy soil and more on very heavy clays and organic soils.
Cost/Acre:	About $7.50 for 80W About $25.00 for 4G

3. Spot treat, using Roundup as a directed spray (on weeds, off nursery stock), to control perennial weeds and grasses and certain annuals that may not be controlled with preemergence herbicides.

TREFLAN (TRIFLURALIN)

Formulations: Liquid (e.c.) 4 lbs/gallon
Granular 5%

Toxicity: Practically non-toxic. Acute Oral LD_{50} greater than 10,000 mg/Kg but LD_{50} of solvent system for e.c. approximately 3,700 mg/Kg.

Crops: Virtually all ornamentals.

Activity: Preemergence, incorporated in weed-free soil will control most grasses and several broadleaf weeds. Weak on broadleaf weeds in general and especially ragweed, jimsonweed, and dock, but it does provide some suppression of Johnsongrass rhizomes.
— Shallow cultivation when applied and several weeks after application may improve effectiveness.
— Best used as a pre-plant, incorporated treatment followed in 2 to 3 months with cultivation and application of another preemergence chemical.

Precautions: Excessive rates and/or very moist soil conditions may cause root-pruning, however, death seldom results from the Treflan alone.
— e.c. formulations must be incorporated promptly to prevent excessive losses.

Rates: 1 to 2 lbs active/Acre (1 to 2 quarts e.c.) when incorporated.
— 3 to 4 lbs active/Acre (60 to 80 lbs 5G) when surface applied.

Cost/Acre: $6.50 to $13.00 for e.c.
$25.00 to $32.00 for granular

LASSO (ALACHLOR)

(NOTE: THIS PRODUCT IS NOT LABELED FOR USE ON ORNAMENTALS)

Formulations: Liquid (e.c.) 4 lbs/gallon
Granular 10% and 15%

Toxicity: Acute Oral LD_{50} (rat) 1,800 mg/Kg.

Crops: Most Ornamentals

Activity: Preemergence primarily but also effective as pre-plant incorporated to control grasses and many broadleaf weeds as they germinate. About the same control as with diphenamid (Enide or Dymid) but costs much less/acre. The e.c. product has shown slight, temporary leaf scorch when applied during moisture stress periods but can generally be applied over the top without crop injury.

Precautions: Do not use in enclosed plastic houses or glass houses.
— Do not use PVC tanks, fittings or nozzles as the solvent softens these materials.

Rates: 4 lbs active/Acre (4 quarts e.c.)

Cost/Acre: About $13.50

DYMID OR ENIDE (DIPHENAMID)

Formulations: 50% and 80% wettable powders
liquefied — 4 lbs/gallon
granular, 5%

Toxicity: Acute Oral LD_{50}, about 1,000 mg/Kg.

Crops: Virtually all commonly grown woody ornamentals

Activity: Preemergence. Apply to weed free soil to kill grasses and many broadleaf weeds as they germinate. Can be sprayed over the top without crop injury.
— Weak on broadleaf weeds, especially summer annuals that germinate more than 6 weeks after application.
— Shallow cultivation does not destroy effectiveness and may benefit when applied during dry period.
— Combination with other herbicides suggested.

Precautions: Very good agitation is required to prevent settling and nozzle clogging due to high rate of wp used/acre. (8 to 16 lbs). Clean strainers and filters frequently.

Rates: When used alone, 4 to 8 lbs active/Acre (8 to 16 lbs 50% w.p. or 5 to 10 lbs 80% w.p.)

Cost/Acre: About $32.00 for w.p.'s.

KERB (PRONAMIDE)

Formulations: 50% wettable powder
Granular

Toxicity: Acute Oral LD_{50} (rat) 8,350 mg/Kg.

Crops: Many ornamentals, not fully tested as yet.

Activity: Preemergence and early postemergence on winter annuals, perennial grasses and certain broadleaf weeds. May be sprayed over the top without crop injury. Kerb is root absorbed. Rainfall or light cultivation is essential.
— Weak on broadleaf weeds in general, but is effective on dock and henbit.
— Combination with other herbicides is suggested for longer residual and more broadleaf weed control.

Precautions: Apply only during the cool seasons. Kerb is not effective during the summer.
— Not effective on organic soils (peat and muck)

Rates: 1.5 lbs active/Acre (3 lbs 50W)

Cost/Acre: About $20.00 for w.p.

DACTHAL (DCPA)

Formulations: 75% wettable powder
Granular 5%

Toxicity: Acute Oral LD_{50} (rat) 3,000 mg/Kg.

Crops: Safe on practically all ornamentals.

Activity: Preemergence control of annual grasses is excellent but is weak on broadleaf weeds. For weed control in species and/or situations that are questionable with other herbicides, Dacthal probably is the safest product to try. Completely safe to apply over the top.

Precaution: Do not disturb soil after application or effectiveness will be destroyed.

Rate: 11 to 12 lbs active/Acre (14-16 lbs 75W)

Cost/Acre: About $30.00

ROUNDUP (GLYPHOSATE)

Formulations:	Liquid (e.c.) 4 lbs/gallon.
Toxicity:	Acute Oral LD_{50} — 4,300 mg/Kg.
Crops:	Use as directed spray *only* around ornamental crops. Not recommended for topical application on any crop, even though some have "gotten-by" with doing so on some plants.
Activity:	Postemergence to most broadleaf and grassy weeds. More effective on mature growth, especially for control of Bermudagrass, Johnsongrass, Thistle, Nutgrass, Dock and other perennials.
Precautions:	Keep off foliage of crop plants.
Rates:	(Commercial Product) 1 fluid ounce/gallon for knapsack sprayer. 4 qts/100 gal — for handgun, high volume. 2 to 4 qts/Acre with boom equipment. (Lower rates for annual grasses and Johnsongrass and the higher rate for Bermudagrass and Nutgrass.)
Cost/Acre:	$26.00 to $52.00

CASORON (DICHLOBENIL)

Formulations:	50% wettable powder Granular 4%
Toxicity:	Acute Oral LD_{50} (rat) 3,160 mg/Kg.
Crops:	Most woody ornamentals except hollies and azaleas are tolerant to the lower rate.
Activity:	Preemergence on most grasses and many broadleaf weeds from seeds. The granular product applied during the winter will control many hard-to-kill perennial weeds and grasses such as quackgrass, artemesia, dock, fescue and wild artichoke.
Precaution:	For best results the granular product should be applied between mid-November and mid-February. —In warm soils must be cultivated lightly to reduce excessive losses. —Make only one application/year. —Careful rate control is necessary to avoid crop injury.
Rates:	4 to 6 lbs active/Acre (8-12 lbs 50W or 100 to 150 lbs 4G) — Use the lower rate for lighter soils and annual weeds and the higher rate for perennial weed control during the cool season.
Cost/Acre:	$37.00 to $55.00 for w.p. $53.00 to $80.00 for 4G

QUESTION: Can you recommend a book or pamphlet that will aid one to identify weeds usually found in southern nurseries.

Yes, there are several: "Weed Identification" published by the University of Georgia Agricultural Extension Service, Hoke Smith Annex, University of Georgia, Athens, Georgia 30602. Another is titled "Weeds of Southern United States"; this should be available from Agricultural Extension offices in all southern states. There is a cost of $.65 for the first-mentioned and $.75 for the latter publication.

MIKE McCALLUM: Do you use any herbicides on your container-grown azaleas?

CURTIS WILKINS: No, we do not use any herbicides on container stock; all the ones we looked at produced too much phytotoxicity to warrant their use on azaleas.

VOICE: Dr. James, did you say that Casoron should not be used on hollies and azaleas?

BRYSON JAMES: I would use it only once per year in the cool season of the year between November and February.

JIM MERCHANT: I know Casoron is very hard on peonies.

VOICE: Our county extension agent did a test with Casoron on rhododendrons in containers during March a few years ago. He used 5 replications of 5 to 25 lbs per acre and got no damage. Weed control was obtained until August. Sidney Meadows, could you comment on what herbicides you use on azaleas?

SIDNEY MEADOWS: We don't use any herbicides on our azaleas. We have tried a few compounds, but we find the best way to control weeds is to exclude them from the nursery as much as possible.

LANNY NEEL: A nurseryman in north Florida I know of has used Lasso sprayed over the top of plants, including azaleas, in his nursery. Initially he was pleased with the results on azaleas, but after several applications found chlorosis and tip die back developing which he attributed to the Lasso.

JIM WELLS: Is anybody using or testing Tenoran? This was written up in The Plant Propagator about a year ago by an Australian who used a wide range of plants and they rated Tenoran No. 1.

BRYSON JAMES: Jim, I've used Tenoran. The main attribute of Tenoran over other herbicides already mentioned is that it controls broadleaf weeds more effectively than the other herbicides. Tenoran is not that safe on ornamentals when used alone at a rate which will control grasses and broadleaf weeds. Used at about 1 lb. active ingredient per acre in combination with one of the other products already mentioned it is effective and safe on at least the conifer and viburnum species I have used it on. It is a good product, but I have found it hard on broadleaf evergreens such as hollies. There needs to be more testing done with this material.

BRYSON JAMES: I have a written question: "How does Kerb kill?" I don't know what system in the plant it disrupts; it is root absorbed and whether or not it disrupts translocation or photosynthesis, I don't know. It kills azaleas though!

LANNY NEEL: Not much is known about specific modes of action of many herbicides. Most can be categorized into groups such as photosynthesis inhibitors, growth hormones, dessicants, electronic transport inhibitors and so on.

VOICE: Lanny, did the nurseryman in north Florida using Lasso on his azaleas try the granular form also?

LANNY NEEL: I believe he may; but because the liquid form was so much easier to apply, he used it. The phytotoxicity he observed was not a burn from the herbicide, but resulted from damage to the roots over an extended time period.

CHARLIE PARKERSON: This is what Dr. Weatherspoon has been talking about. Let's take a look at it over several applications. Often we will sell our material before applications have a chance to build up. If we were to hold our material a second season we might see more of this inhibition.

BRYSON JAMES: I have another question: What is the best source of information on weed control literature?

I would say probably your own state agricultural extension service. They will have information which is most relevant to your own area. Write to your State University.

CHARLIE PARKERSON: Another good source of up-to-date information is the Proceedings of the Southern Nurserymen's Association Research Conference. This contains current research reports from scientists located in the 13 southeastern states and is an excellent source of information on many topics.

BRYSON JAMES: There is no one good reference that I know of for weed control in ornamentals. I have a question for Curtis: "The container mix is said to be a factor in the translocation and residual nature of herbicides; what was your container mix?"

CURTIS WILKINS: Five parts pine bark, two parts sharp sand, and one part rice hulls; you can see we have no "soil" in our mix. The air space is from 18 to 22% so it is quite porous, which is necessitated by our heavy south Texas rains. This is a contributing factor to the leachability of the herbicides; Lasso is quite leachable in this mix. Ronstar supposedly stays on top of the "soil", but I feel we are still getting some leaching into the root zone which explains the stunting effect we observed.

Another question for Curtis: "What is the effect of age on the effects of these herbicides on the test plants and what was the effect of Lasso on newly planted versus established plants?"

CURTIS WILKINS: When we started the experiment the plants in the one gallon containers were approximately eight weeks old. We observed an initial effect, yes, but as others have found, the larger the established root system the less the effect in older plants.

BRYSON JAMES: I have a question for Charlie: "With formaldehyde, is one week's aeration enough and do you spray everything in the house?"

CHARLIE PARKERSON: We have *Thiealaviopsis* problems in the little pots we root in. We root directly in these pots. We put them in, fill them with soil and then seal up the house tight with plastic and spray formaldehyde over everything. Then we close the doors for about a week. After that we go in and knock the soil out of a few pots and smell it. I don't really know how long is enough. It has been recommended that you go in with some tomato transplants when you are ready and observe them for any injury. Our pots are small; larger ones might take longer.

VOICE: Curtis, with your Gandy applicator, do you notice any variation in your application rate depending on the speed of the rig as it is drawn across the bed?

CURTIS WILKINS: No, this is compensated for in the design of the machine; it is chain driven.

JIM WELLS: Curtis, you mentioned two weeds: cress and oxalis, and you said Devrinol was specific for cress. Could you tell us what rate you used Devrinol and how you used it and is there anything specific for oxalis?

CURTIS WILKINS: Our research last year showed that Devrinol was specific for bittercress (*Cardamine hirsutum*) but this year's testing did not substantiate this at all; we got very poor control over the bittercress, but excellent control over oxalis at 6 lbs ai/A.

ROBERT WRIGHT: Bryson, recently I saw a report where the application of Simazine to maples would cause interveinal chlorosis.

BRYSON JAMES: I haven't seen any problem with it on red maple in soils of the McMinnville area, but other people on more sandy soils might have problems with it. Simazine leaches very slowly in the soil and it is this property which makes it selective in most instances. If Simazine does come into contact with roots of ornamental plants, it is usually toxic to the plants and, as indicated, often causes chlorosis.

CHARLIE PARKERSON: Curtis, your paper is entitled, "After Herbicide Trials, a Decision is Made"; did you make one, and are you using herbicides now?

CURTIS WILKINS: Right now Greenleaf (Texas) is using Lasso 15 G at 4 lbs active ingredient per acre. We are not treating azaleas and *Photinia*. We did notice some problems on certain *Euonymus* cultivars, particularly the dwarf ones and also on *Aucuba*. We are applying it every eight weeks with the

Gandy; we don't believe that other applicators are accurate enough.

LANNY NEEL: Dan Weatherspoon has reported root pruning by Lasso after repeated applications with relatively little stunting even after 1/3 of the root system has been killed; the point is, be careful and thorough in your evaluations of any herbicide.

CHARLIE PARKERSON: When we use a preemergence herbicide do we suppress germination or do we kill the seeds?

BRYSON JAMES: When the seed is germinating the herbicide kills the plant. Once the seed coat is broken that seed is killed.

VOICE: Has anyone used Enide before?

BRYSON JAMES: Enide has been on the market for many years and its use on ornamentals has been thoroughly researched; at recommended (diphenamid) rates I have not seen any damage from it (8 lbs active except on a very sandy soil). I have not seen it used on azaleas.

DENNIS McCLOSKEY: If you shouldn't use Pramitol in a nursery under containers, what should you use if roots grow out of the containers?

BRYSON JAMES: I believe that your best bet would be to use a soil sterilizing rate of Simazine (25 lbs/acre of the 80 W).

DENNIS McCLOSKEY: What happens if it leaches into the irrigation water?

BRYSON JAMES: Once it is in the soil, unless it's a very sandy soil, it will not leach and you won't have any problem. A layer of gravel over the soil will provide for drainage. Simazine may be reapplied over the gravel in a year or so and washed down into the gravel where it will again complex with the soil below the gravel and provide a barrier to weed seed germination. If chlorosis develops due to root growth from the containers into the treated soil you can cut the roots and you won't lose the plant. Pramitol poisoning is much worse; by the time you see any symptoms it's too late to save the plant.

JUDD GERMANY: Curtis, have you ever tried pine bark impregnated with herbicide?

CURTIS WILKINS: No.

LANNY NEEL: I have worked with several. Dacthal and pine bark have been marketed under the trade name of Fibrex. We looked at it and found no benefit from added Dacthal when the bark was an inch deep. We also looked at Lasso on pine baka found it to be an effective way to use this herbicide. Using Lasso in this way would add a measure of safety to your program because it would be difficult to overdose. You also get the benefit of a mulch. Mechanical barriers such as plastic or fiberglass will suppress weed growth but can interfere with watering and fertilizer placement and don't prevent weeds from growing up around the edges or through holes in them.

BILL CURTIS: Years ago we grew strawberries and I used chloro IPC in the fall with good results. When we got into the nursery business we began using it on our nursery stock in the fall and since then we have had excellent results and no injury to any of our plants. It takes about 30 days to be effective.

BRYSON JAMES: CIPC is an old herbicide, mainly effective on grassy weeds. It is relatively expensive.

LANNY NEEL: Curtis, we used Ronstar on a number of containerized ornamentals and did not get the phytotoxicity which you reported, although Ronstar applied to the foliage is very phytotoxic. I suspect that this difference might have something to do with your growing medium. Ours had "soil" in it whereas yours did not.

LARGE PLANTS IN CONTAINERS

GEORGE L. TABER, III

Glen Saint Mary Nurseries
Glen Saint Mary, Florida 32040

Possibly I should first define "large plants in containers". These are plants that are produced in a manufactured container of at least a 4-gallon capacity. We are currently propagating 90% of the liners we use. From the day the propagation list is prepared, an attempt is made to plan the course of this liner as it moves from the propagation bed to its final planting in the container where it will be grown to maturity. As an example, if our ultimate goal is to inventory 20,000 4-gallon canned *Ilex* and 5,000 15-gallon canned *Ilex*, we will then shift 20,000 rooted cuttings from the propagation bed to pint containers and 5,000 rooted cuttings into 2-gallon containers. These will be staged in holding areas apart from the main growing area and will then be shifted into their respective 4 and 15-gallon containers for growing on. As you can see, there is only one shift process involved and a minimum of handling. Likewise, in planning for 20-24" boxes, we will stage 4 and 7-gallon stock in the holding area. Occasionally there will be two shifting processes when going to extra-large containers.

Unlike many specimen tree nurseries, all of our material has been containerized from the start and has gone the route of the planned series of shifts. The advantages of controlled irrigagram because it would be difficult to overdose. You also get the benefit of a mulch. Mechanical barriers such as plastic or fiberglass will suppress weed growth but can interfere with watering and fertilizer placement and don't prevent weeds from growing up around the edges or through holes in them.

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Unlike many specimen tree nurseries, all of our material has been containerized from the start and has gone the route of the planned series of shifts. The advantages of controlled irrigation, fertilization, and weed control have prompted us to go with containers as opposed to field growing in mediocre soils.

As a potting mixture for specimen trees in containers we are making a soil from native peat, finely ground pine bark (mostly new bark), and a coarse grade of builder's sand. Our ratio for 4, 7 and 15-gallon containers is 2 parts bark, 1 part peat and 1 part sand. Occasionally, for a little heavier mix to be used in 20-24" boxes, a 1-1-1 mixture is used. The pH averages 5.7 in a newly mixed batch of soil, and this tends to rise under field conditions to 5.9 to 6.0. For acid-requiring plants the amount of dolomitic lime per yard is reduced.

Containers are placed in the growing area according to sizes. The 4-gallon plants are spaced on 50′-wide beds with a 20′ roadway on either side. *Proper regulation of water*, a major factor in producing disease-free quality plants, is better controlled when all containers in a particular bed are the same size. By using a 50′-wide bed, plants are never carried over 25′. Loading can be handled directly to trucks of any size; wagons and orders with smaller quantities can be staged in a nearby loading area. With larger containers in boxes that must be lifted with a front-end loader or fork lift, two rows of plants are placed in 8′ wide beds with a 12′ driveway in between. Square boxes can be placed at a 45° angle to the driveway for ease of positioning with loaders.

Large-sized containers are placed in the field empty and are filled by hand from soil wagons. I have seen a cement truck used for this purpose very effectively. In our fields of large containers, overhead Rainbird irrigation is used in conjunction with 8′ and 10′ standpipes. For containers above 15-gallons, a suitable system for applying water to the individual containers is advisable. Our belief is that 50% of the problems that show up in container nursery stock result from *over-watering*, thereby bringing on soil-related fungi.

Fertilizer is applied by hand to all large containers, and a program of weed control using pre-emergence herbicides has been very successful. Herbicides must be used with caution and ample checks should be maintained throughout the nursery.

Growing container plants is a challenge and requires much supervision along with constant experimentation. No written texts have all the answers nor can any one person claim to be an expert. This is the reason that I am excited about the formation of the Southern Region of the International Plant Propagators' Society. One or two suggestions from many different sources might just fit into one's particular situation. It's worth sharing information with this goal in mind.

JAKE TINGA: Thank you. I agree that if you run out of good soil you'd better grow in containers. I would like to stress a couple of points that Lin mentioned; one of the watering problems is putting all these multi-sized containers together and giving them a common watering scheme. He has solved that by putting all his plants with similar watering requirements together and putting them on one line. This is a very important concept. One of the problems that I also see is inventory control. It is easier to hold material in the field than in a container. Lin is planning ahead and knows how many containers he will have at a given date which is a form of inventory control. One other point: growth is money; you need to shift plants up before they "need" shifting, to prevent costly growth slowdowns.

WILDWOOD NURSERIES PROGRAM

EARLE R. MARVIN

Wildwood Nurseries
Walterboro, South Carolina 29488

I would like to discuss our methods of marketing field-grown plant materials. We use what is called a field-to-can method of marketing and harvesting our plant material. This basically means we dig our plants out of the field, put them in containers and allow them to root sufficiently for transportation to site of sales or planting. We are an old nursery trying to learn a new method of plant production. We do not have, or claim to have, all of the answers. All I can do is share with you some of our ideas and some of the things we are trying to do and learn.

Our plants are planted 18" apart in 4' rows. We plant two rows of plant material and leave one row vacant for harvesting. We start our field program by fumigating all of our acreage before planting with methyl bromide. This assures a good start for young trees and shrubs, free from weeds and soil insects. We have what is classified as Goldsboro type soil, which is fairly sandy but contains sufficient amount of clay to permit this type of digging program. Most of our plant material is harvested by hand digging. We settled on two-men digging crews because it seemed to be the most efficient for our operation. We have tried several types of digging machines and found them satisfactory in certain conditions but for the high quality and types of plant material we dig we think the best way of harvesting for us is hand digging. We use 3, 5, 7, 12 and 20-gallon containers.

Basically, we dig every other plant at the end of the second year. However, before every other plant is dug, the particular plant selected for digging that year must reach sufficient size to

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Basically, we dig every other plant at the end of the second year. However, before every other plant is dug, the particular plant selected for digging that year must reach sufficient size to go in the container designated for it. After the first crop of plants has been completely taken off the field (which is usually by the end of the second year, or shortly thereafter) the remaining plants remain for another year to a year and a half, depending on how long they take to reach the next container size or the next designated size that we wish to use for this particular plant.

When a field has been cleared of all plant material, it is then re-plowed, subsoiled, and landgraded. This field will not again be planted for three years. We use these three years to plant cover crops to rebuild soil structure for the next planting.

The plant, and the time of year it is dug, determine how it is handled from that time forward. All summertime digging is handled as follows: All plants, regardless of cultivar or size, are sprayed with an anti-dessicant before digging. All of our plants are dug, depending on the weather, up to about midday. Plants are not left in the field freshly dug over 45 minutes; by then they are put under a constant mist and remain there for two days. We use a specially designed trailer with a hydraulic elevator-type lift to bring the containerized trees to the mist area. Species and weather conditions dictate somewhat where the plants go from there. The larger trees usually go under a drip irrigation system.

Our winter digging is handled a little differently from our summer digging in that a lot of our deciduous trees are dug and placed directly under an outdoor drip system; again, the plant material dug determines whether the plant material goes directly into an outdoor drip system or into a shaded area for misting and hardening off. In the winter we dig all day. We don't put a lot of emphasis on getting the plant material out of the field within the 45 minutes that we try to adhere to in the summer. Some trees dug in the winter grow roots all winter and are ready to sell before leaves come on in the spring. Some cultivars, on the other hand, have to be held for an additional one to two months in the spring to make sure that they survived the winter digging and put on a good enough root system to support the tree for shipment and sale. Our 5 and 7 gallon plant material, instead of going under the mist, usually goes directly under an overhead sprinkler irrigation system, which we use as a mist for two to three weeks to harden it off.

After 6 to 8 weeks the newly dug plants have established enough of a root system so that they can successfully be moved. The way we test our plants to see if they are rooted sufficiently for moving and transporting is to inspect the roots by pulling them out of the cans to see if we can find a uniform root system fully developed. If it appears from the outside that this is the case, then we try picking up at random several plants throughout the batch by their tops. If the plants can be lifted in a fairly wet condition we know that they are sufficiently rooted and ready for transporting. We have cans specially made for us by the Lerio Corporation in Valdosta, Georgia. These cans allow good drainage, which is important, since we have field soil in the containers. It also gives more aeration to the root systems of the plant, allowing them better and quicker rooting. We have been getting excellent results with this program generally; however, we found several kinds of plants that do not fit our type of digging and program, so we have abandoned them. We have also found that our type of digging is particularly beneficial for certain plants which are hard to dig and move balled and burlapped. Some of these plants are dwarf burford holly and sasanqua camellias. If these plants are dug in the summer, misted properly and allowed to root sufficiently before moving, we get much better results than we did when they were balled and burlapped.

We have tried several containers for our type of operation and found that metal cans are the most satisfactory for us mainly because the metal containers are easier to stack in shipping. Also, the plant material can stay in the metal containers longer than it can in one of the perishable-type containers. These are some of the reasons we think our field-to-can method of plant harvesting is, in some instances, better than a continuously container-grown plant. In South Carolina, the Piedmont areas have an extremely heavy clay soil. When planting a container-grown plant into a clay situation without proper drainage and bed preparation, we find that the clay around the peat or bark ball acts like the walls of a bathtub, holding the water around the root system of the plant and causing it to drown. Let me say however, that if the bed were properly prepared, and the drainage properly done on a particular bed, the containerized plant material would do very well. The water transfer from sandy loam to this clay is sufficient for the plant to live and thrive. In the sandy soil of Hilton Head or Kiawah or any of the coastal areas of South Carolina our sandy loam also gives good water transfer when planting directly into little prepared beds. Our plant material essentially is a B & B plant put into a container and allowed to put on a new root system.

VOICE: Do you find it economical to decontainerize your plants and wrap the roots in burlap for shipping?

EARLE MARVIN: We don't do that because we don't like to disturb the root system, although this method is used successfully by some companies.

JAKE TINGA: Let me add to that: the cost of burlapping (labor and materials versus cans) is greater for B & B.

EARLE MARVIN: We have found the costs to be very close together.

JIM WELLS: What about overpotting? If you put a small plant into a large mass of soil does it grow well as if it is stepped up frequently from small containers to larger containers? My second question is how important is it when transplanting container grown plants to their final position to break up the ball before planting?

EARLE MARVIN: Our landscape company has found that our containerized plants don't require breaking up of the root ball — in fact, we don't recommend it. Very seldom are our plants in containers so long that you would need to do this.

LIN TABER: About overpotting, Mr. Wells; when I first started this business I had always heard you should not overdo it in container sizes between moves, then I began to experiment for myself and found out that we could take a 4 inch liner and put it into a 2 gallon container or a 3 or 4 gallon container and at the end of 1 growing season there was very little difference between them; if anything the liner in the larger container was larger. Thus, these two plants became salable in the same amount of time. If the soil mix is well drained there is no restriction put on root growth in a container.

JIM WELLS: What about breaking up the root ball of a container-grown plant? When planting a field-grown plant into the ground there is no need to break up the ball; what about container grown root balls in artificial media? *If* the plant is rootbound I think you should loosen the roots or cut some, whether planting in a larger container or in the field; one should not let a plant get rootbound.

JOHN ROLLER: Jim, for some time I have been observing that if you take a potted liner or a container-grown plant grown in soil the roots will enter a light, manufactured medium, but a liner grown in an artifical medium has real problems getting its roots out into a heavy soil. Jake, this whole thing gets us back to the question of potting plants. Jim Wells asked can you over-pot a plant. The world is 8,000 miles in diameter and we pot into it every day. That is the grossest kind of overpotting anyone could imagine. Any organic mix is going to shrink when it gets dry, and that shrinkage is a real problem in establishing plants in the ground because a quarter of an inch dry space can develop between the root ball and the native soil and the root cannot get through that very easily, if at all. I have put a Chapin system on a landscape job so that the root ball never got dry and the plants took right off without a problem. An earth ball is very different from an artificial mix ball and the care the latter receives the first two weeks after transplanting is critical.

LARRY CARVILLE: Earle, when you dig these field plants and put them in containers, do you backfill the container with soil?

EARLE MARVIN: It depends on the kind of plant. If it's a magnolia or dogwood we may just put bark in the bottom of the container. If it's a crape-myrtle, then the ball is not as deep as the container and we just put regular field soil down in the bottom.

JAKE TINGA: Another comment about the soil-root ball boundary — when you have a pasty soil and you use one of these machine diggers, the whole outside of the ball is compressed and if it's too wet you'll make an adobe brick out of it and the roots can't get out of it when it dries. I've seen pin oaks planted two years which haven't gotten out of the ball. Another thing, the burlap coming up out of the ground acts like a wick and you can induce drying in the zone around the roots in this way.

CHARLIE PARKERSON: Lin, how did you decide on your container spacing?

LIN TABER: We used trial and error. With our larger containers we try to arrive at a spacing that will allow plenty of room to work with these plants even after they are of salable size. I've found, by trial and error, that I'd rather space the plants a little wide in the beginning than have to go back and respace the beds later on. As for placing our boxes at 45° angles to the beds, our fork lift driver suggested this to save time, and it does. In our watering we are moving toward individual container watering with spitters, not drippers, because spitters are easier to see working. We have had problems with the drippers becoming plugged up or coming out of the container.

SOME WATER QUALITY PROBLEMS FACED BY HORTICULTURISTS

CHARLES R. JOHNSON

Department of Ornamental Horticulture, University of Florida Gainesville, Florida 32611

Water quality is a subject of major concern to all horticulturists. Water problems to nurserymen in coastal areas relate to salt intrusion into wells and heavy salt drift, but in urban areas nurserymen are faced with high levels of chloride (Cl) and fluoride (F) in domestic water supplies. Many water resources earth ball is very different from an artificial mix ball and the care the latter receives the first two weeks after transplanting is critical.

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Soluble salts (SS) are chemical compounds formed when base ions combine with acid ions to form neutral salts. Some examples of base ions are calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K). Acid ions include sulfate (SO_4), bicarbonate (CHO_3) and chlorine (Cl). Problems of salinity arise when SS reach damaging concentrations in irrigation water and media.

Monitoring of SS is often accomplished using a Wheatstone bridge or "Solubridge" which measures electrical conductance of a solution. Acceptable and unacceptable SS values are indicated in Table 1. Sodium levels may be particularly high along coastal areas, creating serious salinity problems. Sodium absorption ratio (SAR) is a useful indicator of harmful sodium levels. SAR is obtained from the molar activities of the Na, Ca and Mg in irrigation water. Safe and hazardous SAR levels are shown in Table 1.

Table 1. Water Quality Values for Inorganic Compounds[1].

Determination and Value of Measurement	Description of Water Quality
1. Electrical Conductance (EC. $\times 10^{-3}$)	1.
a. less than 0.75 or 55 ppm	a. no salinity hazard
b. 0.76-3.0 (or 500-1500 ppm)	b. Increasing salinity hazard, especially to seedlings
c. 3.1-or above 1500 ppm	c. Usually unsatisfactory for irrigation
2. Sodium Absorption Ratio (SAR) $= \dfrac{Na+}{\sqrt{\dfrac{Ca{+}{+} + Mg{+}{+}}{2}}}$	2.
a. less than 5	a. no Na hazard
b. 5 to 15	b. Increasing Na hazard
c. above 15	c. Unsatisfactory for irrigation
3. Boron	3.
a. less than 0.5 ppm	a. no hazard
b. 0.5 to 2.0 ppm	b. Injury to sensitive plants
c. over 4.0 ppm	c. Unsatisfactory for irrigation

[1] Adapted from: Furuta, T. 1974. Environmental Plant Production and Marketing. Cox Publishing Co., Arcadia, Calif.

High SS cause diffusion of water from plant cells (exosmosis) and ultimately cause cellular death. In addition, accumulation of certain ions in leaf tissue results in cellular collapse.

Foliar applications of NaCl and $CaCl_2$ at a 4.2 mmho/cm rate caused leaf burn and reduced yield of bell peppers (2). Na or Cl accumulation in shrubs probably causes injury by interfering with normal stomatal function, causing water loss and leaf injury symptoms similar to drought (3). In addition to causing severe plant cellular damage, Na also causes breakdown of soil structure (1).

Methods of dealing with salinity in order to grow plants are not totally satisfactory. Plants such as azaleas and camellias cannot tolerate the high pH values of most saline water. Phosphoric or sulfuric acid can be added to reduce pH values to acceptable levels (4). Such treatment does not correct salinity, but reduces bicarbonate content to acceptable levels for growth.

Frequent and thorough irrigations with saline water prevents accumulation of salts in growing media, and a well drained medium is essential for the volume of water required to effectively leach.

Fertilizers having a low salt index should be selected for the cultural program. Numerous fertilizers and their salt index values are listed in Table 2. As an example of fertilizer selection, potassium nitrate should be used instead of potassium chloride because it leaves less salt residues in the media.

Table 2. Salt Index of Several Fertilizer Materials.[1]

Fertilizer	Salt Index[2]	Fertilizer	Salt Index
Ammonium nitrate	105	Potassium chloride	116
Ammonium sulfate	69	Potassium nitrate	74
Calcium nitrate	53	Potassium sulfate	46
Diammonium phosphate	34	Sodium nitrate	100
Dolomite	1	Sulfate of potash-magnesium	43
Gypsum	8	Superphosphate, single	8
Lime-Calcium Carbonate	5	Superphosphate, triple	10
Magnesium sulfate	44	Urea	75
Monoammonium phosphate	30		

[1] Adapted from: Rader, Jr., L.F., L.M. White, and C.W. Whittaker. 1943. The salt index — a measure of the effect of fertilizers on the concentration of the soil solution. *Soil Sci.* 55:201-218.

[2] Salt Index compared against equal weight of sodium nitrate which was assigned a value of 100.

Deionization is sometimes used to remove salts, especially on high value ornamentals. This involves removal of anions and cations by exchange resins. The process is very expensive, and ions such as Na and boron (B) are not always completely removed. In addition, deionized water is corrosive to metals in pipes and fixtures. Water softeners should *never* be used as a remedy for "hard" or saline irrigation water, since they exchange Mg or Ca with Na which, of course, intensifies problems to plant growth.

The most plausible solution to high SS is to grow salt-tolerant plants and employ good management practices. There are compilations of foliage (9) and woody plants (6) that are tolerant of saline water.

Specific ions, particularly microelements including the heavy metals, often reach sufficient concentrations to affect water quality. B, for example, causes burning of leaves and plant losses at even low concentrations (Table 1). B is often in water supplies because of its extensive use in laundry detergents and cleaning agents. Halogens, particularly Cl and F also have negative effects on plant growth and are injected into many municipal water supplies. Some of the first research on F showed its negative effects on the keeping quality of chrysanthemums and gladiolus cut flowers (13). F has particularly adverse effects on foliage of tropical plants such as *Cordyline terminalis* (5,8). Levels as low as 0.25 ppm F in the irrigation caused leaf damage. Cl at high concentrations also results in cellular destruction (4).

Water quality is related to organic and biological activity of water. Plugging of drip irrigation tubes, mist nozzles and other irrigation equipment is often encountered using well or other natural sources of water. A severe problem is caused by a white, gelatinous sulfur slime associated with a sulfur bacteria, *Thiothrix nivea* (7). This organism occurs in water containing hydrogen sulfide and traces of dissolved oxygen. Shallow wells, 20 to 50 feet in depth, may contain both hydrogen sulfide and iron (Fe). A filamentous hydrophilic sludge is caused by oxidation and precipitation of soluble ferrous (Fe) in the water and, when iron bacteria are present, clogging of drip irrigation can occur with only 0.4 ppm of Fe in the water source (7).

Fe can be held in solution by organic materials such as tannins, phenolics and humic acids (10,11). The pH of irrigation water affects complexing of Fe on these organic materials, for Fe is more stable at a higher pH (6.5) than at a lower pH (4.0). Fe content in water can be detected using commercially available test kits with such procedures as the ortho-phenanthroline technique. Sophisticated filtration systems have been designed to remove some of the biological pollutants from water sources, but these are expensive and not totally effective.

Pesticides are also common contaminates of irrigation water. Many nurseries inject pesticides through irrigation systems and these are often recycled after drainage into small reservoirs. Many herbicides are damaging to plant growth and often have long residual effects (12). The best solution to this problem is a carefully planned pest control program and thorough knowledge of the potency and longevity of all pesticide materials.

Water quality and quantity are critical factors in considering the site for a plant nursery. Quality relates to the amount of physical, biological, or chemical contamination in irrigation water. Any one of these factors can severely limit plant growth and production. Correction of poor water quality is often expensive and, even with space age technology, is not totally effective.

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WATERING PLANTS

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Of all the problems that I observe in visits to container nurseries, the most frequently encountered and the most serious are those related to the plant's root system. We can only make money in container nursery production by achieving accelerated plant growth. To accomplish accelerated plant growth it is necessary that the root system be continuously growing and functioning. Perhaps half of the root system of a shrub can be non-functioning, yet the plant can remain green and appear healthy. However, it will not continue growth at an accelerated rate.

We are attempting to achieve a balance in our potting mixes between the air and water content. Any grower that is producing high quality plants in a short period of time is achieving this balance.

A plant in a container is in a very different environment as compared with the same plant in the ground. In the ground it has a root system covering a larger area; thus it can obtain water and oxygen from a very large soil volume. When the plant is placed in a container, the environment has been changed tremendously by restricting the reservoir of both air and water. When the potting mix is placed in a container, its drainage characteristics are also completely changed.

A major objective in container production is maintaining a "super active" root system. Poor soil aeration and drainage probably affect root growth more than any other factor. We are encountering three problems when there is poor aeration and drainage: (1) reduced soil oxygen; (2) high soil disease organism populations that are caused by the excessively wet conditions; and (3) toxic soil gases that are present under poor soil aeration conditions.

There are a number of variables that can affect the soil-air-water ratio and result in a reduction of plant quality or reduce the growth rate in container production:

Variable 1 – The Potting Mix. Success that growers achieve in accelerated plant production is based to a great extent upon the use of a well-aerated, well-drained potting mix. Much progress has been made by nurserymen in recent years with the advent of well-aerated pine bark mixes. Commercially available pine bark varies tremendously in particle size. It is possible to

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get poor results even with pine bark if it is ground too finely.

Variable 2 – Inadequate mixing of ingredients. We can begin with the proper ingredients in a mix, but if they are poorly mixed we are starting our production cycle with a variable that can result in uneven growth.

Variable 3 – The container size and shape. The soil in deep containers drains better than soil in shallow containers. Nurserymen would all use more of the deeper containers if they did not "topple" over easily.

Variable 4 – The moisture inside the container. The moisture level in the container is not equal throughout the container. There is always more soil water in the lower portion and in the center of the container; therefore there is less oxygen in these areas.

Variable 5 – Container-plant ratios. Wide variations in sizes of container and plants in the containers under the same irrigation system are common in nurseries. This is a variable that is difficult to overcome but is one that we constantly must seek to minimize. Through foliage transpiration larger plants pull water out of the soil much faster than small plants and thus need to be watered more frequently. Organizing plants of the same size and growth rates is important in reducing this variable. The addition of cutoff valves on irrigation risers is also a very useful means of controlling the amount of water to a given block of plants.

Variable 6 – Variation in liner sizes. At canning time if liners of a given kind of plant are not consistent in size another variable has been introduced. A larger liner will pull water out faster and thus you will irrigate when they need water. In the process the smaller size plants will be over-watered.

Variable 7 – Physical changes in the potting mix. Most potting mixes have different air and water holding capacities at the end of the production cycle as compared to the beginning. The organic matter has decomposed somewhat thus causing the mix to compress together. Also much of the open spaces in the mix are gradually replaced by the dense root system that has developed.

Variable 8 – "Shifting up" plants. When a plant is shifted to a larger container and the original soil mix is more compacted than the new mix, then the original mix is usually over-watered and root injury results.

Variable 9 – Rainfall. We don't have control over rainfall. Nurserymen in California do not have the problems with this variable that exists in the East. They can thus grow good plants in a 1/2 soil — 1/2 organic matter mix that would result in problems in the East.

Variable 10 – Poor drainage outside the containers. Containers that sit in puddles of water due to an uneven bed surface will take water up through the drainage holes by capillary action, thus waterlogging the lower portion of the mix. Crowned beds plus a firm surface will eliminate this variable.

Variable 11 – Irregular water application. We assume that an even distribution of water is made when we irrigate. This is often not true. The average rotating sprinkler puts out an uneven amount of water within its circle of distribution. By proper overlapping of these circles we can minimize this variable. Proper reduction in pipe size is also very important in obtaining equal water pressure down a given irrigation line. The design of an irrigation system by someone knowledgeable is of utmost importance in container production.

Variable 12 – The umbrella effect. Assuming that the irrigation system is distributing a uniform amount of water, it is possible that the soil mix in containers is receiving uneven amounts. This variable is caused by the foliage of some plants producing an "umbrella effect" and shedding water. This happens most frequently in older plants that have a dense foliage canopy.

Variable 13 – Position effect. This is most noticeable with container plants under open shade structures. Wind movement and higher light intensity results in the perimeter plants drying out more rapidly.

Variable 14 – Management decisions. The greatest variable is a "person problem" in deciding when to water and how much to apply. We may have uniformity in production, but, unless the correct decisions are made as to when to apply water and how much to apply, then problems will result. We oftentimes assume that a rain is providing adequate water to saturate the container soil but actually it may not be. The only practical way to find out is to knock the plant out of the container in order to look at the soil mix. The most important thing that a grower can do in deciding when to water is to knock plants out of the containers to determine what the soil moisture content is. Over-watering is due to two reasons, either too much is applied at each application or too frequent applications are made.

Variable 15 – Plant tolerance. Tolerance to wet soil conditions varies considerably; therefore, whenever possible, grouping sensitive plants together would be beneficial. Some plants that are easily injured by overwatering include: *Podocarpus*, *Camellia*, *Rhododendron*, (including azaleas), *Pieris*, *Cornus*, *Buxus*, *Juniperus*, *Cleyera* and *Ilex crenata* cultivars.

It is, of course, never possible or practical to completely eliminate the above-mentioned soil moisture related problems.

Efficient producers do reduce these problems to a minimum, however.

SOIL STRUCTURE RELATIONSHIPS . . . SOIL . . . WATER . . . PLANTS . . . IN CONTAINER GROWN ORNAMENTALS

GRADY L. WADSWORTH

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There are wide and varying types of media that have proven successful in the growing of container ornamentals. If we checked with the many successful nurseries we would find a tremendous range of growing media being utilized. However, three important aspects would have been satisfied. Those are 1) aeration, 2) water holding capacity, and 3) nutrient holding capacity (2,3,6). The key to success is learning to combine proper cultural practices with the particular mix one has chosen. However, there are many factors to consider when selecting a growing medium.

Climatic Conditions. What is the rainfall, temperature (diurnal fluctuation), length of growing season, humidity, wind and day length like in the area where the plants will be grown? California nurseries, for example, are afforded an opportunity to use more native soil in their mixes, due to their low rainfall, than nurseries in the southeastern states (6). Of course, these are variables we have little or no control over, unless we build greenhouses. Therefore, we must consider these factors just as we do when deciding what plants to grow.

Plants to Grow. It is, of course, most practical to grow all of our varieties of plants in the same soil mix. Matkin, *et al.* (3) reported that John Innes Horticultural Institution in England demonstrated that a single soil mixture could, with minor modification, be used for growing a wide range of plants. However, waxleaf ligustrum, azaleas, and bromeliads just cannot be treated alike; but the fewer different formulations of soil mix, the more simplified the growing problems.

SOIL

Things a good soil mix must possess or — the functions of a soil:

1) *Good Soil Aeration.* This will assure that a mix has good drainage, which is so very important in growing plants in containers. Buscher (1) reports a procedure to determine the amount of air-filled pore space. He further states that 15 to 25% air-filled pore space is desirable for container-grown ornamen-

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tals. Our mix provides between 18 to 22%, depending on when it is checked. It must be remembered that a soil mix is always undergoing physical changes. Organic matter decomposes during the growing season and roots are growing in the medium, both of which affect aeration and other physical properties.

Smith (6) reports that three problems arise when aeration and drainage are restricted: 1) there is a reduction in available soil oxygen; 2) possibilities for soil disease organisms to become established, i.e. *Pythium*, *Phytophthora*, *Rhizoctonia*, are greatly enhanced by excessively wet conditions; 3) more toxic soil gases are present during times of poor soil aeration.

2) *Nutrient Holding Capacity.* Cation-exchange capacity (CEC) is the ability of a solid particle, which possesses a negative surface charge, to hold positively charged ions, i.e. potassium, ammonia, calcium, etc. Furuta (2) reports that montmorilonite clay and humus have relatively high CEC's of 10 and 20 respectively, whereas, sand has essentially 0. Vermiculite and peat moss have a CEC of 15 and 20, respectively, while redwood sawdust has a CEC rating of 3. The negatively charged soil holds these positively charged ions until displaced by another positively charged ion such as hydrogen (H^+). The released element is then absorbed by the plant, thus the frequency of fertilization of these positively charged ions is dependent on the CEC of the mix. A mix with a high CEC requires less frequent fertilizer applications compared to a mix with a low CEC. One should realize the drawbacks if he selects a mix that requires continuous fertilizer applications. Although this may result in a good quality plant in the shortest period of time, more money will be spent on fertilizers and plant quality will deteriorate rapidly once it reaches the retailer. A plant that has a reserve capacity of fertilizer goes to the retailer and the ultimate consumer in better shape nutritionally. We have received compliments from landscape firms which utilize our plant material because fertilizer continues to be available to the plant after planting.

3) *Water Holding Capacity.* The ability of a soil to hold this precious commodity, water, determines the frequency of irrigation applications. In selecting a soil mix, this ability and climatic factors, such a rainfall, humidity, and wind must be considered and a compromise reached. Matkin, *et al.* (3) state that a plant which is constantly supplied with the proper amount of water grows continuously, whereas a plant exposed to occasional water deficiencies grows intermittently and is smaller. Of course, if the plant is placed under too much water, stress death results. Thousands of plants are lost annually because of the following: they blow over and are not uprighted, watering tubes get knocked out, the water source or system

fails, or possibly and unfortunately the person in charge of watering just didn't water the plants in time. In equilibrium within the water in the container are the negatively charged ions, such as nitrates (NO_3^-), which are available and essential for plant growth. Therefore, each successive irrigation should contain only enough water to have free water begin to run out of the drain holes, or excessive leaching of these negative charges ions results. These three factors: 1) aeration, 2) cation exchange capacity, and 3) water holding capacity, are the essential properties that must be brought together. If they are combined in the right proportions and good cultural practices are followed, the result will be a beautiful plant capable of being in someone's landscape. Only then do we, the nurserymen, receive the aesthetic reward for our efforts — a beautiful plant in a landscape.

4) *Anchorage and Physical Support.* The soil provides a medium in which the roots grow, thus rendering physical support to the top of the plant.

5) *Readily Available and Affordable.* The ingredients should be readily available and at a reasonable cost, as Patterson (4) stated. Peat moss possesses some excellent properties as a medium. It has a high cation exchange capacity but due to its rising cost, presently $5.80 for a 12 cubic foot bale, many growers have turned to pine bark as a substitute.

6) *Duplicatable and in Good Supply.* One should be able to reproduce the same mix time and time again. The ingredients used must therefore be in good supply and of a uniform consistency or grade.

7) *Lightweight.* The mix should be light enough in weight so that plant size rather than weight is the limiting factor in shipping. For example, our filled 1 gallon can weighs 6 lbs. This allows us to ship approximately 6,000 one gallon plants or 36,000 lbs on a standard 40-foot semitrailer. Of course, the lighter the mix the easier it is for wind to blow the containers over; therefore, a weight between 6 and 8 lbs is ideal.

8) *Free of Weed Seed and Harmful Pathogens.* The medium should be free of weed seed and harmful soil pathogens, i.e. *Pythium*, *Phytophthora*, *Rhizoctonia*, etc. If the ingredients are not free of weed seed and pathogens, the grower must treat them in one of the following ways to eliminate these harmful factors. *Chemical fumigation* — the use of chemicals such as methyl bromide. *Steam pasteurization* — both aerated and regular; in this procedure the soil mix is heated to a high enough temperature to kill most of these harmful pathogens and weed seed. *Composting* — this is a procedure which is becoming accepted. In this procedure enough fertilizer, normally ammonium nitrate, is added to the mix to insure raising the tem-

perature of the mix to a high enough temperature for a period of six weeks to destroy harmful organisms. Leaching of the excess ammonium nitrate is required before the containers can be planted. We prefer to use a combination: gasing certain ingredients, i.e., rice hulls, with methyl bromide, and then composting the entire mix.

9) *Low in Salinity and Toxic Elements.* Soil amendments should not contribute to the overall salinity of the mix. Excess salinity, due to fertilizing, must be easily leached in order to have a good container mix. The ingredients should not contain excessive mineral elements in high enough concentrations to be injurious to plant materials.

10) *Stable Under Chemical or Steam Treatments.* Ingredients must be stable to such treatment.

11) *Handleable and Mixable.* Ingredients should be able to withstand handling by front-end loaders, soil mixers, can fillers, etc. They should also be easy to mix together and, after mixing, should not separate readily. Good mixing techniques and equipment should be used to insure a consistent growing medium and thus reduce the variables we have been discussing.

12) *Low Fertility.* Ingredients should contain little or no fertility so the grower can add the essential fertilizer elements in proper proportions. This will require the application of some elements during mixing, planting, and growing either by hand-feeding or the use of liquid fertilization. Soil tests and/or tissue tests should be made periodically during the growing season to determine which nutrient elements need replenishing and how much is needed.

13) *Stability in Storage.* Ingredients should be stable in storage and not subject to chemical changes or shrinkage or, stated another way, relatively slow to decompose. Straw and sawdust, for example, decompose much faster than pine bark (2).

There are other factors to consider outside of the container such as site preparation and water.

Site Preparation – The areas where the containers are placed should be well prepared, hard-surfaced areas to provide for adequate drainage.

WATER

It is extremely important to consider several factors about the water source just as in the selection of medium.

1) *Water Quantity.* A nursery must have an endless supply of this precious commodity. It is better not to reuse runoff water because the fertility of such water is unknown and it could spread diseases.

2) *Water Quality.* The water must also be low in salinity, free of harmful pathogens, free of weed seed, and contain no toxic elements or elements in excess. Plant injury will result if certain elements are in excess.

3) *Type of Irrigation System.* The type of irrigation system also affects decisions on the soil mix.

Overhead Sprinklers. The use of overhead rotary sprinklers or some type of overhead system is most commonly employed. However, proper spacing of the sprinklers is required to do an adequate job since sprinklers throw different amounts of water at different distances. It is advisable to have gas cocks or valves on each sprinkler for cleaning out debris during operation and to be able to cut selected sprinklers off thus making the water system more flexible.

Tube Systems. This system employes a tube running to each container. Tube systems, when installed properly, deliver an exact amount of water to each container, do not waste water, and allow the foliage to remain dry. These systems do have their drawbacks, however. They are not feasible for one gallon and smaller containers, rabbits and rodents eat the tubes, and feeder tubes are easily knocked out of the containers.

There are three things that happen to water inside a container: 1) gravitational water runs out the drain holes 2) evaporational water returns to the atmosphere and 3) transpirational water is used by the plant.

PLANTS

Plant Requirements for Water & Nutrients. Plants have varying needs for water and nutrients and more research is needed in these two areas. Yuccas do not require the same amount of water as waxleaf ligustrum. Plants should be grouped based on their water, fertility and spray requirements. This means planting charts must be prepared well in advance of planting just as one prepares propagation schedules in advance.

Raulston (5) has reported that the total leaf area appears to be more important in determining water loss than species, shape, size or foliage characteristics. Raulston further states that, in low transpiration plants, i.e. *Podocarpus*, with large medium surface exposure, twice as much water was lost by evaporation from the medium as through transpiration. In other species, i.e. *Ligustrum*, the medium surface areas were shielded from the sun and wind by the larger vegetative growth. One must conclude that plants should be grouped based on their overall size, larger plants thus requiring more watering than smaller plants. For this reason 1, 2, and 4 gallon containers should not be treated alike, but plants should be watered based on their needs. It might be necessary for growers to have 5 or more watering classifications, as we do, if they are planning to grow a wide range of plant materials.

Large plants, such as Wheeler's dwarf pittosporum, develop canopies which act like umbrellas and make it almost impossible to get water into the container with overhead irrigation. The color of the containers, amount of exposure to sunlight and spacing of the containers also affect the amount of water required. It is possible to alter temperatures by occasional overhead watering during the heat of the day, thus taking advantage of its evaporative cooling effect.

In conclusion, there are many factors and variables that must be considered in soil/air/water relationships. The key is learning to manage these variables to the grower's advantage.

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SOIL ADDITIVES FOR IMPROVEMENT OF WATER RELATIONSHIPS

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Abstract. Soil drainage influences soil color; state of oxidation of iron, manganese, nitrogen, sulfur, and other elements; soil acidity; type and activity of microorganisms, production of certain toxic substances; and soil temperature. Poor drainage of many soils has encouraged consideration of several additives for the improvement of water relationships. Gypsum ($CaSO_4 \cdot 2H_2O$) has been found to be an excellent material for use in maintaining soils in good structural condition and for reclaiming structure in soils where poor structural conditions exist.

Soil Additives: Need. Soil additives come in many different sizes, shapes and forms. For the container grower, vermiculite, perlite, humus, sand, gravel, pine bark, etc. are very much a part of his mix. For many, one or a combination of the above may constitute the entire medium. But what about field grown on their needs. It might be necessary for growers to have 5 or more watering classifications, as we do, if they are planning to grow a wide range of plant materials.

Large plants, such as Wheeler's dwarf pittosporum, develop canopies which act like umbrellas and make it almost impossible to get water into the container with overhead irrigation. The color of the containers, amount of exposure to sunlight and spacing of the containers also affect the amount of water required. It is possible to alter temperatures by occasional overhead watering during the heat of the day, thus taking advantage of its evaporative cooling effect.

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SOIL ADDITIVES FOR IMPROVEMENT OF WATER RELATIONSHIPS

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Abstract. Soil drainage influences soil color; state of oxidation of iron, manganese, nitrogen, sulfur, and other elements; soil acidity; type and activity of microorganisms, production of certain toxic substances; and soil temperature. Poor drainage of many soils has encouraged consideration of several additives for the improvement of water relationships. Gypsum ($CaSO_4 \cdot 2H_2O$) has been found to be an excellent material for use in maintaining soils in good structural condition and for reclaiming structure in soils where poor structural conditions exist.

Soil Additives: Need. Soil additives come in many different sizes, shapes and forms. For the container grower, vermiculite, perlite, humus, sand, gravel, pine bark, etc. are very much a part of his mix. For many, one or a combination of the above may constitute the entire medium. But what about field grown stock? The above additives will quickly become too expensive for large acreage application.

Under field conditions, soil additives are usually needed to correct soil drainage problems. Soil drainage may be a cause or an effect of chemical, physical and biological properties of soils (3,13).

Precipitation varies considerably from place to place, but the total volume is no guide to the actual amount entering the soil. This is determined by intensity of precipitation, vegetative cover, infiltration, permeability, and slope or relief. Of these factors, infiltration, permeability, and slope or relief are inherent with the soil. If, for example, soil parent material is uniform on a slope, it is possible to find a sequence of soil sites with progressively deteriorating drainage conditions (3,7,8).

Infiltration and permeability may be a function of clay type, percentage of clay, and the percentage and type of cations absorbed on the clay colloids. A soil which contains absorbed sodium, generally in excess of 10% - 20% of the total cations, will have poor structure. Martin, et al. (11) suggest that sodium may be responsible for poor structure when it is present even in very low amounts. The detrimental effect of sodium is due to its high dispersing effect on soil colloids. Some detrimental effects of dispersion include: swelling, reduction in pore space, and increase hydration leading to reduced water infiltration and imbalanced nutrition of plants and soil micro-flora (12).

Soil color is one of the most obvious and easily determined soil properties. It has little direct influence on the functions of the soil, yet one may frequently estimate the degree of natural drainage from this characteristic. The state of oxidation of iron compounds, which is related to soil drainage, largely determines soil color in soils with low organic matter content. Red colors indicate good drainage and are usually due to oxidized and dehydrated iron oxides.

Yellow colors of soils are generally dominant when iron oxides become hydrated. However, if organic matter content is present in sufficient quantity to subdue red or yellow colors, soils with a brownish cast may result.

Gray colors usually occur in soils that are permanently water saturated unless artificially drained. Under these conditions iron is in the ferrous form.

Now that the effects of soil drainage have been established, are additives available that will improve soil water relationships? Many "soil conditioners" are on the market. Some work to a limited degree and some fail to produce any effect.

Gypsum as a Soil Additive. Gypsum is a mineral found in abundant quantities in the earth's crust. Chemically, gypsum

($CaSO_4 \cdot 2H_2O$) is calcium sulfate combined with two molecules of water. It occurs as a sedimentary rock, interbedded in most places with shale, limestone, or dolomite. It is soft and crystalline, with color varying from white to shades of pink, gray, yellow, or brown (3,12).

Gypsum can play a significant role as a clay soil conditioner. In this role, gypsum is used to flocculate the clay colloids. The effectiveness of gypsum is greatest when soil pH is optimum for plant growth.

Arizona Extension Service Bulletin 200 (1), states of gypsum, "this soil corrective is used as a major corrective for poor structural conditions in soils regardless of whether alkali or other causes are responsible. It aggregates or builds the fine soil particles into crumbs. In brief, gypsum is an excellent material both for maintaining soils in good structural condition and for reclaiming structure in soils where poor structural conditions exist."

The cation-exchange capacity (expressed in meq/100g) (7) is known to vary according to clay type, percent clay, and percent organic matter of the soil. Since flocculation is electrokinetic in nature, structural improvement of a soil is greatly influenced by the nature and proportions of cations in the soil.

When gypsum is applied to a soil containing a high concentration of sodium ions, the monovalent sodium ions are replaced by the divalent calcium ions. This results in a considerable reduction in dispersion and swelling due to flocculation of the soil colloids. The flocculation action of gypsum is the first step toward the formation of aggregates and good soil structure. Floccules are stable only as long as either the flocculating agent is present or the floccules are transformed into stable aggregates (2,3,12).

Several factors influence aggregate stability. There is the temporary mechanical binding action of microorganisms, fungi with their mycelia being especially effective. Intermediate products of microbial synthesis and decay, such as microbially produced gums and certain polysaccharides are important as cementing agents. However, most of the long term aggregate stability is by the cementing action of the more resistant stable humus components. Inorganic soil colloids, notably iron oxides, also contribute toward the formation of stable aggregates (2,11).

Marshall (10) states, "gypsum does not need the presence, or absence, of organic material; and, in the correct concentration, will form water-stable crumbs of between 1 mm and 4 mm in diameter, depending on the clay content of the soil. The higher the clay content, the larger the crumbs. In use, however, it must be mixed with the top 2-3 inches of soil and not just scattered on the surface."

CONCLUSION

We have seen that gypsum is effective in the improvement of physico-chemical conditions of soils. However, gypsum will be of little or no value if there is a hard, thick impermeable clay pan, silt layer, or massive rock layer at an appreciable depth below the surface layer causing the poor drainage condition. In such cases, the favorable effect of gypsum may be evidenced where the hard pan or rock layer has been broken mechanically prior to the application of gypsum. Examination of the soil profile characteristics provides the basis for determining the use of gypsum on a particular soil.

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TEMPERATURE MANIPULATION USING WATER

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Temperature manipulation using water is a major concern of our nursery operation. We are located on the Eastern shore of Maryland and subject to frosts as early as the first part of October.

To explain why temperature manipulation using water is so important to us. I would mention that about 8 years ago we shifted our complete growing operation into wholesale production of broad-leaved evergreens. Our goal was to produce a full, dense, premium quality plant for the discriminating garden center and landscape contractor in the Northeastern United States.

We propagate practically all of our plants and grow them over the first winter in heated fiberglass houses. The transplants are lined out in raised beds the following spring, grown on for two or three years, then dug by hand and shipped in fiber containers.

These plants are vulnerable to frost and freeze damage, particularly the one year old plants. Distressed at severe damage from early fall frosts in 1968, we decided to experiment with water as a method for the prevention of frost and freeze damage.

Over the past 7 years we have developed a system of frost protection using our solid-set irrigation. Although we do not consider it 100% foolproof, we do consider it a vital and necessary part of our operation.

It is the best insurance we have against the extreme hazard of catastrophic damage by early fall and late spring frost or freeze.

For years we have used shade lath over the plant beds, and it offers some protection by holding in the ground heat and moderating the temperature fluctuation. Other nurseries use protective coverings of cloth or burlap. Several nurseries in our area store their finished plants in wooded areas.

All of these measures are helpful, but it is impossible for us to have a protective covering over 500,000 plants when a 25°F temperature and a frost comes as early as October 3rd.

This is made possible due to the release of heat when water turns to ice. As we irrigate, ice forms and heat is given off, some to the plants, some to the ground, and some to the air. Thus the temperature under the ice stays at 32°.

The watering must be continued until the air temperature rises enough to melt the ice completely off the plants. This necessitates a dependable supply of water. We pump from an 11 acre pond.

We have kept soft plants from stem-splitting during extremely heavy freezes, but it requires a lot of water and a heavy build-up of ice. Most of the azaleas and *Ilex* which we grow can withstand a fairly heavy ice load. Some more limber plants such as *Pieris*, *Rhododendron*, and *Ligustrum* sustain more breakdage due to the ice load.

Our solid-set irrigation system consists of 1-1/2" PVC pipe lateral lines with No. 20 TNT Rainbird Sprinklers spaced 40' × 40' offset. We use a small nozzle, 7/64", and try to maintain 40 lbs P.S.I. pressure. These sprinklers apply about 2.2 g.p.m., or about 0.13 inches of water per hour. The sprinklers should rotate 360° at least once per minute.

Our soil is a Matapeake loam with a slow absorption rate. It is often necessary to run the system for 8-10 hours or more which results in too much surface water. This is a distinct disadvantage if you need to get into the block for shipping purposes or other operations.

At any time when there is a chance of a frost or freeze, fall or spring, we have a 2-man team on "Frost Watch". Thermometers are in place at plant level. Temperatures are checked hourly. When the temperature drops to 33°F we turn the system on. During a time when the chance of frost is slight (cloudy or windy) I usually check the top of a vehicle out in the open. A glaze of frost will form there very quickly if frost is imminent.

The "Frost Watch" team checks regularly for any pressure drops indicating leaks or ruptures in the irrigation system. Also, they make sure sprinklers are kicking around. I repeat, the water is not turned off until the ice is completely melted.

Even though we have used this method of temperature manipulation for several seasons, I feel there is much we do not know about frost and freeze control. One example is, "When are the plants hardy enough to withstand a frost or freeze without protection? Is fall foliage color a good indication?" Also, "When unusually warm weather in late November occurs, is the plant, which had become hardy, again subject to frost or freeze damage?"

So far I have dealt entirely with temperature manipulation at the freezing or near freezing levels. There is, of course, a desirable manipulation of temperature by water when the air temperatures reaches high levels near or above the 90°F mark. During May or June, when these temperatures occur, we turn the water on tender transplants for 5-15 minutes. This can prevent sun scorch and is very beneficial to newly planted material. Temperature manipulation in our propagation houses is done by means of an intermittent mist system.

The use of water to manipulate temperatures is indeed a useful and necessary part of growing broad leaved evergreens.

JOHN MACHEN: Jim Fountain, on this chiseling-in process, how thoroughly does the gypsum have to be plowed in? Also, would you tell us how this reacts with soil that has very fine sand particles in it that tend to compact and therefore does not drain well? You dealt mainly with clay soils. What about sandy soils?

JIM FOUNTAIN: Chiseling is done to make sure that if a plow-pan is present it is broken up. It is not done to get the gypsum down. Harrowing would be as good as turning the soil and probably better. Gypsum is a clay soil conditioner; it does not affect sand because sand has virtually a 0 CEC rating.

JAKE TINGA: I have a pin oak that I'm putting in a clay in a 2 × 2 × 1 foot hole and I'm going to put some plant food pills down in the bottom of it. Would you recommend I put 3 or 4 cups of gypsum in the bottom of the hole too?

JIM FOUNTAIN: No, not in the bottom of the hole. Spread it around on the surface uniformly and water it in. You want the clay to break up all the way from the top to the bottom.

JAKE TINGA: But the poor drainage is in the bottom of the whole.

JIM FOUNTAIN: Well, put it in the bottom then.

JOHN ROLLER: In a loose soil with a 4.5 pH, can gypsum furnish calcium to the plants?

JIM FOUNTAIN: Yes, and this also holds true for Florida sandy soils.

DICK AMMON: We have a clay loam soil and the way I understand it, our soil is like toothpaste and this gypsum is going to make it like popcorn? How often and about what rates should we apply gypsum and should it be plowed under or disked in the top and can we surface broadcast it in shade tree rows?

JIM FOUNTAIN: I tried to point out that gypsum is not a "cure-all." No, we're not going to make popcorn out of your toothpaste, but we can improve your soil structure. The normal rate is from 2-5 tons per acre. Gypsum does alter soil pH to some degree. For every ton you apply the pH will drop by 0.1 pH unit. Frequency depends on rainfall patterns; the more rain, the sooner it leaches out of the soil profile. We recommend early fall and a late spring application. Even though gypsum is water soluble, for best results it should be incorporated to prevent surface runoff from carrying it off. We have found that if 5 lbs/yd^3 gypsum is mixed with sterile potting soil it will help in suppressing *Pythium* attacks at times when the soil might be overwatered, as for instance in freeze protection. We have also found that when you use gypsum in azaleas and camellias, you get a better growth in the spring.

DICK AMMON: When gypsum leaches down does the soil become like it was?

JIM FOUNTAIN: Yes. Organic matter helps to overcome the leaching, though.

JUDD GERMANY: Dick Marshall, you were talking about near freezing temperatures. Have you successfully used water protection in really cold weather, say 10°F and below?

DICK MARSHALL: No, we have not. We feel from all the information we have, though, that this would not work at such low temperatures; 22°F should be about as low as this will work.

JOHN ROLLER: Dick, is this technique effective under low humidity and high winds at 24-30°F temperatures?

DICK MARSHALL: Yes, in that range we certainly can get protection with this system. Even water distribution is harder in a wind, though, and this is essential for good protection. I might point out that we are talking about plants in the field; container growing is a different proposition.

CHARLIE PARKERSON: Gerald, you mentioned root growth in relation to top growth. We can stimulate top growth by pruning at the right time of year. Is what you say based on research?

GERALD SMITH: No, this is not based on any research to my knowledge at all. I've knocked thousands of plants out and root growth is one of the things I was interested in. If that root system is "sitting still", I just don't see any top growth occurring. Does anybody disagree with me on that?

BRYSON JAMES: Gerald, not in containers, but certainly in field grown stock we quite often see top growth start in early spring before there is much root activity — and likewise, you get root activity in the fall for much longer than you get top growth — this may be different from what you are talking about, but it is something to consider. I follow what you are saying although I'm not sure of the relationship between field conditions and containers. I believe you could get air temperatures permissive of top growth before the soil warms up enough to promote root growth.

GERALD SMITH: Roots begin growth about 10°F cooler than the shoots, generally.

BRYSON JAMES: Yes, but the air warms up very rapidly in spring compared to the soil.

CHARLIE PARKERSON: Our plants seem to make better roots in the fall and growth begins in spring with the roots already to the bottoms of the containers. By August we're losing roots.

BOB WRIGHT: If you come back next year we may have the answer to this. We are investigating root growth of hollies and rotundifolia hollies which grow in flushes and we want to see if root growth is related to shoot flushing. Early indications point to root growth followed by shoot growth.

LANNY NEEL: Dick Marshall, you asked a question as to how you can tell if a plant is winter hardy. In experiments, the last several inches of stem sections were frozen at lower and lower temperatures, then thawed. Electrodes hooked up to the stems to measure electrical resistance across the stem can detect when the cells rupture (due to freezing) which allows the cell sap to escape into the woody tissues of the stem. One can be precise with this method and can use it to accurately predict winter hardiness. This would become even more useful if records and observations were kept over several years.

GERALD SMITH: Ed Brown, would you tell us whether your results in Florida have been similar to Dick's?

ED BROWN: The only real experience we ever had was on December 13, 1962, when the temperature dropped about 50°F in about 45 minutes around noon. We decided to turn on the sprinklers that night when the temperatures got down to 34°F and we left them on all night and straight through the second day and night. We did not melt the ice off the plants, but we did turn the water off when the temperatures got up to about 38° and warmer weather was predicted. A neighbor of ours used Rainbird #20 sprinklers on his groves and they froze because not enough water was put out fast enough. We have #40 heads and we had no damage.

DICK MARSHALL: We have a neighbor who used to grow about 40,000 outdoor azaleas about three years ago. He turned on his irrigation system about 3 AM to try to protect against a frost and by 6:30 he ran out of water in his small supply pond. He lost all of his plants. That same day we ran ours until the ice was completely melted off and we had no damage.

ED BROWN: I would say that the reason why his plants froze was because the temperatures were still below freezing when his water ran out and not because he did not wash the ice off. You should turn the water on and off when the temperature reaches 36°F because of the chill factor.

GRADY WADSWORTH: There's an excellent publication available about frost protection put out by the University of Washington in 1974, and it says to leave the water on until ice stops forming and free water is on the surface of the ice, or else freeze injury can occur.

DICK STADTHERR: As far as electrical conductivity tests go, I've conducted quite a lot of them and I would like to caution you that there is quite a bit of difference between cultivars. We tested roses and found as much as 10° difference between cultivars. The University of Minnesota is doing quite a bit of work on the onset of hardiness and I think there are some newer tests out than the electrical resistance method.

ROBERT WRIGHT: Measuring electrical conductivity requires special instruments which a nurseryman might not have. On the other hand, you can determine when the tissue is damaged by freezing; you can take leaves and put them in distilled water and shake them. If there has been injury the soluble salts will escape from the damaged cells and cause the conductivity of the water to increase markedly.

HUNTER BOULO: Robert, what kind of reading would you expect on the solubridge to know if you had damage?

ROBERT WRIGHT: This is a relative thing; you'd have to compare uninjured leaf wash water to injured leaf wash water to determine this. We hope to have a paper out soon in *HortScience* on the effect of the nutritional status of the plant and freeze damage.

CHARLIE PARKERSON: Charlie Johnson, water is getting more and more scarce and we're hearing about salt water intrusion. I feel that we've got to conserve every drop of water we can and recycle it. How do you feel about the use of persistent insecticides and herbicides which might accumulate in the water?

CHARLES JOHNSON: Changing pesticide use patterns and the installation of filters can reduce the hazard.

JAKE TINGA: Grady, what do you do in Texas when the wind blows the water away?

GRADY WADSWORTH: We block plants adjacent and make wider beds and use portable sprinkler heads strategically located on corners.

PHIL BEAUMONT: Grady, I heard you say you used lime to solidify mushy areas under your plastic. How did you do that?

GRADY WADSWORTH: We got this from the Texas Highway Department. We lime stabilize the ground with 10 lbs of commercial powdered lime per square yard. Check with your state road department; they'll know more about stabilizing land than anyone else.

GERALD SMITH: Has anyone had any experience with irrometers?

CHARLIE PARKERSON: I was reading what Mr. Flemmer at Princeton nursery had said. He puts them around selected indicator plant material and calibrates them that way. Mr. Hill of the D. Hill Nursery had tried them in 1952 and he didn't like them at all. Fred has used the bake-o-lite blocks on field stock and had very good results with them.

EARL ROBINSON: Were you referring to these electronic probes? I've had experience with a hand probe in New Jersey where I've stuck it in a glass of pure water and it read about 10% wet. After putting some table salt in the water it read 100% wet. Apparently it is based on conductivity and you might have to use relative comparisons under similar watering procedures to get any value from them.

BOB WRIGHT: Tensiometers and blocks were developed for use in field soils. The large pore spaces of container media interfere with their proper function.

BRYSON JAMES: Jake Tinga suggested a long time ago, and Charlie mentioned it again, use an indicator plant. A bean is a good one; it wilts quickly and can be easily removed.

QUESTION BOX

Bryson L. James, Moderator

1. What effect does the use of systemics have on the rooting of cuttings? — (systemic insecticides, fungicides)

CHARLIE PARKERSON: We use Meta Systox-R and Benlate with success on Japanese holly and Junipers.

BRYSON JAMES: As far as effects on rooting of cuttings, has anyone experience with this? I know that work done at N.C. State a number of years ago showed no effect of materials sprayed on the foliage on rooting of cuttings; I've done some work on this and had similar results.

VOICE: Does this hold true with Benlate and Truban used on soils to prevent fungus diseases? I've heard some greenhouse operators say that these will affect rooting when used in soils.

BOB WRIGHT: With herbicides, we found no effect on cuttings unless the stock plants were damaged.

MIKE McCALL: We use Banrot on all our cuttings and don't see any bad effects from it.

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2. Describe the best method to root *Nandina domestica* 'purpurea' (dwarf).

RICHARD TAYLOR: We've rooted winter (February) cuttings similar to juniper cuttings very easily.

ED KENZIE (Knoxville): We root it about any time of the year if we can get the new growth (clean soft wood); treat with a light hormone and root in a flat of peat and perlite. We wash our cuttings in a Captan-Benlate mix (July & September) and put them under intermittent mist with no bottom heat. We wound it slightly but don't strip the leaves back any.

3. How important is the pH of the medium for rooting cuttings? Does anyone know the pH of their medium?

WYLIE ROACH: I use composted oak bark with a pH of 7.25 for propagation; we add a little sulfur to bring it down to 6.5.

BILL COLBURN: I'd be careful with that sulfur if I were you; it will burn if it's not well aged. We use peat, sand and cypress sawdust with a pH of about 6.0.

VOICE: Aren't we trying to get all our plants to put roots on as they grow? Wouldn't it make sense to root plants in the same compost in which you want them to grow?

VOICE: All I want to do is get roots on the cuttings. We've tried all kinds of media and we've come back to a basic mixture of German peat and perlite 1:1, v:v.

VOICE: John, we've rooted azalea cuttings in sand at pH 7 and as long as you move them as soon as they're ready, I believe you can root cuttings in many different kinds of media. We use 50% Canadian peat; 25% sand and 25% perlite for all our cuttings.

BRYSON JAMES: This agrees with other research I've read; as long as you move the cuttings soon after they're rooted, pH is of little consequence.

LANNY NEEL: pH is a primary factor in regulating ion availability in the soil, and if there are no rootings, then ion uptake is non-selective and occurs through the cut end of the stem. The cutting basically relies upon nutrient reserves it contains when it is taken from the plant.

4. What are some effective ways of protecting canned stock from freezes below 15°F?

CHARLIE PARKERSON: We're using 7½ oz burlap put over the top of our plants. We think that wind dessication plays a large role in freeze damage and we want to protect the tops of the plants. We make it up in 20 × 50 foot strips and treat the outside edges with copper naphthenate. We jam the plants and we cover a couple hundred thousand 1-gallon containers in a day. Rain goes through it and we've had 8 inches of snow on it. It lasts at least 6 or 7 years. We take it off the latter part of March. We store it dry but it is very flammable.

VOICE: We jam our containers into plastic quonset huts to try to prevent wind dessication in central Oklahoma. The temperature inside is not much different than outside; we average around a 17 mph wind and can get down to around 0°F at mid-winter.

VOICE: We cover our field-grown azaleas with 50% saran. It's not how cold it gets, but it's how quick it gets cold and how quick it thaws. Quick temperature changes are bad for our plants.

LANNY NEEL: In mid-winter the low sun angle allows vertical container surfaces and tree trunks to warm up rapidly, which may be a factor in winter kill of such exposed surfaces.

VOICE: We don't want the early morning sun to hit our plants and raise them from 15° to 34°F in an hour or so, so we place our saran to shade our plants from the early morning sun.

DICK MARSHALL: Does anyone have an opinion on what height the shade material should be above the plants?

BILL CURTIS: At the Chicago meeting a speaker stated that the heat comes from the ground and the lower the roof the more heat would be trapped within.

BILL COLBURN: We recently started raising foliage plants in Central Florida and we have to build houses in the winter, too. At a nearby nursery they built their houses 20-25 feet high and they maintain that this keeps the heat in. They are in a cold area and I know they have gotten outside temperatures in the 20's, but they have never yet had to heat their houses.

VOICE: When you are building a greenhouse and determining the heating requirements, you measure the outside surface area; the more surface exposed to the weather, the more heat you have to have.

5. What effect might the water content of a plant have in protecting it from below freezing temperatures? If a plant is wet before the cold comes, does that coating of ice do more good than if it's dry beforehand?

DICK MARSHALL: I don't know if there's a significant difference, because we haven't ever let our plants get very dry in the fall; I'm not aware that this would make any difference.

BOB WRIGHT: Recently we put some azaleas in some dessicator chambers at various humidities and let them equilibrate before subjecting them to cold and, to a certain extent, reducing the moisture content of the plant resulted in reducing freezing points for the plant tissues and thus imparted some protection. One of the major causes of freeze injury comes from the fact that the roots freeze and cannot supply the shoots with moisture when they thaw and lose water.

DICK STADTHERR: Most roots do not have the ability to harden like shoots and if they freeze, damage occurs. Sawdust and jamming help to conserve heat around the roots.

6. What effect does watering plants before a hard freeze (15°F) have on preventing root damage, and how long can a saturated root ball resist damage? Do you water before the temperature drops below freezing, not water at all, or turn on the water after the freeze?

JIM MERCHANT: If you turn the water on before the freeze you will insulate the plant from damage.

DICK MARSHALL: We do not use irrigation for cold protection in mid-winter, but only in the fall and spring, our plants are hardy by mid-winter. You ask if we would turn the water on after the temperature got to 15°F. If we waited until then, the water in our risers would be frozen solid and we would have to thaw them out individually. We grow no container stock, only field grown material.

7. What good preservative is safe to use on wood for planter boxes or around plants?

VOICE: Wolmanized wood or copper naphthenate. PCP is volatile and will cause damage.

VOICE: We've had damage to cuttings in a propagating structure from wolmanized wood, but not to rooted cuttings.

8. How do you measure Cation Exchange Capacity (C.E.C.)?

BRYSON JAMES: You saturate the soil with a given cation and then you use a different cation to replace the first and measure the amount of the second ion taken up.

LANNY NEEL: Work done in Forida on C.E.C. with peat and sand showed that a 50/50 mix of sand and peat had as much C.E.C. per 6 inch pot as did a pot of pure peat because the peat was so light relative to the peat-sand mix. C.E.C. is traditionally measured in terms of millequivalents per 100 grams, and 100 grams of dry peat occupies a much larger volume than does a 50:50 mix of peat and sand.

9. Is anyone using filtration to eliminate weed seeds?

VOICE: Rainbird water filters are used for filtering trickle irrigation water; that will take weed seeds out.

10. Is there a cheap way of filtering pond water to get herbicides or insecticides out?

VOICE: Activated charcoal is about the only way.

CHARLIE PARKERSON: We're more concerned about distributing pathogens than chemicals.

BRYSON JAMES: The dilution factor in a reasonable sized pond ought to take care of most materials; clays on the bottom absorb a lot of material too.

CHARLIE PARKERSON: If you are worried about a hazardous material, don't use it. The EPA is going to take away long residual materials so we won't have to worry about that aspect soon.

11. In research results distributed by Dr. Self, it was stated that Banrot at 4 to 6 oz/yd^3 has stimulated azalea growth, presumably by suppressing *Rhizoctonia*. Does anyone have any comments on this?

BOB LAMBE: Banrot will suppress *Rhizoctonia*, *Pythium* and *Phytophthora* at the registered rate of 8 oz/100 gallons. There is a difference between the methyl-carbamate in Banrot and Benlate, even though they have similar activity. We have found the former to cause some toxicity in poinsettias, so I don't think you can interchange Banrot with a mixture of Benlate and Truban or Dexon; you will have to be more careful with Banrot. I myself have not observed any phytotoxicity with Banrot in azaleas.

VOICE: Then you would recommend a mixture containing Benlate over Banrot?

DR. LAMBE: Yes, I would, although it is going to require *very* thorough mixing to incorporate a wettable powder with a soil mix.

BRYSON JAMES: Bob, do Truban and other related soil drenches actually kill soil-borne fungi or do they just contain them temporarily?

DR. LAMBE: Truban is more active than Dexon. Both are suggested as a protectant. The main advantage of Truban over Dexon is that Truban will persist longer in the soil, with the minimum recommended time between Truban applications being 4 weeks, compared to every 10-14 days for Dexon. Neither is much of a systemic. Although Truban has a longer residual life in the soil, and it can cause more phytotoxicity problems than Dexon because of this longer life, neither will eradicate the fungi; they protect the plants.

12. Are there nurserymen propagating plants in greenhouses where humidity is maintained around the plants with fog nozzles? If so, what are the pros and cons of this method?

CHARLIE PARKERSON: We ran an experiment with Dan Milbocker using two fog generators in a house on 30,000 azaleas (it's in the Plant Propagator's Proceedings). Our problem came with heat; our fans would come on and blow out the humidity. We tried some cuttings during the late winter and had the humidity high during the day, but at night we were using a dry heat, and we didn't get any rooting. Sidney Meadows uses a moist heat at night and that's what makes him successful at this. Misting plants leaches nutrients out of them; fogging doesn't. If a way could be found to keep the heat down in the warmer parts of the year, fogging would be the best way.

JOHN MACHEN: We tried a compressed air nozzle and water to make a fog. We got fantastic results with Japanese maple in May; however, in June we couldn't keep the temperature down and we lost the next crop.

13. When do you collect seeds from Live oaks? When do you sow them? And how do you stratify them?

VOICE: The best time is when the acorns fall; plant them immediately. Live oaks don't need a stratification period.

14. Has anyone eliminated peat moss altogether from their regular potting mix?

BRYSON JAMES: Most people have gotten away from peat.

VOICES (consensus): Most people have been using pine bark or composted hardwood bark, although some growers around Mobile, Alabama, are still using some peat.

BILL CURTIS: When fir bark dries out you have a difficult time wetting it.

BRYSON JAMES: The same thing happens with peat. Three parts pine bark and one part sand is an excellent mix.

15. A question was raised about plants on the job which were grown in very porous mixture. Discussion revealed that peat in the medium was helpful in keeping some water holding capacity around the roots, but that the most important thing was to water the root ball itself every day until the plant was established in the surrounding soil. Comment: We've got to remember the ultimate consumer of our product and try to give the consumer a product which will survive and grow on the job.

DICK AMMON: We grow the plant from a cutting all the way through to the landscape plant on the job, and we use composted hardwood bark and sand. We've never had any problems with this except with *Ilex* when it becomes rootbound. If we tear the roots apart we can get around this somewhat. We don't just dig a hole and stuff the plant in it; we prepare the site carefully. The big secret is not to let the plants get rootbound.

BILL CURTIS: We use 1/3 each of peat, bark and sand; I'm going to raise the price rather than cut back on peat. How do you feed your plants, Dick Ammon?

DICK AMMON: We use a granular fertilizer with our bark mix which contains a slow release form of N, and have had good results. We like to compost our oak bark mix for at least 6 months; we take soluble salt readings on it before we use it and if salts are high we leach it further.

CHARLIE PARKERSON: A good compost mix contains many different fungi; we have heard about mycorrhizae from previous speakers and I believe that this will be the next wave of the future. We will be adding fungal cultures to our soil mixes to help our plants get established and grow better.

TECHNICAL SESSIONS
Tuesday, November 29, 1977

The second annual meeting of the Southern Region of the International Plant Propagators' Society convened at the Angus Restaurant Tuesday morning, November 29, 1977. The meeting was opened by President Charlie Parkerson, who introduced the Tennessee Commissioner of Agriculture, Edward S. Porter.

COMMISSIONER PORTER: We are pleased that the Society *is meeting in Tennessee and want to welcome you to our state.* Agriculture is the number one industry in Tennessee; nationwide, we rank 25th as far as agricultural production is concerned. Agricultural exports are becoming increasingly important in our state. We are among the top 10 states in production of tobacco, soybeans and cotton. The nursery industry also plays a very important role in our agricultural production. The sale of nursery products provides the fifth largest cash crop in our state and we are proud to be a part of this important industry. Enjoy your stay here!

FIELD SEEDLING PRODUCTION OF *CORNUS FLORIDA*

DON SHADOW
Shadow Nursery, Inc.
Winchester, Tennessee 37398

Seedling propagation of *Cornus florida* is essential to our total dogwood production, and I will give the procedure we use in the field propagation method.

The seeds are gathered from local native stands by collectors and brought to our nursery, where they are purchased by the pound. They are then placed in 55-gallon barrels to soak for several days prior to cleaning with a mechanical seed cleaner. The most effective method for determining whether the berries are well ripened is to press them between the thumb and forefinger; if the seeds press out freely, they are ready to be picked.

After the berries are cleaned, the seeds are air dried on burlap for several days, depending upon weather conditions, and then hung in lots of 25 pounds until ready for planting or storing. We find this is a convenient amount to handle easily.

During the months of October and November, when weather permits, the seeds are planted in the open field in 54 inch rows which have been ridged up to 6 to 8 inches, with a V-shaped furrow about 2 inches deep pressed into it. After this is done, an application of 20 to 25 pounds of 6-12-12 fertilizer is applied to the furrow. The seeds are then covered with well-decayed hardwood sawdust, which is available in our area.

Germination usually begins between April 1 and 15, depending on weather conditions. This is the most critical time in the life of the germinated dogwood seed. It has been our experience that the embryo is lost if water puddles over it more than 24 hours. We ordinarily do not irrigate during germination unless conditions are extremely dry and topsoil begins blowing. Blowing soil damages seedlings.

Another method that has been used successfully in the past is the stratification of the seed by January 15 in equal parts of sand and sawdust. The seeds are mixed into this mixture and stored in steel barrels at 40°F for 60 to 75 days. The seeds are then removed by use of a 1/4 inch screen before germination begins. The seeds not used in the year of collection are stored in clean lardstands, sealed with heavy tape and placed in cold storage at 34 to 36°F, which insures seed for the next year in case of seed failure due to natural causes. Seeds can be stored up to 3 years without appreciable decrease in germination.

The tiny seedlings are then cultivated, sprayed, fertilized and hoed if necessary, according to good cultural practices. We apply Enide 50w after weeds have germinated. Paraquat can be used over the entire area prior to seed germination. Kerb and Princep, in combination, can also be used.

Seedlings that come up in the spring can be budded in early August.

PROPAGATION OF DOGWOOD SEEDLINGS IN CONTAINERS

HENRY H. CHASE, JR.

Chase Nursery
Huntsville, Alabama

Recently we have experimented with growing dogwood seedlings in small tube containers, hoping to improve the percentage of livability by taking the seedling to the field in its own pot. Two types of container-trays were used. One is heavy black plastic with 101 round cavities 1/2 inch by 4 inches, with 4 holes in the bottom of each cavity. The same type is currently being made with ridges to prevent roots from spiraling, as was the case in our smooth round tubes. The second type tray is made of styrofoam and has square cavities with one hole in the bottom of each cavity.

The mix was 2/3 finely ground pine bark and 1/3 sand, fumigated prior to filling the containers. Flats were filled by hand and shaken down to get an even compaction of the mix.

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The mix was 2/3 finely ground pine bark and 1/3 sand, fumigated prior to filling the containers. Flats were filled by hand and shaken down to get an even compaction of the mix.

Three cleaned seeds were sown in each cavity about November 1. The container-trays were then placed on raised benches in open plastic houses. The house was left uncovered to provide cold stratification, then covered about March 1 as seedlings started to germinate. This prevented damage to the newly germinated seedlings from a late spring frost.

Fertilization with Peters' 20-10-10 at 150 ppm was started when the seedlings were 8 inches tall and continued every 10 days to 2 weeks during the growing season. Some of the seedlings were 18 inches tall when planted in the field in September. The same planting procedure was used as with our bare root seedlings.

Containerized seedlings had less than 50% live compared to 70 to 80% live of bare root seedlings. The most startling thing, however, was the growth following budding; the maximum size of the budded containerized seedlings was not as large nor was it as heavily rooted as the bare root seedlings.

What conclusions can be drawn from this experiment? First results were poor, but changes that should improve quality and percent of livability will be tried next year. One of the problems was that the plant was in the container entirely too long. As soon as there are enough roots to hold the ball together, seedlings should go immediately to the field. Roots never broke out of the original tight spiralled small ball. No attempt was made in the field to break open the ball during transplanting. We believe this practice would help.

In the field, transplanted containerized seedlings were very dry in the root ball, even after heavy rain. Next year we plan to add clay to the mix, making it more compatible with the soil where the transplant will be growing.

Another point is that the plants growing in test tube containers are not easy to water. A traveling boom watering system would be essential for large scale production.

A good source of additional information is: Tinus, Richard W., William T. Stein and William E. Balmer, Eds. *1974 Proceedings of the North American Containerized Forest Tree Seedling Symposium*. Great Plains Agricultural Council, Pub. 68. Lincoln, Neb.

FIELD BUDDING OF DOGWOOD

HUBERT NICHOLSON
Commercial Nursery Co. Inc.
Decherd, Tennessee 37324

Normally, field budding of dogwoods begins with us between August 1st and 15th, depending upon the seedlings' development. If transplanted seedlings are used, budding can be started earlier. We have found that thinning of seedlings to a stand of 10 to 12 to the foot is desirable. If this thinning is done early in the growing season, it speeds up the date budding can begin and gives a larger caliper seedling for budding. We have found early thinning of the seedling row without field irrigation is risky. As 90% or more of our dogwood are budded on field-grown seedlings, we will limit ourselves to budding on this type of seedling for now.

Under the best of conditions field budding of dogwood is done on very tender seedlings, and it is very important to have budwood in a similar condition. For these small tender seedlings we want small tender budwood but firm enough to push into the seedling. A lot of skill and dexterity is required to handle these tender buds and tender seedlings. The first operation performed on the seedlings is what we call "scratching". This scratching removes the lower 4 to 6 leaves and any grit or dirt on the seedling, any small side limbs, any seedlings too small to bud, and any gravel, loose dirt or other debris in the seedling row, just to clean the row for the budder. This operation we normally perform right in front of the budder; but sometimes it may be done a week or more in advance, if plenty of moisture is present. In hot dry weather we never let the scratcher get more than a half day's budding ahead of the budders.

The budwood is normally gathered a day in advance, pruned, wrapped and allowed to stand in one inch of water overnight. Occasionally we may refrigerate budwood at 40 to 45°F a few days.

The budder cuts a shield bud about 1/2 inch to 3/4 inch long by making a slanting cut under the bud and a cross cut above the bud only through the bark, so that when the bud is snapped off the budstick, the wood from the underside of the bud will remain on the budstick and not be inserted into the seedling. If a little bit of very soft wood does stick to the bud, we leave it there as the bud can easily be bruised trying to pry out this small piece of wood. If too much wood is coming off under the buds, we look to the way the budder is cutting his budsticks or to the hardness of the budstick. These budsticks have been previously prepared for the budder, wrapped in burlap and plastic, and carried around his waist. A vertical cut about 1 inch long is made on the seedling, preferably on the southwest side. We bud on the prevailing wind side as we feel some pressure from the wind will help make the bud grow up rather than out from the seedling. A cross cut is made at the top of the vertical cut with a rotating motion of the knife blade, which opens up the vertical slit. The bud is then removed from the budstick and inserted under the bark of the "T" slit and pushed down until the slit is opened a little deeper by the tip of the bud. This assures a tight fit on the nose of the bud. The bud is placed as low on the seedling as practical, usually about 2 inches above the ground.

The wrapper is immediately behind the budder no more than a few minutes. If there is too much time between budding and wrapping, the bud will curl and the lip will open. The bud is wrapped tightly into the vertical slit using rubber bands (4" × 1/4" × 10 gauge). The wrapper starts his wrap below the eye of the bud, makes at least 2 turns below the eye, leaves the pruned leaf stem of the bud exposed, makes about 3 or 4 turns above the eye, and ties the rubber strip on the last round of wrap. The rubber wrap is being stretched as it is placed on the seedling, which makes for a tight connection between the bud and seedling. Rubber wraps have replaced raffia which is hard to prepare and had to be cut off the seedlings about 2 weeks after budding to prevent girdling. The rubber wraps will expand as the seedling grows, and normal deterioration will remove them in about 4 weeks.

We normally bud dogwood through the month of September. The seedlings are more succulent and bud better in September than in August. We do not cultivate the seedlings any more after they are budded. It is very profitable to use irrigation when no rain has fallen.

Usually in December, after the plants are thoroughly dormant, these budded seedlings are root pruned to induce the development of a fibrous root system. A flat blade is run under the row about 8 inches deep, disturbing the plants as little as possible. For weed control over winter and into the following spring we have satisfactorily used Kerb and Princep.

The following spring (around Arpil 1st) before bud growth starts and after hard freezes, the seedling top is cut off just above the bud, and all hard suckers are removed. As soon as the ground will work the row is cultivated and a complete fertilizer (10-10-10) is applied as a side dressing on each side of the row at about 800 pounds per acre. As the bud begins to grow, so will suckers below the bud and these must be kept removed. A side dressing of ammonium nitrate is usually applied in July at the rate of 200 pounds per acre.

By the end of the first growing season we will have plants from 12 to 36 inches in height, depending on how good a growing season we have had. If we have a good stand of buds and have done a good job of growing, we may have 3 to 6 salable plants to a linear foot of row.

When the trees have lost most of the leaves and are well ripened and dormant, usually mid-December, we run the digger. If we are going to harvest all the plants, we will use a slight lifter on the digger blade. We prefer to get the digger under the plants and let them sit where they are. Then we can bring them in for grading as needed. They store better in the ground than in a storage house.

We usually grow a small percentage of our dogwood on one year transplanted seedlings, lined out in the spring and budded that summer. Usually the transplanted seedlings can be budded earlier, they are insurance against a seedling failure, they grow a heavier tree in one year, and they can accept bigger budwood. On the other hand, they require staking which is expensive, they are more expensive to line out, they give a lower percent of "takes", and they do not make as smooth a tree at the bud union as a dogwood budded on a field-grown seedling.

The basic techniques described above have been field proven over many years by the production of hundreds of thousands of dogwoods in middle Tennessee.

PRODUCING DOGWOOD BY CUTTINGS

CARL BAUER

Phytotektor, Inc.
Huntland, Tennessee 37345

We have been rooting dogwoods in the nursery for three years. Initially we were prompted by lack of competent budders. Also, we felt that rooting would possibly reduce some of the disease and virus problems, since there is no man-made wound. Rooting also appeared to be the logical answer since we are in the business of producing liners, and 95% of our other liners are from cuttings. I began by reading everything I could find on the subject. The best paper that I found was a graduate paper by Mr. Morris of Eva Nurseries, Eva, Alabama, which was written while he was a student at Auburn. I would like to state in the beginning that while we have been very successful in the rooting of dogwoods, we have developed no new technique.

Most of our work has been with softwood cuttings of current year's growth. Our work has been confined to cultivars that we normally produce: *Cornus florida rubra*, and *C. florida* cul-

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Most of our work has been with softwood cuttings of current year's growth. Our work has been confined to cultivars that we normally produce: *Cornus florida rubra*, and *C. florida* cultivars: 'Cherokee Chief', 'Cherokee Princess', 'Cloud Nine' and 'First Lady'. We have done no work on *Cornus florida* because rooting would never be more efficient than seed production. Cuttings can be taken any time from mid-June until late September. The best cuttings are produced from stock plants that have been heavily pruned and fertilized. Tip cuttings are best. Second cuttings will root and are about 85% as efficient as tip cuttings. The use of second cuttings normally produces crooked trees since an existing bud takes over and forms the leader. This defeats the purpose of putting the dogwood on its own roots — to get a straight tree. We like a cutting five to six inches long with at least three leaves cropped to half a leaf.

Dogwoods respond to heavy dosages of IBA. Our best results have been with a 2% quick dip. However, I have seen good results using Hormodin No. 3. Wounding cuttings is not absolutely essential, but we have adopted it as a standard practice. I believe that it is helpful, especially on the red cultivars as they are a little more difficult than pink or white.

Dogwoods will root in almost any medium. Peat pots were unsatisfactory since they fell apart. I prefer dirt beds which contain our native clay soil, finely ground pine bark and coarse sand. We have used a peat and sand mixture, which is all right for rooting, but it is not as good as the soil mixture for growing on. We build a bed right on top of the clay soil. The soil is broken up 12 inches deep, then bark and sand are added to give, ideally, a mix of not over 60% bark, 20% clay and 20% sand. The average rooting time is six weeks; some roots appear in three weeks. The mist interval is 5 to 10 seconds every 10 minutes.

Young liners need some winter protection as the roots must not be allowed to freeze. After plants have broken dormancy and made new growth, freezing is no longer a problem. Winter protection can be provided by a cold frame or plastic house with sufficient heat or sufficient insulation to prevent freezing. Normally, light splitting of the bark is not serious.

Rooting dogwoods is no problem for us, and I believe almost anyone can do it with reasonable success.. There is very little difference among cultivars, although reds are slightly more difficult. The big problem is getting the plant to the field, which is all a matter of timing. It appears that the dogwood cannot be successfully transplanted until it has broken dormancy and made some new growth. In this respect I believe that it is similar to the carlesi type viburnums. I have seen about 90% fatality of plants that were rooted in the bench and immediately potted. For best results the plants should be potted after new growth begins or allowed to grown an additional year in the beds. Even with the problems that we have experienced, I still think that rooting dogwoods is practical and believe that within 2 or 3 years we will be producing all of our dogwoods from cuttings.

DOGWOOD LINER TO FINISHED PLANT

CARL FLETCHER FLEMER, III

Ingleside Plantation Nurseries, Inc.
Oak Grove, Virginia 22443

As the speakers before me have attested, there are different ways to produce white and pink dogwood liners. Once at the liner stage, there are different ways to produce the finished plant. At Ingleside Plantation Nurseries we line out about 5,000 pinks and 10,000 whites each year, which are handled just alike.

We try to plant our dogwood liners around March 15 while they are still dormant. The best size liner is at least 12 inches in height, but not taller than 24 inches. Planting is done with a "homemade" one-row planter. Dogwood liners are planted in rows which are 6 feet wide. Plants are spaced either 18 or 24 inches apart within the row, 18 inches if they are to be grown for larger lining out stock, 24 inches if they will be sold as 4/5, 5/6 and 6/8 foot trees. Liners which are planted 18 inches apart are grown for two or three years until they are 4/5, 5/6 and 6/8 feet. Then they are dug bareroot and transplanted in 10 or 20 feet rows during December, January or February. Dogwoods in 10 feet rows are spaced 3 to 4 feet apart, yielding trees for B&B digging which are slender 6/8's, 8/10's and 10/12's. Liners in 20 foot rows are planted 4 to 5 feet apart. They yield the same height trees, but they have broader heads.

Cultivation begins in the spring as soon as it is feasible and continues into late fall when the ground gets too wet. We try to cultivate all dogwoods once every week. One row cultivators are used until the trees get too tall for the tractor to go over. We then use Ford 3000's, which are 48 inches wide and can go between the rows using discs, rakes or rotavators. Cultivation helps control weeds between the rows and also, we think, helps makes moisture available to the plant. Our observations seem to indicate that keeping the soil worked improves rain penetration, and under dry conditions brings more moisture into the root zone. Although dogwood will not tolerate "wet feet", irrigation is important. We use portable 6-inch pipe with Rainbird sprinklers.

We fertilize in the early spring with 16-8-8 or 20-10-10 at 500 pounds per acre. In the early fall we fertilize again using 5-10-10 at 500 pounds per acre.

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We attempt to control weeds with granular Casaron and liquid Lasso. Casaron 4G is applied at 150 lbs. per acre between November 15 and February 15, when temperature is below 50°F. Lasso is used throughout the summer every 4 to 6 weeks at 4 quarts per acre. Occasionally Paraquat is mixed with Lasso at the rate of one quart per acre.

We spray for dogwood borers in the early spring, using Lindane 20% E.C. mixed at the rate of 3 pints per 100 gallons of water. We start spraying in early May with three applications 2 to 3 weeks apart.

We do not dig any B/B dogwoods until after a heavy frost, around the latter part of October. Dogwoods can be safely dug both B/B and bareroot after November until buds break in the spring around the middle of April. B/B dogwoods are dug both by machine and by hand. We use a Jiffy Baller to dig 12, 14, and 16 inch sizes. Balls 18 inches and larger are dug by hand and drum-laced. Plants dug in the field are placed on pallets and handled with a forklift until they are loaded for shipment.

DOGWOOD DISEASES

ROBERT C. LAMBE

Department of Plant Pathology
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

Disease may be an important factor in the production of salable flowering dogwood (*Cornus florida* L.). Recently several different virus diseases have been reported by various researchers, but little is known about their impact on the production of dogwood. Historically, fungus diseases of the foliage, twigs, roots and trunks have been considered important. These diseases occur frequently under certain environmental conditions of excess rainfall and low temperatures. More recently a fungus root rot and trunk canker of undetermined cause have assumed important positions in the commercial production of dogwood.

Foliage Diseases. Foliage diseases reported on *C. florida* have included leaf spots, blights, mildews, and viruses.

Ascochyta leaf spot, caused by *Ascochyta cornicola* Sacc., was first reported in 1942 by Hepting at Biltmore, North Carolina (7). Leaf spotting begins as early as mid-June, being characterized as round or slightly irregular areas, ranging in size from 1.5 to 6.5 mm in diameter. Tiny black puntiform spore masses form on gray to tan centers, surrounded by a somewhat prominent border of brown to red (7).

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Botrytis petal blight, due to infection by *Botrytis cinerea* Pers. ex Fr., affects bracts, leaves, and young shoots. The disease generally occurs during periods of cool, wet weather. Bracts are most commonly infected, expressing brown patches of large, irregularly shaped lesions and having a wrinkled appearance. In humid weather, lesions become covered with fuzzy grayish-brown fruiting bodies. Other symptoms include discoloration or fading of bracts, leaf rotting, and the occurrence of blemishes on any floral parts, leaves and shoots (8).

Cercospora cornicola Tracy and Earle has been reported as the causal agent of Cercospora leaf spot, which occurs as irregular brown areas without definite borders, 5 to 10 mm in diameter. The disease appears in Georgia in late September, often causing defoliation (3,7).

Colletotrichum gloeosporidiodes Penz. was reported by Toole and Filler (11) to cause necrotic spots on foliage. Defoliation and dieback of one-year cuttings and seedlings due to this pathogen were also observed (11).

The disease caused by *Elsinoe corni* Jenkins and Bitancourt is referred to as blossom blight, blossom spot, or spot anthracnose. This disease was first reported by Jenkins and Bitancourt in 1948, as a disfiguring disease of the blooms (7). The fungus infects bracts, foliage, and twigs in developing stages, but petioles, peduncles, and fruit clusters may also be infected (7,8). Leaf spots are circular, angular, or elongate, ordinarily 1 mm in diameter, but sometimes larger. Spots may number over 100 per leaf. Dead tissue in the centers of spots becomes pale, yellowish-gray, and readily drops out, while surrounding tissue may darken. The disease may reduce leaf size or kill tissue outright. Owen (8) reported that trees normally infected by *E. corni* failed to produce symptoms when hot, dry weather conditions prevailed during the usual infection period. Spot anthracnose may cause damage under overhead irrigation. Dead tissue falls out of the leaves, which are small and stunted.

Elsinoe floridae, as well as *Ramularia gracilipes* Sacc. are mentioned by Pirone (9) as leaf spotting organisms on flowering dogwood. *Phyllosticta cornicola* (D.C. ex Fr.) Rabh. and *P. globifera* Ell. and Ev. are reported to be easily confused with *Ascochyta cornicola* in early spore stages (7).

Septoria cornicola Desm. is the cause of a leaf spot having small, angular, and typically haloed margins (6,9). *Septoria floridae* Tehon and Daniels, the cause of Septoria leaf spot, produces small angular leaf spots, limited by veins. Color is generally uniform but may become light in the center and dark at the borders. The spots range from 1.5 to 6.5 mm in diameter and may be numerous by September. Small puntiform masses of spores form late in the summer on the necrotic centers (7).

Viruses reported on flowering dogwood include Dogwood Ringspot Strain of Cherry Leafroll Virus (DRSCLV) and Tobacco Ringspot Virus (TRV). DRSCLV was reported by Waterworth and Lawson in 1973. Leaves exhibit faint chlorotic ringspots or arcs, usually adjacent to primary veins, while other leaves may show a mild mottle. In the case reported, ringspot symptoms disappeared by early summer, and during midsummer leaves of infected trees showed upward rolling of leaves similar to CLRV-infected cherries (13).

TRV was first reported on dogwood in 1972 by Waterworth and Povish from trees in Maryland. Symptoms appeared as a general unthriftiness of the trees, small and sparse flowers, and death of many twigs and leaf spots (12).

More recently Brunt and Stace-Smith have reported on tomato bushy stunt virus on dogwood (2). A witch's broom disease of *Cornus amomium* has been attributed to a mycoplasma-like organism by Raju, *et. al.* (10).

Twig Blights. Fungi causing twig blights reported on dogwood include *Botryosphaeria dothidea* Ces. and deNot., *B. ribis* (Tode ex Fr.) Gross. and Dug. (6,9), *Corticum stevensii* Pers. ex S.F. Gray (5) and *Myxosporium* sp. (*M. everhartii* Sacc. and Syd.) (6,9). A twig blight in the South caused by the fungus *Diplodia natalensis* Fr., may be synonymous with *Physalospora obtusa* (Schw.) Cke. (6).

Root Rots. *Armillaria mellea* Vahl ex Fr. is cited by Hepting (6) and by Batra (1) as a cause of root rot in the northern United States. *Clitocybe tabescens* (Scop. ex Fr.) Bres. is mentioned by Pirone as a root rotting organism in the South (9). Dogwood is reported to be extremely susceptible to Texas root rot, caused by *Phymatotrichum omnivorum* (Shear) Dug. (6,9). Recently a root rot caused by *Phytophthora cactorum* (Leb. and Cohn.) Schroct. has been reported (14).

Trunk and Stem Cankers. *Botryosphaeria ribis* has been reported by Hepting as a twig blight and also a canker fungus, occasionally causing dieback, killing branches and whole trees in the northeastern United States (6). Toole and Filer reported canker formation as a result of stem inoculations with *Colletotrichum gloeosporidiodes* (11). *Nectria galligena* Bres. causes the development of zonate cankers having conspicuous bark-free callus tissue. This area folds, and tiny red, balloon-shaped perithecium develop around the edges in wet weather (6). Crown canker, caused by *Phytophthora cactorum* (Leb. and Cohn.) Schroet. is not easily recognized in early stages, although investigation of the cankered area reveals that the inner bark, cambium and sapwood are discolored. As the canker at the crown increases, the bark ruptures and sap oozes in the form of slime-flux. Bark over older areas dies, sheds and reveals a parabolic, zonate surface indicating different periods of growth of the pathogen. General symptoms may included a severe die-back of the crown, with defoliation associated. Leaves become small, sparse, and chlorotic. An abnormal abundance of fruit may be borne several years prior to the killing of the host (4,9).

Crown, Wood Rots and Seedling Diseases. *Agrobacterium tumefaciens* (E.F. Smith and Town.) Conn. occasionally causes stem and crown galls (6). *Fomes scutellatus* (Schw.) Cke. is mentioned by Hepting as the only wood rot fungus isolated from living trees (6). *Pythium* spp. have been the cause of seedling diseases in wet, poorly drained soils (6).

Current Important Diseases. In Virginia we have been studying root rot of *C. florida* caused by *Phytophthora cactorum* (Leb. and Cohn.) Schroet. In the nurseries this disease appears in the areas of the field considered by the growers to be poorly drained and generally tight. Diseased plants are stunted, have sparse foliage and show top decline. The roots on the diseased plants are severely rotted. When artificial inoculation of seedlings with *P. cactorum* from dogwood was compared with *Phytophthora cinnamomi* Rands. from azalea in the greenhouse, symptoms of top wilting and root rot were more severe with *P. cactorum* than with *P. cinnamomi*.

Virginia nurserymen have noticed a trunk canker disease of disturbing importance for several years. Not only are young trees damaged in the nursery, but lightly cankered trees have a poor record of survival in the landscape. The disease has been observed on trees brought in from out-of-state and planted out in Virginia nurseries. The source of trees seems to affect the development of the diseases.

Cankers produced on diseased trees are unlike those reported for Nectria canker and we have not observed the nectria fungus fruiting on the cankers. Various fungi, including several different ones frequently isolated from stems of other woody plants, have been isolated from the dogwood cankers, but none of these have been successfully introduced into experimental trees. Tests to date with fungicides have failed to prevent an increase in the number of cankers or severity of disease. Several different experiments, including work on fertility, are in progress to determine the cause and effect on growth.

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FLETCHER FLEMMER: Dr. Lambe, what insecticide do you use for borers?

DR. LAMBE: We have found the organophosphates more effective than Lindane.

DAVE BYERS: Could herbicides or mechanical damage increase susceptibility to disease?

DR. LAMBE: Fungi can enter wounds caused by mechanical damage at the ground level. Collar canker entering in this way causes symptoms resembling *Phytophthora*.

TECHNIQUES OF JUNIPER GRAFTING

PHILIP M. HALL[1]

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Grafting upright junipers is a year-round operation. While the actual grafting is done in Oklahoma only in the winter from about December 15 through March 1, there are many other items requiring attention throughout the year to produce the final product.

Understock. The first step is to build a good supply of understock. We use both *Thuja orientalis* and *Juniperus chinensis* 'Hetzii' as understock for upright junipers. *Thuja orientalis*, more popularly called biota, understock is grown from seed in open beds for 2 to 3 years. Seed is sown in early to mid-spring at a high density. In the fall of the following year we undercut the seed bed and selectively harvest the seedlings of a size acceptable for grafting. Oversize seedlings are discarded and undersize plants are left in the bed for one more year. After harvesting, the roots are trimmed back just enough to allow easy potting in a 3-inch round clay pot. We use these larger pots with *Thuja* in order to give more room to the plants when set in a bed of peat moss. In the past we have had difficulty with *Thuja* having a foliage blight when packed too tightly under conditions of high humidity.

Juniperus chinensis 'Hetzii' is started from cuttings taken during the winter months. In Oklahoma, the most acceptable time is between November 15 and March 1, when the stock plants are in a dormant condition. For understock applications it is very important to impress upon the cutting crew the kind and size of cuttings which should be taken. The correct stem diameter is the most critical factor in selecting cuttings, with the optimum diameter being about 4 mm to 7 mm at a distance of 5 to 6 cm from the base of the cutting. On vigorously growing stock plants this diameter will usually be 20 to 25 cm from the apex of each growing terminal. An important factor concerning rapid and vigorous rooting is selection of cuttings from the current season's growth. Stock plants which are weak or growing under unfavorable conditions often have the acceptable diameter well back on 2 year old wood. In general, cuttings from 2-year-old wood should be avoided due to increased difficulty of rooting; however heel cuttings, which include just a small portion of old wood at the base, are quite acceptable and, according to some sources, preferable. When cuttings are taken from the stock plants, we then strip the foliage off the basal 3

[1] Presented by Eddie Spears, Spears Tree Farm, Tahlequah, Oklahoma.

inches and bundle them in groups of 25 with the bases matched. The entire bundle is then topped to give the cutting an overall length of 6 to 8 inches. The bundles are brought to a cool, dark storage room, immersed in a disinfectant solution and placed on wire racks. We mist the cuttings once or twice per day until they are stuck in the rooting beds.

We root most of our *Juniperus chinensis* 'Hetzii' in ground beds under quonset type structures with a rooting medium of sand, peat and bark. Previous to sticking, the beds are sterilized with methyl bromide. The cuttings are stuck on 1-1/2 inch centers using a nail board to insure consistant and accurate spacing. This spacing yields about 35,000 cuttings in a 6′ by 96′ bed. We stick the cuttings about 3/4 inch deep or just deep enough to hold the unrooted cutting upright during a hand watering. Just prior to sticking, the basal end of the cuttings is given a 5 second dip in a solution of 5000 ppm IBA in 50% water and 50% isopropanol. Misting is clock controlled but usually changed daily depending on weather conditions. Every 2 to 3 weeks until rooting takes place, the cuttings are drenched with Banrot or Benlate. In 9 to 12 weeks the cuttings begin to root and new top growth becomes noticeable. At this point we begin to use a 20-20-20 water soluble fertilizer on a biweekly basis. Once rooted, the cuttings can be hardened off from the mist rather quickly in just 1 to 2 weeks. The cuttings are maintained in the ground beds through the summer. For us, the best time to pot the rooted cuttings begins toward the end of September and preferably ends by the first of November. In the harvesting operation, the beds are heavily watered and the cuttings carefully dug with as little disturbance to the roots as possible. After trimming the roots back to a length of 3 to 4 inches, the cuttings are potted in 2-1/4 × 2-1/4 × 3 inch plastic pots and placed in a shade house to be maintained until root establishment. The potted understock plants are left ouside until about November 15 or until they have been through one or two good frosts. In a relatively dormant condition, they are then transferred to the glasshouse where they are brought into an actively growing state with a maintenance schedule of moderate water, moderate fertilizer applications, and one or two drenches with Banrot. The day prior to grafting, the group of plants to be used are given a very heavy watering since, if all goes correctly, they will not be hand watered again for about 8 weeks.

Labor. At our nursery the actual grafting operation usually begins about December 15 and ends about March 1. A well synchronized operation is an absolute necessity for juniper grafting, both from a cultural point of view and from an economic point of view, so it is very important to maintain a work force of just the right number of people. Since the output of each worker may vary greatly, it is good for the propagator to have some idea of each individual's potential in order to schedule the labor properly. In general, the best experienced scion makers can be expected to produce about 2500 to 3000 scions per 8 hour day, while our best grafters will produce an average of 1200 grafts per day. On the other hand, inexperienced workers can be expected to produce about 1000 scions per day or 600 to 700 grafts per day after a 2-week learning period. Therefore, the decisions regarding placement of labor must depend on the experience and ability of the individual employees. For our particular grafting operation, the work force usually consists of 1 or 2 scion makers, 2 to 5 grafters, 2 or 3 people to collect scions from the fields, 1 or 2 workers to bring understock to the grafters and set the completed grafts in the beds, and one person to supervise the entire operation and fill in where a need exists.

Grafting technique. The basic technique for making a juniper graft is well known throughout the nursery industry. However, every nursery and, no doubt, every propagator involved in this field has different ideas of the finer points of the operation. Scion material is collected in the field, preferably from young trees which have been sheared 2 years previously but not sheared during the growing season preceding grafting. Due to lack of availability, however, it is often necessary to collect scion material from older trees. The workers try to select material with a diameter closely matching that of the understock and which is of current season's growth. This material, usually 10 to 15 inches in length, is brought to a cutting room, dipped in disinfectant solution and placed on wire racks. They are misted 2 or 3 times per day to keep them in fresh condition. Our policy is to use the material within 3 days of collection even though storage, under proper conditions, could last 2 to 3 weeks.

The scion maker's technique is very important. A good scion will have a longitudinal slice about 30 mm long removed along the inside curve (if a curve exists) of the stem and a similar but slightly shorter (28 mm) parallel slice removed from the outside curve. It is of the utmost importance to leave a strip of undisturbed bark and cambium along each side about 2 to 3 mm wide. Finally, a wedge is made at the basal end starting the cut on the shorter side. We prefer the wedged scion to one that simply tapers along the length of the cut to a point. Ths reduces the amount of very thin material at the basal end that might be more subject to desiccation. A well prepared scion is of great importance in the survival chances of the graft. A poorly made scion almost assures either complete failure to unite or a weak graft union if healing does occur.

Once the scion is properly prepared it goes to the grafter, whose job of making the side graft is equally critical. Starting as low as possible on the stem of the understock, the grafter makes a longitudinal incision about 30 mm long to a depth 1/4 to 1/3 the diameter of the stem. The cut must not be all the way through so that there is a flap. The scion is then inserted into this incision so that the long cut is toward the center of the understock. The flap is brought into contact with the shorter cut of the scion. All this is done while being careful to match scion and understock cambial layers at least on one side of the graft. The grafter then wraps the graft with a budding strip, applying just enough tension to keep scion and understock in close contact. The wrap should spiral down the graft union leaving small gaps between turns and tying off below the union.

The next step is to place the completed graft into a bed where the scion and understock may callus and develop connective vascular tissues. The healing process requires proper maintenance of moisture and temperature around the union. In our case, we place moist peat moss just to the top of the union without burying the foliage where fungus problems might arise. However, we are careful not to leave any of the union uncovered so as to prevent drying which would result in failure to heal.

The facility. With the graft now in place in the healing bed, success or failure depends upon the facility and its proper maintenance. Three essential factors — moisture, temperature and light intensity — are critical in the healing of a well made graft. It is in view of these factors and their interdependence upon one another that the facility must be designed and maintained.

The method of moisture control has changed drastically with the advent of mist systems. Our grafting beds were built long before mist systems were in general use; and hence controlling moisture was more a matter of keeping water in rather than adding water to compensate for losses. Our beds were built to a depth of about 24 inches, which allowed placement of glass frames or, more recently, plastic tents over the plants. This created an enclosed environment with nearly 100% humidity and virtually no water loss. The system had two major drawbacks: high humidity coupled with high temperature around the foliage encouraged disease problems; labor costs were high because of the need for frequent aeration by lifting the glass frames or rolling back the plastic tent. With the automatic mist system the deep beds are not absolutely necessary but are probably helpful in cutting down on drying air currents. The question of how much water to apply with mist no doubt varies greatly among propagators involved in juniper grafting. Of course, the amount applied must be considered along with the other two critical factors of temperature and light intensity. Some propagators apply water liberally to keep the graft union constantly wet, especially when using a well drained packing medium. In our case, the peat moss packing medium has a large water holding capacity; therefore, our philosophy is to apply as little mist as possible without allowing the peat or the foliage to dry out. On a cloudy winter day, for example, the clock might be set for 20 or 30 minute intervals with 3 to 4 second bursts. On a bright day, misting might be increased to 12 to 15 minute intervals with 5 second bursts. No steadfast rule for misting can be relied upon, and during the critical healing time I consider my first and foremost duty to be checking the moisture conditions in the beds hourly and adjusting the mist clock according to needs.

The heat source for the greenhouse is a gas-fired boiler. Steam mains run overhead down the center of each section of the greenhouse. At the far end, the main branches and steam lines run beneath the raised benches and back to a common return for recycling. We are great believers in the benefits of bottom heat for grafting applications. In fact, we believe that bottom heat is the only important source of heat in our system. We much prefer the foliage to remain cool in the 50 to 65°F range, while the graft union is in the 75 to 85°F range. We do not want the tops to get so cold as to curtail metabolic activity, but the 50 to 65°F range provides ample metabolism and discourages excessive transpiration. Our experience shows that heat is quite important for healing of the graft union. Early during the past grafting season we noticed a distinct temperature gradient from one end of a bed to the other. The cooler end was substantially slower to callus and had a greater loss percentage. To correct this gradient, plastic skirts were placed around the grafting beds with ventilation holes at the warmer end. After some experimentation we obtained a reasonably consistent bed temperature along the length. Bed temperature is maintained by a thermostat with the probe inserted directly into the peat moss at graft union level.

The third factor critical to the facility is light intensity. My experience indicates that high light intensities are, in our system, detrimental. With high light there follows higher air temperatures and increased transpiration. More mist is then needed, which increases chances of disease problems. Our best success has been with a shading just dense enough that shadows are not cast even on a bright day. As is obvious, the three factors of moisture, light and temperature cannot be dealt with separately. Any alteration of one factor requires a reassessment of the other two.

Post Healing Treatment. The easier cultivars (most of the *Juniperus scopulorum* cultivars) usually show callus in 7 to 14 days. Time for complete healing is variable, but in 6 to 8 weeks the callus starts to turn a dull brown color indicating the onset of lignification and formation of vascular connections. New growth from the scion preceded by a "spring" color change is also noticeable at this point. The hardening off procedure may then begin and should last 10 days to 2 weeks with gradual reduction of mist and increased hand watering. Constant random sampling is necessary to decide when to cut back the understock. This is done only after considerable lignification when the unions seem physically strong. We cut back the understock all at once rather than in steps because, quite frankly, we have seen no cultural advantages in the latter, more labor intensive method. The cut is made with a pair of sharp clippers at an angle in order to avoid a pronounced stub which might be subject to infection. In the same operation, the budding strips are removed and replaced with a thin piece of masking tape. The union is still tender and could be broken if handled too roughly. The cut back grafts are then reset in the beds and maintained on a water and fertilizer schedule until shipping time in mid-May.

FIELD PROPAGATION OF SEEDLINGS IN MIDDLE TENNESSEE

MICHAEL HOBBS

Warren County Nursery, Inc.
McMinnville, Tennessee 37110

Seed beds. The term "seed bed" implies the preparation and cultivation of seedlings en mass, closely spaced, and cultivated intensively in a confined area. This practice is not generally carried out in this region except under greenhouse or hothouse conditions in the propagation of evergreen liners. Most seed propagation in this area is, and has traditionally been, the row type of cultivation, which differs very little from the other types of nursery cultivation.

Seed sources. The seeds used for propagation of the liners and understock used in this area come from several sources. The wild collected seeds are the oaks, dogwoods, maples and many others. There are more plant species native to the McMinnville area than in the Great Smoky Mountains, which explains why the Tennessee nursery industry originated in this area. The seeds are harvested at the proper time of the year by people commonly known as "seed collectors." The collectors are usually older people who are capable of knowing the differ-

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Seed sources. The seeds used for propagation of the liners and understock used in this area come from several sources. The wild collected seeds are the oaks, dogwoods, maples and many others. There are more plant species native to the McMinnville area than in the Great Smoky Mountains, which explains why the Tennessee nursery industry originated in this area. The seeds are harvested at the proper time of the year by people commonly known as "seed collectors." The collectors are usually older people who are capable of knowing the different types of seeds, although this in no way insures a true-to-name seed bank. The next general seed type is the cultured or semi-cultured seeds. These include chestnuts, pears, and southern magnolia. The seeds may come from landscape trees or abandoned rows of stock. Peach and other specialty seeds are purchased from canneries as a byproduct or from other commercial sources. The peach seed will become understock for the budded fruiting peaches as well as the flowering peaches and plums.

Seed culture. There are several factors which play an important role in the variation of the culture methods for the seeds. The type and condition of the seeds determine the propagation measures; that is, the choice of type and slope of the soil in which they will be planted, the method of soil preparation, the depth of planting, the amount of compost covering for the seed, the correct fertilization program and the proper weed and pest control.

Land types used for seed propagation. Land used in the nursery industry in this area can be basically grouped by the length of time it has been cultivated. Land that has not been cultivated in the last 20 years is considered to be "new land." The new lands have traditionally been used for dogwood and this type of seed for several reasons. First, the crop can easily be grown while the ground is still heavy with roots; second, there are generally fewer weed and grass problems in these areas; and third, the new land is more friable and has a good organic makeup. The use of the new land is probably based on the fact that the leaf mulch contains natural bacteria and fungi that have a great influence on the growth and germination of these seeds. There are several of these fungi, molds, and bacteria now appearing on the market, but a tremendous amount of testing and experimentation will have to be done before they can become effective in the hands of the average nurserymen.

The established, or "old lands", that have been cultivated regularly or used for any crop growing or pasture are more compacted; however, they are of very good quality and more accessible and can be farmed with a minimum of difficulty. The established lands consist of sandy loams in the bottom lands, and from sandy to red clay on the hills. Excessive wetness in bottom land can result in seed decay and can preclude seed planting in these areas. The red hills are uniquely suited for peach and other fruit seeds. Tradition has it that the chemical composition of the red soil is best suited for these crops, and it will only take one year of field observation in this area to confirm the traditional belief. With the field tiller the nurserymen can pulverize the soil adequately so that plantings in recent years have worked well on established land.

Selection and preparation of seed land. Production pressure on the lands in this area are no different from those in any other. The necessity to produce, to pay taxes, and show a profit are as real as ever. Some lands are not available to be cleared for nursery use for several reasons. The underlying rock formations, which are usually limestone, tend to produce sinks that continually enlarge with time and make cultivation impossible. The size and number of rocks will, of course, be a factor as will also the degree of slope. These lands are usually left in timber production or pasture. After a suitable area is selected the bulldozer is the most efficient and economical way to begin the preparation for the planting. The initial work will remove the trees and large rocks. The direction of the push is the one with least resistance. The material is pushed in windrows, usually in the area where the greatest slope is located, in order to catch any runoff. This can be very important in some of the sandy soils. After the dozer is finished, an attempt is made to deal with the roots remaining. By use of a rooter, loose roots left by the dozer are carried to the windorws and those left remaining are removed by chopping with axes by hand. After the removal of the surface material, the land can be disced to raise enough soil for planting. The land cleared by these means will still be infested with stumps for several years, making future plowing difficult but not impossible. The dependable old mule is still used today in many instances.

The same factors apply for old land as new land. Degree of slope as well as rock formation are still important, but a more dominant consideration for established soils is fertility. What has previously been grown on the soil would determine the fertility. Once the selection has been made, there are two ways to prepare the soil for planting. The first, usually the easiest and most economical, is to spray with a good herbicide such as Roundup at the proper time for good kill. The time and amount of spray will vary with the type of weeds. Second, one can continue to work the soil during the summer months for weed control, but usually the cost is greater than for spraying. In addition, cultivation takes man-hours that can be applied where needed in other jobs. With the new herbicides on the market and with new land being difficult to obtain, more seedlings will be grown in the future on established land.

Very little work has been done on the effect of herbicides on the planted seeds, therefore any information presented is not to be taken as a recommendation but as a report on the results of experimentation. The pre-emergent herbicide Enide, at 8 to 10 pounds per acre, has produced good results in our area with no damage to the emerging seedlings. As a control on established seedlings, a combination of 8 pounds Enide with 2 pounds Simazine gives good results. More research must be completed before adequate safeguards will be available for nurserymen.

Seed placement. Before the seeds are planted each cultivar has to be treated in a different way, either mechanically or by natural ways. Heat from a roof, covering with sand for a number of days, or even treatment with acid can be used to increase productivity and decrease the number of days required for germination.

After the discing, furrows are made at different levels, again depending on the cultivar, by mechanical means or by hand. All seeds in our operation are sown by hand. The placement of the seed in the rows is dependent on the type or cultivar of seed. The larger seed, such as black walnut and different acorns or chestnuts, are generally placed one to two inches apart down the furrow of the laid off row. The smaller seeds, such as white dogwood, are poured into the row in large numbers. The smaller the seed, the more can be placed in the row and still have a well defined row. An ill defined row will suffer great damage during cultivation in the growing season. After being placed in the rows, seed is covered either by dirt or sawdust. The determining factor as to covering depends on the strength of the seed. Many of the smaller seedlings do not have the physical strength to push through a large layer of dirt. The majority of these types of seeds are those that normally appear from a humus layer on the forest floor and are not adjusted to this transfer to the open field. Decomposed sawdust is placed over these types of seed to keep the covering medium friable through the winter.

Seed fertilization. The fertilization which precedes the planting of the seed is usually in the furrow. A plow is run through the furrow to mix the fertilizer with the soil to prevent chemical burning of the seed. Side application of fertilizer is done after planting the seed. The makeup of the fertilizer is generally similar to 10-10-10; however, the nitrogen level will vary depending on soil type.

We have now completed the basic steps taken in preparation and growing of seeds in field propagation. Some seedlings will be harvested at the end of one year's growth and some will extend on for three or possibly four years.

The crop will be maintained each year with herbicides, pesticides, mechanical cultivation and hand weeding. After the crop is dug, it will then be decided whether to put the field back in a seed crop or to use it for cutting-grown material. After several years' use the best soils with correct slope will even be used to grow shade trees for bare root or balled and burlap purposes. We have found these procedures for seed propagation give us very good results.

OPEN-FIELD PROPAGATION OF JUNIPERS

DAVID BYERS

Byers Nursery Co., Inc.
Huntsville, Alabama 35811

I appreciate the opportunity to be with you today to discuss the subject of outdoor propagation — open-field propagation — of hardwood juniper cuttings. The idea is not original with us, although it is original in the geographical area of our nursery. In the early 1920's, a firm known as D.E. and J.O. Kelly Nursery began propagating in this manner, and since that time, almost every nursery in the area has attempted it. Most have been fairly successful because it is a simple method. Now, not so many are doing it for two reasons: more people are using the more modern methods of propagation such as mist, and the lack of consumer demand for junipers seems to have slowed somewhat the need for propagation.

We are in the very center of North Alabama, Zone 7, where temperatures sometimes drop to zero, but ordinarily are not quite that cold. Overall we have a very moderate climate. We have a fraction over 50 inches of rainfall annually in normal years. Our soil is a heavy, red-clay type. I think all these factors are important in considering how we propagate because, really, we let Mother Nature do the worrying.

A list of cultivars that we are propagating in this manner will give you an idea of the range we can do. We root a wide range of junipers, beginning with the naturally-layering types, such as *Juniperus horizontalis* 'Glauca', *J. conferta*, and *J. horizontalis* 'Plumosa. Other cultivars include *J. chinensis* 'Pfitzeriana', *J. virginiana* 'Kosteria', *J. chinensis* 'Pfitzeriana Compacta' and *J. chinensis* 'Hetzii'. Several *Juniperus communis* cultivars root well; some of these are fastigata, 'Hibernica', 'Ashfordii', 'Kiyonoi', and 'Suecica'.

There are certain cultivars for which this method of propagation is not successful, and one of the most obvious for us is the *J. chinensis* 'Pfitzeriana Aurea'.

Generally, our procedure is this: From vigorous, well-cared-for plants, we take cuttings of the current season's growth, approximately 8 to 10 inches long. The length varies with availability of the wood. The second cuttings would be just as easily rooted as the tip cuttings and sometimes root more easily. These cuttings are made in the field. In other words, poses. We have found these procedures for seed propagation give us very good results.

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The cuttings are gathered in big burlap bags and moistened unless the wood is wet from rain or dew. We do not allow the cuttings to dry out. The cuttings are carried in these bags, one cultivar at a time, to the field.

To prepare the soil for planting, we turn it in late summer and work it to prepare a seed bed situation. After a rain and just before planting, we disc again, then lay off rows as they are needed to avoid allowing them to dry out.

If the soil lacks moisture, we put water into those rows with a water wagon before sticking. We have a 550-gallon water wagon, tractor drawn, which can wet four rows, 220 feet long, per 550 gallons of water. Into that muddy soil, we stick the cuttings. In the planting we have just completed, there was enough natural moisture in the soil that we felt the water was not necessary. Sticking the cuttings is then much easier, but in most years additional water is necessary.

The cutting is stuck about halfway into the soil, so that 2 to 3 inches of the top are left above the ground after we have completed the planting procedure. It is important to lay the row off to the proper depth, so that the man who is sticking can gauge depth as he is pushing cuttings into the ground. The cuttings are put as close together as possible in the row, although it would be better to space cuttings 1 inch to 1-1/2 inches apart, if land were available.

The next step is to push the soil together with a garden rake, or something of that nature, on either side of the row to hold the cutting more firmly into the ground. This is really a filling process of the row, and holds the moisture in if we have added water. If the soil is already moist, it supports the cutting in an upright position.

We then come in and do what we call "foot-packing." Each man takes a row and, using his weight and the heels and soles of his shoes, compresses the soil so that the air is pushed out, seating the plant solidly in the ground. This, we think, is one of the most important factors of the whole propagating process; that is, the plant must be solidly seated in the ground.

Every year we have used the next step, we have had good luck. We use a vehicle to compress the soil even more firmly — any light car or pickup will do. Each side of each row has a wheel driven right against the plant; we really pack the cuttings in the ground, so that if you grasp a cutting by the tip and pull on it, the tender top will break off. We have done this for 15 years with good results.

Occasionally in the winter, we might have to repack the cuttings with a vehicle or by foot, whichever is necessary, if freezing and thawing cause heaving problems. We feel the cutting must remain in firm contact with the soil, and the air pocket left under the cutting after a lifting freeze is definitely detrimental to the rooting process.

This past winter (1977) we had a problem with heaving; for the first time in all these years we lost our crop. It has not made us lose faith in the process, but we do know that we cannot do it in terribly cold winters when the ground stays frozen for a long period.

Following packing would be the time to top cuttings, if needed, although normally we don't do it. Finally we plow the area with a little Super A or 140 tractor, just to break the hard-packed soil in the middles, which was the result of foot traffic and vehicle movement over it. We leave the field in very nice condition after the planting process.

Now, this is all done in the fall, beginning about mid-September and extending until we begin digging. We have successfully planted until Christmas. The amount of time we spend sticking cuttings depends on two things: how much wood we have, and how much open weather we have before we start digging our fall orders.

We feel that as soon as they have had a good rain on them, we can pre-emerge these cuttings with Dacthal — something very mild. We don't want to put any strong herbicides on them since they are unrooted cuttings. There might be some inhibition of rooting from a herbicidal application, so we want to be very careful.

Through the summer months we cultivate these cuttings with the small tractor. Because the cuttings are firmly in the ground, we can hoe across the row with fork hoes, pulling from the plants any soil piled up by the tractor. It is important to avoid mounding soil on the cuttings. Irrigation is used during the summer as necessary.

Between the middle and the end of September, we root prune these cuttings, using a U-shaped digger blade that is about 12 inches wide. We like to find a period when rain is forecast, and there is some moisture in the ground. We try to cut off the roots that have been formed through the spring and summer at about 12 inches, six inches from the plant each way. This early fall root pruning promotes a tremendous amount of new growth of the roots, so that when we begin to ship the plants after frost, about the 15th of October, they are well-rooted plants.

These plants are then pulled, graded, bunched into 25's as orders come in for them. We prefer shipping directly from the field, avoiding any long period of warehousing.

An advantage of this system is that we are producing a very heavy, strong, hardy liner, exposed to field conditions from its origin; and nurseries who buy it can turn it into money. In a container or in the field, it will survive and it will grow and do well. Of course, for us, there are some other reasons we grow junipers in this way. We think this method fits our schedule nicely. When we end cultivation and other summer activities, it gives us a procedure that takes two or three weeks, is productive as far as sales go, and fills the need of something for our men to do at that time.

We can stick approximatley 100,000 cuttings to an acre in this manner, using rows 42 inches apart. To our thinking, it is a very cost-effective means of propagating. We are constantly searching for less expensive ways to propagate plants — for ways of growing and handling plants that are more cost-effective and more efficient.

Certainly, in an open field propagation, we avoid the need for greenhouses, especially heated greenhouses; we have little need for water or irrigation, and we give hardly any attention to these plants through the summer other than general culture. We use no rooting hormones. We fertilize in the spring to encourage growth. The rows are watered before sticking the cuttings, but there is no more watering unless it is absolutely essential. We expect an overall average rooting of 80%.

This procedure generally is the way we do all our hardwood cuttings. Of course, the timing is varied, but many plants are rooted in this way. Crape myrtle is one of our biggest items and others we root are *Hibiscus syriacus*, *Euonymus kiautschovicus* 'Manhattan', *Thuja occidentalis* 'Woodwardii', *Forsythia* × *intermedia*, *Spirea* sp., *Punica granatum*, *Buxus*, and other flowering shrubs.

Botanical names and common names of plants mentioned:

Buxus sp. — boxwood
Euonymus kiautschovicus 'Manhattan' — Manhattan euonymus
Forsythia × *intermedia* — forsythia
Hibiscus syriacus — althea
Juniperus chinensis 'Pfitzeriana' — Pfitzer juniper
Juniperus virginiana 'Kosterii' — Koster juniper
Juniperus chinensis 'Pfitzeriana Compacta' — Nick's compact Pfitzer juniper
Juniperus chinensis 'Hetzii' — Hetz juniper
Juniperus chinensis 'Pfitzeriana Aurea' — gold tip Pfitzer juniper
Juniperus communis 'Ashfordii' — Ashford juniper

Juniperus communis 'Hibernica' — Irish juniper
Juniperus communis 'Kiyonoi' — Kiyono juniper
Juniperus communis 'Suecica' — Swedish juniper
Juniperus conferta — Shore juniper
Juniperus horizontalis 'Glauca' — Sargent's blue juniper
Juniperus horizontalis 'Plumosa' — Andorra juniper
Lagerstromia indica — crape myrtle
Punica granatum — pomegranate
Spiraea sp. — spirea
Thuja occidentalis 'Woodwardii' — Woodward globe arborvitae

MIXING ROOTING HORMONES

JOHN MACHEN
Mobjack Nurseries
Mobjack, Virginia 23118

By definition, "plant hormones" are chemicals occurring in living plant material that affect plant growth. Chemicals affecting growth that have not been isolated from living plant material are called "growth substances". For the purpose of this paper, both types of chemicals will be referred to as "hormones".

The process of mixing rooting hormones is a relatively new one, which affords the convenience of having on hand a wide range of concentrations and combinations of several rooting compounds. These various concentrations and combinations can, and should, be used to compare results produced on any given crop which is to be rooted in your nursery.

All of the compounds most commonly used as plant hormones are readily available from chemical supply houses (1) both in bulk or as pre-weighed samples. Naturally, the bulk material is least expensive.

Our first procedure deals with mixing rooting hormones with talc. I will use 3-indolebutyric acid (IBA), as an example. A brief look at the mathematics involved shows:

To make 100 gms. of 1.0% (10,000 ppm) IBA in talc combine 1 gm. IBA and 99 gms. talc

To make 100 gms. 4.5% (45,000 ppm) IBA in talc combine 4.5 gms. IBA and 95.5 gms. talc

A small amount of rubbing alcohol (70% isopropyl) is used to dissolve the IBA in a small container. This is poured over the talc in an electric blender. Additional alcohol is used to rinse the IBA container to be sure all of the IBA is recovered; this rinse is added to the talc. Sufficient alcohol is then added to the mix to make a thin, creamy mixture. This mixture is blended at high speed for 4 to 5 minutes.

Juniperus communis 'Hibernica' — Irish juniper
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A flat pyrex bowl serves well for the evaporation pan. The well-mixed solution is poured into the pan, the mixture is rinsed with alcohol and this rinse is added to the pan. The mixture is left in a warm place for the alcohol to evaporate. When evaporation is complete and the mixture is quite dry, the residue is scraped into a mortar and ground with a pestle until the talc is pulverized to its original fineness.

The IBA and talc are put into a clearly marked container more than twice as large as the volume of the mix. The contents of the can are mixed thoroughly with a mechanical paint can agitator for 10 to 20 minutes. At this point the IBA-talc mixture is ready to use. Heung, et al, (2) have shown (using IAA) that this alcohol solution method ensures a more uniform product than simple mechanical mixing and will therefore give more consistent results.

It is possible to use a combination of chemicals. We have used the following in *Rhododendron* propagation (3):

To make 100 gms. of 1% IBA in talc plus 5% Benlate and 50 ppm boric acid (3)

Combine: 1 gm. IBA, 10 gms. 50% Benlate, 5 mg. boric acid (USP), and 89 gms. talc (USP).

In this instance the IBA, boric acid and Benlate are dissolved in rubbing alcohol and added to the talc in the blender. The same procedure as given above is followed to completion. At this point I would like to emphasize that it is not my purpose to advocate or recommend specific mixtures to be used. I am simply presenting the mathematics and mechanics of mixing combinations of chemicals which can be used. The literature of this Society is full of excellent articles recommending specific concentrations or combinations for specific crops.

The next method deals with the mixing of rooting compounds with 50% isopropyl alcohol. Isopropyl alcohol is used because the 70% formulation is readily available at any drug store and is relatively inexpensive. The first step is to make a 50% solution of isopropyl alcohol.

To make 50% isopropyl alcohol

1000 ml. is equal to 1 liter

1 liter of 70% isopropyl alcohol contains: 700 ml. isopropyl alcohol, 300 ml. water

Add 400 ml. distilled water to 1000 ml. isopropyl alcohol which yields 1400 ml. of 50% alcohol.

(Dilution ratio is always 10 parts alcohol to 4 parts water.)

A 50% solution is used because it contains sufficient alcohol to afford reasonable solubility and yet is fairly stable; *i.e.* free from excessive evaporation when used during hot summer weather. Although there is a slight loss of volume when alcohol and water are mixed, the concentration is not significantly affected. If hormone concentrations are high it may be necessary to use 70% alcohol to get the material into solution. We also prefer to use 50% alcohol to reduce danger of plant damage.

To make 1 liter of 2% IBA

A 2% solution is equal to 20,000 ppm

1 ppm is equal to 1 mg./liter

2% solution contains 20,000 mg./liter

or

2% solution contains 20 gms./liter

20 gms. IBA + 770 ml. 70% isopropyl alcohol + 230 ml. distilled water = 1000 ml. 2% IBA

Here again 3-indolebutyric acid is used as an example.

The IBA is dissolved in approximately 700 ml. of 70% isopropyl alcohol and the remaining 70 ml. is used to carefully rinse the IBA container. The rinse is added to the IBA solution. To this solution is added 230 ml. distilled water, and again the mixture is shaken well.

These processes would apply as well to the incorporation of indoleacetic acid (IAA), naphthaleneacetic acid (NAA) (4), Benlate (5), Captan, boric acid, 2-(2,4,5-trichlorophenoxy) propionic acid, etc. Although 2,4,5-TP is used primarily as an herbicide, very minute quantities have been used in rooting compounds.

Obviously, now, a mixture of 1 part (500 ml.) of 2% IBA solution and 1 part (500 ml.) of 50% alcohol will give 1000 ml. of 1% IBA solution. A further 1:1 reduction of this would give 0.5% IBA and a further 1:1 reduction of this would give a 0.25% IBA solution.

Here, again, is the "rhododendron formula", this time to be prepared as a concentrated dip. The mixture produces a solution the consistency of milk; and if shaken often while using, it is quite acceptable.

To make 1 liter (1,000 ml.) of 1% IBA with 5% Benlate and 50 ppm boric acid

Add 10 gms. IBA to 770 ml. 70% isopropyl alcohol

Add 50 mg. boric acid (USP)

Add 100 gms. Benlate

Mix well and add 230 ml. distilled water.

Each stock solution of a given concentration should be stored in a well-marked container; a milk jug or anti-freeze jug serves well. The solutions should be sealed and refrigerated when not in use. A smaller container (a pint bottle serves well), is used to hold the stock solution to be used. A wide mouth plastic medicine bottle is used to hold the solution into which the cuttings are dipped. The solution from this container should never be returned to stock solution bottles. This is to prevent contamination of the stock solution or accidental mixing of different concentrations of stock solution. Another simple step to be taken to prevent accidental mixing is the addition of vegetable food dyes of different colors to different concentrations of different mixtures. This greatly facilitates the use of several solutions during a given period by unskilled workers.

My first dramatic experience in comparing results given by different concentrations on a specific crop involved *Acer palmatum* 'Atropurpureum'. We were using 0.8% and 2% IBA in talc and could only get very long single or double roots from the very base of the cutting, even with heavy wounding. These, of course, broke off easily during handling or potting. We tried a quick dip of 0.5% IBA, 1% IBA and 2% IBA in alcohol, and found that 2% IBA would stimulate good root initiation all along the stem of the cutting.

As Wain (6) has pointed out, the concentration of hormone or hormone-type substances which most actively produces roots is that concentration closest to the toxic level. I have noticed that concentrations which produce good adventitious root initiation will often burn and kill the plant tissue at the very base of the cutting, but will produce a superior root system just above this area. Conversely, it has been my experience that a concentration too low will sometimes produce a large callus formation with very few adventitious roots initiated. When the concentration is correct, we have very little callus but strong roots. We feel that hormone concentration affects callus formation more than the water level in the medium.

Whalley (7) indicates that the addition of 2-(2,4,5-trichlorophenoxy) propionic acid (2,4,5-TP) at low concentrations (0.1 ppm) will reduce auxin burn and will, therefore, let us use higher concentrations of rooting hormones on difficult plants. Our actual procedure includes wounding as well as a dip into Benlate, Clorox, or other fungicides. The cuttings should be drained before dipping in hormone in order to avoid dilution of the material. We feel wounding increases the absorptive surface of the cutting.

There is still much to be learned about the effects of different combinations and different strengths of rooting hormones on the plants being rooted.

These simple procedures will afford you the convenience of having on hand a wide range of combinations and concentrations of rooting hormones.

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COSTING AS A MOTIVATIONAL TOOL

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Hamilton, Mississippi 39746

Can costs be effectively tracked in the nursery business? How can tracking costs help you on an everyday basis? How often do you take a look at costs? How about your supervisors? Why budget? Who creates your budget?

These are some questions I want to deal with here today. I have had the privilege of working side by side for the past two years with a CPA. He has devoted the last 8 years to developing and refining a cost accounting system that is simple enough to give daily information in running a nursery business and motivating supervisors in a positive way.

At American Garden Cole, budgeting and reporting are a way of life. If no useful benefit comes from this effort at the branch level and by the people reporting, this becomes a burdensome task.

American Garden Cole (Hamilton) is a container growing facility that has been developing over the past five years. The *motivational* aspect of costing actually begins with the preparing of a budget for the next fiscal year. Our budget is prepared by the people actually responsible for the work. For example, the pesticide budget is prepared by the man in charge of all spraying, the herbicide budget by the man in charge of weed control. Labor is budgeted by comparing past performance and looking at new methods and changes in procedures. With all these "numbers" in and budget approved, we begin to track our costs on a daily or weekly basis and compare with what we said we would do.

Now of course, you have other benefits from budgeting, too. For example, cash flow requirements are easily determined. But

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COSTING AS A MOTIVATIONAL TOOL

EARL H. ROBINSON

American Garden Cole
Hamilton, Mississippi 39746

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Now of course, you have other benefits from budgeting, too. For example, cash flow requirements are easily determined. But from a production standpoint the greatest aid is in knowing what costs are running compared with a given goal in regard to labor. We now have a sound basis for praise, bonus incentives, or looking into problem areas before they get out of hand. We use the following forms to record field information:

1. Foreman's Daily Report — gives time spent on the various activities, each of which is given a simple code.
2. Secretary's Summary — hourly rates are computed to each cost, or operation.
3. Secretary's Weekly Summary — hours and dollars are summarized.
4. Secretary's Weekly Comparison of Actuals to Budget — face the music.
5. Secretary's Daily Comparison of Unit Cost for Production — costs are given for cuttings, potting and canning.
6. Month End Reports — the overall status of our operation is summarized.

As you can see the only demand on our skilled men is on the daily report. This form, as well as all others, has been designed by Bill Yarbrough, our comptroller (CPA), for simplicity and ease of using them.

Seldom are we right on target. The variances are discussed to see what is causing the difference, particularly when unfavorable, as we need to make changes at once.

All our supervisors enjoy helping to "build" the budget and are eager to see the results when we start comparing our "actuals" to what we said we would do.

Our system is such that we do not spend a great deal of time in hunting this information; it flows rather smoothly as long as everyone follows through. Actually the management and control of spending is transferred to more people. In this way the people in control are on the firing line and can make needed adjustments as they go.

As you no doubt have gathered, we have been dealing primarily with costing labor, and the reason for this is that labor is our biggest cost and where the most savings can be realized. The cost of containers, soil mix amendments, pesticides and fertilizers are all generally fixed. We do need to use them efficiently and effectively, and buy right, but this will not affect cost to the same extent as efficient management of labor.

Now, let's answer the questions:

1. Can you effectively track costs in the nursery business? Yes, by using simple systems and an uncomplicated means of reporting what is happening.

2. How can tracking costs help you on an everyday basis? I think that by keeping up with unit costs of production on a daily basis it is possible to know the status of your operation at all times. It certainly aids supervisors to assist in the control of these costs as they work *with* you.

3. How often do *you* take a look at costs? How about your supervisors? I will answer this from my experience. We look at unit costs of production daily; that is cuttings, potting and canning. All other costs for labor we examine weekly. Monthly we study over-all performance, which includes purchases of supplies and services.

4. Why budget? Who creates your budget? Again, from my standpoint, we budget to have some idea where we are going and what it *should* cost to get there. Budgeting also gives a measure with which to compare our performance as we go. Our budget is prepared by all supervisors contributing from their vantage point.

The objective from a motivational standpoint for budgeting and costing is to get everybody involved that is going to participate in controlling costs. Objectives established by responsible people are as effective a motivational tool as I have found. They will make every effort to accomplish the goals they have helped establish.

Bonus incentives, if desired by management, can be based on reaching these goals at year end or throughout the year at definite time intervals.

PRODUCTION OF LINERS FOR FIELD CULTURE

DENNIS V. McCLOSKEY

Windmill Nurseries, Inc.
Franklinton, Louisiana 70438

There are numerous ways to root cuttings and germinate seed — most of you have selected a method that is most productive and profitable for your business.

This morning I would like to explain the method we use at Windmill Nurseries to produce liners and to transplant these to our field. All of our broadleaf liner production for the field is handled as follows:

First: The cuttings are rooted in metal flats or seed is germinated in flats. Our medium is composed of 17 4-cubic foot bags of perlite and one 6-cubic foot bale of peat moss. Depending on cultivar, from 150 to 500 cuttings are placed in each flat. Women do all of this work on an hourly wage basis. They take, strip and stick the cuttings. I am satisfied with a 2000 per day

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Second: The flats of cuttings are placed in the mist houses and handled accordingly. I will not go into detail as this subject has been discussed in other papers.

Third: After the cutting has rooted, we move the flat out of the mist house as soon as weather permits.

Fourth: The next step is potting the rooted cutting or seedling into either a 3 or 4-inch pot, pint or quart container, depending upon what cultivar is being potted. We are presently changing so that all liners for field use will be potted in no smaller than a pint container. Some items will be grown in quarts. Our reason for changing is that the most critical time for a young field plant is from the 2 to 6-inch stage. Cultivation damage is highest at this time. The larger liner is more able to withstand mechanical abuses.

At this point in the process, the potters are on a piece work schedule of 1-1/4 cents per 3-inch pot, or 1-1/2 cents per 4-inch pot, pint or quarter container. The worker pots the cutting or seedling and places the pots in flats and sets the flats in beds. Each flat holds 30 three-inch pots per flat or 20 pints per flat. Generally the liner is grown for one season in this container.

The potting medium is composed of 80% pine bark, 20% sand, 8 pounds dolomitic lime, 11 pounds Sta-Green Soil Mix number 3, and 10 pounds of 18-6-12 Osmocote are added per yard. Our bark is fine; it has been aged 5 to 8 months and run through a hammermill. The sand is directly out of a gravel pit unscreened and may contain some pea gravel.

Going to the field: We do not limit our field planting to any set time. Being on the border of Zones 8 and 9, 50 miles north of New Orleans, a major effort is made to plant our potted liners in September, October, and/or November. In the winter of 1976-77 we had 18 nights less than 20°F. It got down to 10°F, which is extremely unusual for us. During a normal winter, the temperature drops to the mid 20's a few nights. We ordinarily do not provide wind protection, although during the winter of 1976-77 we did have considerable damage on podocarpus and viburnum that we failed to protect properly.

The next step is to prepare the area in which we will plant. After chisel plowing to a depth of 20 inches, the land is then bottom plowed, disced and leveled with a harrow. A 60-inch Howard Rotavator, with a homemade bed shaper, then builds the row. It takes a 70 horsepower tractor to pull this. It leaves a well-tilled bed. A converted pine seedling planter is then used to plant the liners on 24-inch centers. This distance varies with the type of plant being planted. A two-man crew can plant 8000 to 10,000 plants per day. Standard cultivation then follows.

Alternate liner production method: On some limited cultivars we stick the cutting in a pot using our regular soil mix, which does contain fertilizer. We force grow these cuttings in heated houses and use them for late spring planting the last of April or the first of May. We have used a multipot tray; however, we are not particularly fond of it. Although it is a very durable product, the roots tend to grow out of the bottom, making it very difficult to remove the cutting. We prefer putting the cutting directly in a single pot. Even if the root grows out the bottom, it does not damage an entire flat of cuttings to remove it. At transplanting time, liners produced in pots will be handled in the same way as those rooted in flats.

CHARLIE PARKERSON: How long have you been using pine bark medium with your liner production going out to the field? How many more years will it be before you root everything in pots?

DENNIS McCLOSKEY: The nursery is 16 years old and we have been rooting in pine bark for 15 years. We may never go completely to pots because of the space problem. We are trying to grow 750,000 liners a year for use in our container and field production. This would require a tremendous amount of space. The space problem is magnified if we use the larger pint or quart containers, which we prefer. We have very good livability of the potted lners. It is unusual to lose one if it has been properly planted.

ORGANIZING CUTTING, LINER AND CONTAINER PRODUCTION

PETER VAN DER GIESSEN

Cottage Hill Nursery, Inc.
Irvington, Alabama 36544

Organization is the key word in production of cuttings, liners and containers at Cottage Hill Nursery. Without this many hours are wasted and it is nearly impossible to come up with a balanced production. About 3 years ago we began by dividing the nursery into sections, each designated by a letter. So instead of sending people to a general area we are now able to give them the exact location. Each section was divided into terraces, which were numbered. We figured the capacity of each terrace in order to know the total capacity of a section. The lath and the type of plant being planted. A two-man crew can plant 8000 to 10,000 plants per day. Standard cultivation then follows.

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Another step to cut down on wasted motion was labeling each group of plants so that everyone would know where to find the information in the field. The label on the first plant on the left hand side of each cultivar gives such information as number of plants, plant name, potting date, soil mix and feeding. Not only did this cut down on labor, but it gave us information at a glance when we were in the field.

The number of plants per terrace presented a problem. We did not know the total number of plants a terrace held, and we simply filled it up leaving 15 inch walks in between beds. When time came to space these plants, we often had to carry them to the opposite side of the nursery at great expense in labor and wasted motion. Today all beds are of equal width. the distance between the left corner of the first and the left corner of the second bed is 7-1/2 feet. This leaves rather wide aisles when plants are set pot/pot in rows of five 1 gallon plants, four 2 gallon, and two 3 gallon.

When these plants are spaced, the beds are 6 feet wide with an 18 inch walk between each bed. We save both labor and money by spacing out on the same terrace. We make an exception to this when we pot 1 gallon cans for future shifting into 3 gallon, then the entire terrace is filled — leaving 18 inch walks. At the time of shifting we leave the exact number of plants needed to space that terrace, the remainder is loaded on the wagons and taken to the area where the three gallon are to be potted. These three procedures, I feel, have helped a great deal in cutting down operating cost.

Monthly and weekly worksheets are another part of organized production. Each month a master worksheet is made which lists all the work anticipated for that month. Information pertaining to the production is brought into the office and recorded on index cards. These cards give information including number of plants potted, size container, location, date and soil mix. From these cards we project future production in liners and containers using our sales records as a cross index. In most cases we take cuttings from plants which still have a full season of growing ahead, preferably in 2 or 3 gallon containers.

Up to a few years ago, cuttings were stuck in flats, rooted and transplanted in 3-inch and 3-1/2-inch pots. Today nearly all cuttings are stuck directly into 3-1/2-inch pots. The advantage here is a great saving in labor and a better quality plant. When we were rooting in flats, a house held 400,000 cuttings; or if we used cell packs, a house held 140,000 cuttings. Timing here was extremely important. If we left the cuttings too long in the flats, the roots became entwined, the plants grew too leggy, and often became too hard. A great many cuttings were discarded because of these conditions. The capacity of a house filled with 3-1/2-inch pots is 42,000 plants. Rooting directly in the pot gave us a space problem, but we took care of this by adding a few more houses. Once the house is filled, there is no more shifting until the plants are sorted, packed and shipped. The losses were reduced and the quality of the plants improved noticeably.

All of these changes were made through planning and organizing. Future plans call for: semi-automatic watering, boom spraying in the greenhouses with a tractor, and propagation in open beds without shade. All of you here have a system. Some are on a computerized program, but all spell out the same thing — organization. Any system needs an overhaul now and then to update its operating methods. Constant planning and organizing are key factors in the success of any operation.

FIELD PRODUCTION OF AZALEAS

ROB HOLLINGS

Carolina Floral Nursery
Monck Corner, South Carolina

Our method of field production of azaleas at Carolina Floral Nursery spans a time of about 18 months from when the liner is first planted until the finished plant is ready about two growing seasons later. We typically begin planting on the first Monday following the 20th of April.

Bed preparation is a very important process. In the summer preceding the spring planting, we apply limestone to the field at the rate of about 1000 to 3000 pounds per acre. Following that we plant a cover crop of sorghum, usually in August. Sorghum will get 7 or 8 feet tall in a matter of months. The purpose of planting sorghum is to put a lot of organic matter into the ground. Once we dig the azaleas, we must replace as much organic matter as possible. During the winter, we disc the field 3, 4 or maybe 5 times and also subsoil it. Subsoiling is really a very important step in this production to break up the pan that builds up year after year and allow drainage. Furthermore, cracking this hardpan allows moisture from underneath to rise to the surface level of the soil in summer months. After subsoiling, we contract for fumigation of the field with an application of methyl bromide. The tractor rolls ahead injecting methyl bromide down into the soil, and we follow immediately behind, covering the entire field with plastic. We find this gives us field soil that is completely free of insects and most weed seeds.

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There are a few seeds, however, that are tough and are not killed by methyl bromide. It also seems to help eliminate a lot of the root rot fungi. We disc and aerate the soil after the methyl bromide has been on for at least 48 hours.

The layout of the beds is our next step. We allow an 80 inch center from alley to alley, which allows for a 5 foot bed and a 20 inch alley to accommodate the tractor tires and equipment. The first step in laying off the bed is to put a pair of middlebusters on the tractor and mark off 5 foot increments down the row the way the beds are running. This helps to define the bed. The next step is to pull a pair of tiller discs through the field. This process throws the soil in the air and piles it up on the bed. The key ingredient of field production is the alley. You can prepare beds, take liners into the field, spray, fertilize, and harvest using equipment pulled through the field. One of our important, and we think unique, pieces of equipment is a modified manure spreader. It will hold about 8 yards of material, and has an adjustable gate. The rate of application can also be controlled by the speed of the tractor. We vary the amount of pine bark and peat according to the density and drainage of the soil. Standard application should be about 3 inches of pine bark and 3 inches of peat. If the soil is heavier, we may add two runs of bark, the second about half as much as the first run. Over this we apply a low nitrogen fertilizer, about 80 pounds to the 2000 square foot bed, or 2 pounds per 100 square feet. We also add about 20 pounds of castor bean meal to 100 pounds of fertilizer to discourage ground moles that can ruin a bed. On top of the fertilizer we add about 75 to 100 pounds of slag in addition to the lime we put on the field the preceding summer. We have found a pH between 5.5 and 6.0 to be ideal for a deep root system on azaleas. Following this we lightly irrigate the soil to improve the workability and prevent peat and bark from blowing in the alleys. We then rototill the beds to a depth of 6 or 8 inches. We have cut an arch in the cowl with a 3 or 4 inch rise in the center. This allows for contour of the bed to be shaped as the tiller passes over the bed. We feel drainage of azaleas is very important. The rounded shape of the bed prevents a slump as the bed weathers over the next 2 years.

The last step in preparing the beds is to roll them. We have a custom-built drum that is again 5 feet wide; the middle of the drum is squeezed slightly so when it is placed on the bed it will follow the contour and lightly pack it. A series of 5 hoses are attached to the drum in order to make longitudinal marks down the bed as a guide for planting.

Two of the 3 elements for good azalea growth are in the beds at this point. We feel the bed has good nutritional quality and good drainage capacity. The other important element is water. Azaleas need water, but they must also have good drainage.

At planting we start with liners out of the greenhouse. If a liner does not have a good root system, it is discarded. Liners are carried to the field on a tractor. A person on the back of the tractor drops the liners along a line. Three or 4 people use trowels to plant the liners. Two people follow these planters and level the bed with their hands starting at the outside edge and working towards the center. We feel that this helps maintain the contour of the beds and prevents sinking in the middle. In a good day of planting, we might get 18,000 to 20,000 liners in the ground. We use a Skinner irrigation system (no longer available) which applies water in a square pattern. We make sure the liners are not planted too deeply; we like them planted at the same level they were in the propagation medium. Soil is firmed around the liner as it is planted. The first watering-in is the most important. We make certain all the material we have added is absolutely wet by watering for several hours. For two year growth of an azalea, we plant on 12-inch staggered centers. We do plant some on 10 inch centers, not staggered, with 6 azaleas across the bed. We can grow these plants for one year, dig them in the winter when we have time, and pot them up.

In the past we have mulched with pine straw. Pine straw worked well, but it was not economically feasible as it took 2 weeks to rake straw. We have found that a light layer of dime to quarter size pine bark makes a very good mulch that will not settle out or shed water, but allows water to fall through.

The single greatest expense in growing azaleas in the field is weeding. We weed both in the one and two year stage. The methyl bromide treatment keeps the field very clean for 6 weeks or so in the one year stage. Starting sometime in mid-June we treat that field just like a second year crop. Weeding requires an average of 140 work-hours a week per field. As soon as the 6 to 8 workers weed the one year old crop, they go to the 2 year old field, then back to the one year old crop, etc. until the beginning of September. Recently we have inaugurated a program of chemical weed control using Roundup in all areas, including alleys, ditch banks, bed ends and roadsides in addition to our regular mowing program.

Pruning azaleas is another important aspect. We do this to encourage compact growth in both 1 and 2 year old plants. One year plants are lightly shaped in mid-July to remove rank growth. Liners can be pruned while they are still on the bench, but if they are not ready this must be done later in the field. Some we mechanically prune and use Off-Shoot-O while we let others grows out. The landscape demand is not for as tight and compact a plant as is florist demand, so our method is determined both by cultivar and ultimate market.

Another important element of our field production is our fertilization program. Sometime in early June when visual inspection of plants indicates it is necessary, we give an application of Sta-green 12-6-6. A second feeding follows usually about mid-July. We use about 80 pounds to each bed or about 4 pounds per 100 square feet. In the past we have fertilized our one year crop with a Vertagreen quick release 8-8-8 lawn and turf fertilizer before the end of August. The theory was that the plants could take up the fertilizer before it leached out, and growth would slow up and harden off before the advent of cold weather. However, we have decided to discontinue this quick release feeding. At the end of August we are going to a very light application of slow release 12-6-6, about 2 pounds per 100 square feet, which will not push the plants. When the temperature drops, the plants slow up, but they maintain a very good color and healthy appearance.

The final element in our field production of azaleas is winter protection. We place hoops of 3/4 inch conduit over the beds at 10 to 12 foot intervals. We then stretch a 6 foot wide piece of Saran shadecloth from the first pipe the whole length of the bed, and wire it down. We take care to pull the Saran down on the east side where the sun first hits the plants. This is to avoid a quick thaw of the leaf tissue, which is what we feel does the damage. Additional elements of field winter protection include maintaining a good nutritional balance in the field, and keeping the plants well watered. If we know a freeze is coming, we water the bed thoroughly. We feel that a well watered plant can survive the cold much better than one lacking water.

PRUNING AND TRAINING OF ORNAMENTAL NURSERY TREES

WILLIAM R. STUDEBAKER

Studebaker Nurseries, Inc.
New Carlisle, Ohio 45344

All of you know how to prune a tree. There are many books on the theory of correct pruning and training, from the proper cutting angle, to developing main scaffold branches, to the proper time of year to prune. The problem in most nurseries is that you don't have time to trim all or any of your trees yourself, and furthermore may not have time to spend several seasons working with someone, teaching them by example how to prune. What I would like to focus on today is developing some compact a plant as is florist demand, so our method is determined both by cultivar and ultimate market.

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Studebaker Nurseries, Inc.
New Carlisle, Ohio 45344

All of you know how to prune a tree. There are many books on the theory of correct pruning and training, from the proper cutting angle, to developing main scaffold branches, to the proper time of year to prune. The problem in most nurseries is that you don't have time to trim all or any of your trees yourself, and furthermore may not have time to spend several seasons working with someone, teaching them by example how to prune. What I would like to focus on today is developing some training aids to assist inexperienced pruners to do an acceptable job of pruning by your standards.

So first of all, what are your standards? You need to analyze:

1. What is your market? Homeowners want full-headed low-branched trees for the corner of the yard, while municipalities want street trees limbed up 5 to 6 feet for clearance.

2. At what size are you selling? A 1-1/4-inch tree limbed to 6-foot height may have few, if any, lateral branches left to form a head.

3. What are some growth characteristics of a particular species that almost always require corrections? For example, Norway maples often develop double leaders, and honeylocusts characteristically have excessive growth.

4. What action needs to be taken to get the desired finished production? That is, what should be the limbing up height at different tree calipers?

5. And, most importantly, what *guidelines* must you give fledgling pruners to get the *correct action* so that you get the *desired* finished product? This is the area where the communication with the pruning crew most often breaks down.

We have developed a handout to aid in this communication at our nursery. There is nothing sacred about the contents of this handout. Each of you would have different contents depending upon how you defined your standards of finished product, as we previously discussed. This handout was merely a result of my trying to analyze, back in October, 1975, exactly how I went about pruning a tree to get the effect I wanted. In addition, I tried to record some of the characteristics common to each species that often needed correcting. The handout has since been revised a couple of times and needs constant revision as new species and cultivars are added, as the market changes, and as more mistakes are invented by the people doing the pruning. (See appendix.)

We have a varied market. We sell trees from 1-1/4 inch to 4 inch caliper for residential as well as street planting. As for now, we don't designate at planting which trees are to be marketed at which size or for which type of market, although we are beginning to move in that direction. So we limb up the trees gradually, a little more each year as they develop caliper. This gives a well balanced tree at any size and avoids removing too large a branch at any one time. We try to obtain a limb-up height which is not too high for a homeowner, yet is high enough that the removal of just a few more branches will make the trees acceptable for street use. We also try to develop a central leader and a dense branching habit that will be attractive as a 4 to 5 inch tree without sacrificing the balance and eye appeal of the younger tree. This is important since it may be sold at 1-1/2 inch or at 2 inch caliper.

The appendix is divided into two parts, one on limbing up and one on top pruning. As you can see, the limb-up heights are given for groups of genera, species, and cultivars, by age or caliper. Some exceptions are also given. For example, trees should not be limbed up more than one half of the height, and spindly or whippy trees would have the height reduced. It is important to give the pruning crew measuring sticks — "eyeball technique" hasn't proven too successful although that is how the correct heights were originally determined.

The second part of the appendix consists of notes on certain species and cultivars that require special attention apart from the normal structural pruning. It is also important to develop a list of specific mistakes a new person may make and have this available for the crew leader. This would include such things as cutting with the wrong side of the shears next to the trunk of the tree, cutting too close or too far away from trunk of the tree, using poor judgment on the exceptions to limb-up rules and limbing up trees grown intentionally low branched.

As mentioned earlier, techniques may vary some from nursery to nursery, depending on the product desired. I would like to mention a few specific points about techniques to use.

The types of pruning shears are chosen to fit the particular job and size of material. The rachet type is used for pruning large tree roots before planting in the field. They do not make a clean cut and should not be used on the top of a tree.

We find that locusts require the most pruning. It is especially important on these trees to prune close to the bud and on a slant as the stub will die back to a bud. We try to eliminate double leaders.

Top pruning of larger trees is done with a combination of pruners and a fork lift. Working from the ground with long poles is very tiring, and it is nearly impossible to cut close to the bud. Even though two people are required using the fork lift, the work can be done much more effectively and efficiently.

Some trees that are planted as whips tend to get rangy. We try to leave some feathery growth on the trunks to encourage caliper growth. This growth is removed before it reaches pencil thickness.

It is important to emphasize that the distance a cut is made from the main stem is critical when removing side branches.

There is only about 1/16 inch difference between the location of a correct and an incorrect cut.

My main point is: Do not assume that your people know intuitively the way you want a tree pruned! Spell out the procedure in detail. Most employees can learn to prune a tree acceptably. The handout will not teach these people to prune, but we consider it an important aid in the learning process.

APPENDIX

Limbing Up Height

	1 yr.	2 yr.	1-3/4", 2"	2-1/2", 3"	3-1/1", 4"
Acer spp., *Quercus* spp., *Ginkgo* sp., *Gleditsia triacanthos* 'Imperial', *G. triacanthos* 'Sunburst'	48"	48"	48"+	54"	60"
Tilia spp.	42-48"	42-48"	48"+	54"	60"
Gleditsia sp., *Fraxinus* spp., *Platanus* sp.	48"	48"	54"	60"	72"
Gleditsia sp. (whips only)	42"				
Liriodendron sp.	42"	48"	48"	54"	60"
Liquidambar sp.	42"	42"	42-48"	54"	60"
Sorbus sp., *Betula* sp., *Pyrus calleryana* 'Bradford'	36"	36-38"	40-42"	48"	
Malus sp.-broad upright, *Crataegus* spp., *Prunus cerasifera* 'Thundercloud', *Pyrus calleryana fauriei*	30"	30"	36"	42"	
Malus × *atrosanguinea*, *M. floribunda* & *M.* 'Bob White'	24"	24"	24-30"	30"	
Malus 'Mary Potter', *M. sargentii* 'Rosea', *M.* 'Van Eseltine', *Eleagnus* sp.	24"	24"	24-30"	30"	
Malus 'Red Jade', *M.* 'Oekonomierat Echtermeyer', *Betula pendula verrucosa* 'Youngii'	Limb up only high enough that the tips of branches do not quite touch the ground.				

Notes to Limbing Up

1. Do not limb up more than one half of the height, *i.e.*, on short trees you cannot limb up to height shown.
2. On spindly or whippy trees, leave branches 6" to 1' lower than indicates.
3. Don't measure from top of soil ridge when it is extra high but rather from prevailing ground level.
4. For branches that are close to the cut-off height, whether to cut or not depends on the branch caliper relative to the main stem caliper. In general, if the branch's caliper is 1/2 or more of the main stem caliper, remove it.
5. As you limb up to a certain height one year, keep in mind what height the branches on that tree will be limbed up to the next year or two. You may need to do some corrective pruning on strong lower branches that grow close enough to the main stem to inhibit the growth of young branches from the stem.

General Pruning Notes

1. Summer pruning — work on leader, limb up and correct branching (locust and ash head back in summer also).
2. Winter pruning — head back and work on branching.
3. Locust — Heading Back
   (A) In the late spring and summer as the trees get about 18 inches of new growth, remove approximately 1/2 of new growth on young trees up to 1-1/2 inches, 1/3 of new growth on 1-1/2 inches and 1-3/4 inches, less than 1/3 and spot prune on 2 inch and up. Repeat with each flush of growth.
   (B) Prune more off each branch the higher it is in the tree so you get a broad pyramidal growth habit.
4. Prune out any dead branches 2 to 3 inches behind the dead part.

Special Varietal Notes

Acer platanoides cultivars

Often have one or two branches too long, strong and out of balance — so cut back; cut to single leader.

Acer rubrum cultivars

Cut to single leader (almost always double)

Crataegus

Crataegus oxyacantha superba 'Crimson Cloud' (P.P. 2679) needs heading back severely. Do not try to establish a leader and do not thin out too much.

Fraxinus

Fraxinus pennsylvanica var. *lanceolata* 'Marshall' — Needs to be headed back. Cut to central leader.

Fraxinus excelsior 'Hessei'-Head back somewhat. Often has just one or two strong growing branches.

Gleditsia triacanthos cultivars (General notes)

Needs heading back.

Watch for bad (too narrow) crotches and correct.

Prune to bud where possible, inside or outside depending on direction you want new branch to take.

Cut back any lower branch tending to dominate leader.

In general, prune from the upper branches to the lower branches (*i.e.*, the upper ones first).

In general, prune 1-1/2 inches and below hard, 1-3/4 inches moderately, 2 inches and above prune very lightly.

'Imperial' — A globe headed tree. Do not try to shape like a 'Skyline'. Do not worry about a central leader, just keep branches from becoming too rangy.

'Skyline' r (P.P. 1619) — Pyramidal shape. Do not prune lower branches too severely in relation to top branches.

'Sunburst' r — Tends to become rangy. Prune 2-3 times lightly in summer.

'Green Glory' (P.P. 2786) — Broad oval shape, strong grower. Do not prune upper or lower branches too severely in relation to each other. Top leader must be cut back as it grows too vigorously.

'Moraine' T.M. — broad oval shape. Similar in habit to 'Green Glory', only not quite as vigorous.

Malus

Malus × *atrosanguinea* and *M. floribunda* — head back; reduce clutter or thin out some branches.

M. 'Inglis' — Head back severely, especially lower branches in young trees.

M. 'Van Eseltine' — should be narrow upright — but top the young trees to encourage fullness.

Prunus subhirtella 'Pendula' — Watch for one or two strong shoots that aren't weeping.

Quercus species

- Work hard to get a central leader
- Head back the occasional wild branch.
- Lift branches

Tilia species

- Watch for leader bent over; prune back to straight bud.
- *Tilia cordata* and *T. cordata* 'Greenspire' (P.P. 2086) — Occasionally head back some branches.
- Thin out branches from main stem at least 6-8 inches apart vertically or 120° radially. Prune to central leader. Watch for bad crotch and correct.
- *Tilia × euchlora* — Head back. Thin out some branches. Watch bad crotches.
- *Tilia × euchlora* 'Redmond' — Head back, especially strong lower branches which tend to crowd main stem and inhibit lateral branching from main stem.
- Trim to outside bud since these strong branches tend to grow tight to stem.

HOW SOIL CHEMISTRY CAN WORK FOR YOU

GEORGE R. McVEY

O.M. Scott & Sons
Marysville, Ohio

Developing maximum plant quality with minimum cost can only be realized by proper monitoring of the nutrient level in the soil. An understanding of the optimum nutrient levels and balance in the soil will prevent "hidden hunger" or phytotoxicity, which can happen to even the best grower of containerized nursery stock.

Proper selection of media is essential. A guaranteed supply of uniform ingredients (media and fertilizer) which will provide proper drainage and porosity is needed. Media containing heavy metals or other toxic compounds should be avoided.

A representative sample of each component in the mix and a composite sample of the final mixture, before any nutrients are added, should be submitted for analysis. The analysis of the individual components will provide information on which fraction is providing the most nutrients to the final product. Nutrients should be added to the medium based on the soil analysis. Excess or deficiency of nutrients can cause an imbalance, which can result in abnormal plant growth. The optimum balance of cations (H, K, Mg, Ca and Na) for maximum growth is shown in Table 1.

Modifying the soil chemistry in the medium prior to planting is the ideal time to make adjustments. Topdress applications are time consuming and are less effective. The pH and

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Modifying the soil chemistry in the medium prior to planting is the ideal time to make adjustments. Topdress applications are time consuming and are less effective. The pH and

Table 1. Cation Exchange Capacity (CEC) and optimum balance of cations for maximum nutrient uptake.

CEC Range	Optimum % Base Saturation				
	H[1]	K	Mg	Ca[1]	Na
0 - 5	0-5	6.8-7.0	15-20	65-75	0-5
5 -10	0-5	6.0-7.0	15-20	65-75	0-5
10 - 15	0-5	5.0-7.0	15-20	65-75	0-5
15 - 20	0-5	3.0-7.0	15-20	65-75	0-5
20+	0-5	2.0-7.0	15-20	65-75	0-5

[1] For ericacious plants the optimum range for hydrogen will increase to 15-25 and the optimum range for calcium will drop to 50-65.

nutrient level can be maintained for a number of months after potting if proper nutrients are selected.

Selection of the nutrient ranges which result in poor, good and excellent growth have been under evaluation at Scotts using many soil mixtures and locations throughout the U.S. and Canada. These ranges provide guidelines for proper fertilization programs and practices. Interpretation of the results requires some experience, however.

Sampling Procedures. Prior to potting, a representative sample of the medium can be obtained by collecting a grab sample from 15 to 20 locations in the stack. Mix these samples vigorously in a clean plastic bucket, then remove a one pound sample for analysis.

After potting, sampling frequency will vary depending on the objectives. It is advisable to follow pH, buffer pH, NO_3 and soluble salts on a 2 to 3 week basis. Analysis of major, secondary and minor elements can be done less frequently (every 3 to 4 months) unless nutrient deficiencies or excesses are expected, then the frequency should be tightened up (every month). Collect a minimum of 10 soil samples from the area in question. Remove the pot from the soil ball and select a soil sample as close to the middle of the ball as possible. Place the soil samples in a clean plastic bucket, mix vigorously, and remove one pound of soil for analysis.

Soil Analysis. Select a reputable soil lab which can provide a short turn around time of the information requested. The nutrient ranges shown below were determined by the following procedures: *If other procedures are followed, the nutrient ranges reported in this paper are not meaningful.*

Nutrient	Procedure
NO_3	Water/specific ion electrode
P	BRAY P-1
K	Neutral ammonium acetate
Ca	Neutral ammonium acetate
Mg	Neutral ammonium acetate
Minors	DTPA

A number of factors should be considered in interpreting soil analysis and making recommendations (Table 2). Other chemical characteristics of major, secondary and minor elements are shown below.

Table 2. Factors to consider in interpreting soil analysis.

pH:	Dramatically affects minor element availability, particularly manganese and iron.
Soluble Salts:	Critical during the establishment phase.
Phosphorus:	Critical during the establishment phase. High levels (100 ppm) can tie up Fe, Mn, Cu and Zn.
Potassium:	High levels (300 ppm) can suppress Ca, Mg, NH_4 and Mn uptake.
Calcium:	High levels (4000 ppm) can suppress K, Mg and B uptake.
Magnesium:	High levels (600 ppm) can suppress K and Ca uptake.
Sodium:	High levels (500 ppm) can suppress K uptake and cause deflocculation of the soil.
Sulfur:	Increases availability of B, Cu, Fe, Mn and Zn.
Zinc:	High levels (12 ppm) can suppress Mn and Fe uptake.
Manganese:	High levels (48 ppm) can suppress Fe uptake.
Copper:	High levels (10 ppm) can suppress Mn and Fe uptake.
Iron:	High levels (50 ppm) can suppress Mn and Zn uptake.
Boron:	Liming strongly acid soils may suppress B uptake. High levels (9 ppm) can be very phytotoxic.

I. Major Elements (See Table 3)

A. *Nitrogen*

1. Soil analysis is of little value unless the chemical extraction is done immediately after sampling since this nutrient fluctuates dramatically during storage.

2. Lime and nitrogen applications should be spaced two weeks apart to avoid nitrogen loss by volatilization.

3. Soil with a low CEC (less than 10) are prone to leaching of nitrates and ammoniacal nitrogen. To avoid leaching losses, use a slow release source of nitrogen.

B. *Phosphorus*

1. Maximum phosphorus availability to the plant is realized between a pH of 6.2 and 6.7. Cool soils (less than 50°F), high levels of iron, manganese, zinc, copper, aluminum, calcium and magnesium reduce phosphorus availability.

2. If phosphorus and lime are in intimate contact, phosphorus availability is greatly reduced.

3. If minor elements are low in the soil, deficiencies can be induced more easily when phosphorus levels are high.

C. *Potassium*

1. Under increased moisture tension (dry soil) the concentration of calcium and magnesium in the soil increases which can depress potassium uptake.

2. Maximum potassium availability occurs above pH 6.0. Below pH 6.0 availability of potassium decreases rapidly.

3. High levels of potassium (300 ppm) can inhibit the uptake of calcium, magnesium, ammonium and manganese, particularly if these elements are low in the soil.

Table 3. N, P & K recommendations for supplementing potting media used for growing woody ornamental plants.

				Corrective Treatments[1]	
				Incorporation	Top Dress
		Range	ppm	lbs/cubic yard	tsp/1 gal. can
Nitrogen	NO_3-N	VL	0-10	6	1-1/2
		L	11-30	4	1
		M	31-50	2	1/2
		H	51-80	0	0
Phosphorus	P	VL	0-6	6	1-1/2
		L	7-12	4	1
		M	13-25	2	1/2
		H	26-50	0	0
Potassium	K	VL	0-22	6	1-1/2
		L	23-45	4	1
		M	46-90	2	1/2
		H	91-181	0	0

[1] Based on 25-10-10. Rates would vary when using another analysis fertilizer.

II. Secondary Elements (See Table 4)

A. *Calcium*

1. If the ratio of calcium/magnesium exceeds 5/1 or calcium/potassium exceeds 20/1 (based on the percent base saturation), additional magnesium and potassium will be needed to counter the high calcium levels which can block potassium and magnesium uptake.

B. *Magnesium*

1. If the ratio of magnesium to potassium is less than 3/1 (based on percent base saturation) then magnesium deficiencies may be induced by potassium suppression of magnesium uptake.

III. Minor Elements (See Tables 5 and 6)

A. *Boron*

1. Under climatic conditions which lead to the development of strongly acid soils, boron is readily leached from the soil.

2. High rates of nitrogen, potassium and lime can induce boron deficiencies.

Table 4. Ca and Mg recommendations for supplementing potting media used for growing woody ornamental plants.

				Corrective Treatments[1]	
				Incorporation	Top Dress
		Range	ppm	lbs./cubic yard	tsp./1 gal. can
Calcium	Ca	VL	0-150	18[2]	3[2]
		L	151-250	12	2
		M	251-500	6	1
		H	501-1500	0	0
Magnesium	Mg	VL	0-62	10[3]	3[3]
		L	63-113	7	2
		M	114-213	3	1
		H	214-362	0	0

[1] If soil is deficient in calcium and magnesium use dolomitic limestone at rates indicated for calcium.
[2] Ag ground limestone (30-40% Ca)
[3] Magnesium sulfate (10% Mg)

B. *Copper*

1. The availability of copper in the soil decreases as the organic content increases.

2. A low level of copper in the soil can prevent the normal uptake of potassium.

3. Plants are more responsive to copper when soil phosphorus levels are medium to low.

C. *Iron*

1. Iron availability is reduced by high soil pH, presence of calcium carbonate, high phosphates, manganese, copper or zinc in the soil or plant, high soil moisture, low soil temperature and soil compaction.

D. *Manganese*

1. Manganese deficiency is more severe on high organic soils during the cool spring particularly if soils are waterlogged.

2. Manganese deficiencies are largely a result of soil pH levels above 6.8, but it can be induced by an imbalance of calcium, magnesium and ferrous iron. In soils with a low CEC (less than 5.0) manganese can leach readily from the soil.

E. *Zinc*

1. Zinc deficiency is often associated with cool, wet spring weather.

2. Overliming can bring about zinc deficiency, particularly on soils high in natural phosphates.

3. Heavy applications of phosphates reduce zinc absorption and translocation.

Table 5. Iron, manganese and zinc recommendations for supplementing potting media used for growing woody ornamental plants.

				Corrective Treatments[1]	
				Incorporation	Top Dress
		Range	ppm	gms./cubic yard[1]	tsp./1 gal. can[2]
Iron	Fe	VL	0-6	80	1
		L	7-12	40	1/2
		M	13-18	20	1/4
		H	19-24	0	0
Manganese	Mn	VL	0-6	32	1
		L	7-12	16	1/2
		M	13-18	8	1/4
		H	19-24	0	0
Zinc	Zn	VL	0-1	36	1
		L	1-2	18	1/2
		M	2-4	9	1/4
		H	4-6	0	0

[1] Use iron sulfate, manganese sulfate and zinc sulfate or a complete minor element package as found in 24-9-9 plus minors. The very low range (VL) can be corrected by the addition of 4# of 24-9-9 plus minors/cubic yard.
[2] To prevent deficiencies use 24-9-9 plus minors.

Table 6. Boron and copper recommendations for supplementing potting media for growing woody ornamental plants.

				Corrective Treatments[1]	
				Incorporation	Top Dress
		Range	ppm	gms./cubic yard	tsp./1 gal. can
Boron	B	VL	0-.20	36	1
		L	0.21-1.00	18	1/2
		M	1.01-3.00	9	1/4
		H	3.01-6.00	0	0
Copper	Cu	VL	0-0.6	32	1
		L	0.61-1.20	16	1/2
		M	1.21-1.80	8	1/4
		H	1.81-2.40	0	0

[1] Use calcium meta borate and copper sulfate or a complete minor element package as found in 24-9-9 plus minors. The very low range (VL) can be corrected by the addition of 4# of 24-9-9 plus minors/cubic yard.

IV. Soluble Salts (See Table 7)

Soluble salt levels (total soluble minerals) can be used as a tool to determine excess or deficiency of nutrients. When the soluble salt level is very low or excessively high, plant growth is often very poor. High salt levels can be leached from the rooting media by heavy watering and low salt levels can be increased by adjusting your fertilization program.

As shown in Table 7, soluble salt ranges vary with plant age. As the plant matures higher soluble salt levels can be tolerated before plant injury occurs.

V. Controlling the pH (See Tables 8 and 9)

Table 7. Soluble salt ranges of potting media used for growing woody ornamental plants.[1]

Range[2]	Seed or Cutting	Seedling or Rooted Cutting	Established Plant
	Millimhos/Cm		
VL	0.01	0.05	0.15
L	0.05	0.15	0.45
M	0.15	0.45	0.90
H	0.45	0.90	1.80
E	0.90	1.80	2.70

[1] Based on 2/1 water/soil extraction
[2] Very low (VL), low (L), medium (M), high (H), excessive (E)

Controlling the pH of the potting medium can be very difficult but if done correctly the rewards are far reaching. It is desirable to incorporate the acidulating or alkalating agent at potting time in order to realize maximum benefit. Surface applications may be essential, however, before the crop matures. If you are using hardwood bark in the potting media, the pH tends to drift to the alkaline side. In addition if you have a source of water which contains calcium, magnesium or sodium, the pH will increase.

Certain nitrogen sources are also acidulating (e.g. ammonium nitrate, ammonium sulfate) while others are alkalating (e.g. potassium nitrate, calcium nitrate). Some slow release sources will drop the pH 1 to 2 pH units while other sources have little impact.

Soil pH can be modified to obtain the pH level desired as shown in Table 8 and 9. If the potting medium contains hardwood bark, acidulating is very difficult.

Table 8. Making soil more acidic.[1,2,3]

Present pH	Desired pH 5.5 Incorporation lbs./cubic yard	5.5 Top Dress tsp./1 gal. can	6.5 Incorporation lbs./cubic yard	6.5 Top Dress tsp./1 gal. can
8.5	3.00	2/3	2.00	2/5
8.0	2.40	1/2	1.50	1/3
7.5	1.80	2/5	1.00	1/4
7.0	1.50	1/3	0.50	1/9
6.5	1.00	1/4	—	—
6.0	0.50	1/9	—	—

[1] Agrisul (90% granular sulfur)
[2] Double the rate if mix contains greater than 50% hardwood bark.
[3] Repeat application every six months until desired pH is obtained.

Table 9. Making soils more alkaline.[1,2]

Buffer pH[3]	Desired pH 5.5 Incorporation lbs./cubic yard	5.5 Top Dress tsp./1 gal. can	Desired pH 6.5 Incorporation lbs./cubic yard	6.5 Top Dress tsp./1 gal. can
7.4	0.0	0	0.0	0
7.2	0.4	1/10	0.5	1/10
7.0	0.7	1/8	1.0	2/10
6.8	1.4	1/4	2.0	3/10
6.6	3.8	7/10	5.4	1.0
6.4	6.1	1.0	8.7	1.4
6.2	8.4	1.4	12.0	2.0
6.0	10.7	1.8	15.3	2.6
5.8	13.1	2.2	18.6	3.2
5.6	15.3	2.7	21.9	3.8
5.4	17.6	3.1	25.2	4.4

[1] Ag ground limestone or dolomitic lime if the soil is low in both calcium and magnesium.
[2] If present pH is less than the desired level, add amount shown above.
[3] Buffer pH measures total soil acidity (H^+ & Al^{+++}) while pH measures H^+ only.

SUMMARY

Information on the nutrient content of soil is of value only when the soil is properly sampled, accurately analyzed and the results correctly interpreted. This report attempts to provide guidelines for interpreting soil analysis results and suggests nutrient sources and rates to correct an imbalance or deficiency of a nutrient.

FIELD FERTILIZATION PRACTICES

DICK AMMON

Ammon Nursery
Burlington, Kentucky 41005

Soils in the Cincinnati area are not ideal for agriculture. They are a clay loam top soil, which is rather shallow, with a heavy clay subsoil that is very slow to percolate. Nurseries in our area are much delayed for spring digging because of the wet soil. Our nursery is located on the highest point in our county. It is slightly rolling ridge land, and still drainage is a problem. The fertility of the soil is poor, and unless we apply ample fertilizer, the nutrients are not there. Now, with all this against our soils, we do find some bright sides. We have no rock until we get 9 feet deep and, if the nursery business is not profitable, the land is very valuable for development! Our biggest claim to fame is that we can successfully transplant trees even in the summer months. We contribute this to the

Table 9. Making soils more alkaline.[1,2]

Buffer pH[3]	Desired pH 5.5		Desired pH 6.5	
	Incorporation lbs./cubic yard	Top Dress tsp./1 gal. can	Incorporation lbs./cubic yard	Top Dress tsp./1 gal. can
7.4	0.0	0	0.0	0
7.2	0.4	1/10	0.5	1/10
7.0	0.7	1/8	1.0	2/10
6.8	1.4	1/4	2.0	3/10
6.6	3.8	7/10	5.4	1.0
6.4	6.1	1.0	8.7	1.4
6.2	8.4	1.4	12.0	2.0
6.0	10.7	1.8	15.3	2.6
5.8	13.1	2.2	18.6	3.2
5.6	15.3	2.7	21.9	3.8
5.4	17.6	3.1	25.2	4.4

[1] Ag ground limestone or dolomitic lime if the soil is low in both calcium and magnesium.
[2] If present pH is less than the desired level, add amount shown above.
[3] Buffer pH measures total soil acidity (H^+ & Al^{+++}) while pH measures H^+ only.

SUMMARY

Information on the nutrient content of soil is of value only when the soil is properly sampled, accurately analyzed and the results correctly interpreted. This report attempts to provide guidelines for interpreting soil analysis results and suggests nutrient sources and rates to correct an imbalance or deficiency of a nutrient.

FIELD FERTILIZATION PRACTICES

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Soils in the Cincinnati area are not ideal for agriculture. They are a clay loam top soil, which is rather shallow, with a heavy clay subsoil that is very slow to percolate. Nurseries in our area are much delayed for spring digging because of the wet soil. Our nursery is located on the highest point in our county. It is slightly rolling ridge land, and still drainage is a problem. The fertility of the soil is poor, and unless we apply ample fertilizer, the nutrients are not there. Now, with all this against our soils, we do find some bright sides. We have no rock until we get 9 feet deep and, if the nursery business is not profitable, the land is very valuable for development! Our biggest claim to fame is that we can successfully transplant trees even in the summer months. We contribute this to the heavy clay soils having nothing to offer any further down. There are ample moisture and nutrients near the surface if we apply them properly, and the root system has no reason to grow a long distance as it does in the sandy and more granular soils. As a result, there is a more compact root system in the ball area.

We produce shade and ornamental trees from one year seedlings grown in close rows and later transplanted as whips or branched trees. We also use whips or branched trees purchased from others, mainly nurseries on the West Coast. Conifer trees are lined out into the field as heavy transplants. Grafted plants such as Hoopsi blue spruce, weeping blue and green spruce, pyramidal and weeping pines, and upright junipers are grown in one gallon containers and lined out into the field when they become heavily rooted in the container.

Before we replant a new field, a green manure crop of sudan grass is planted in late spring. Before the sudan grass is planted we plow under 800 pounds of 4-12-12 fertilizer and 2 tons of ground limestone per acre. When the sudan grass is about 5 feet tall, it is cut with a bush hog mower and allowed to grow back to that height again. In late summer it is again mowed, and we then apply 250 lbs. of ammonium nitrate and 3 tons of gypsum per acre. The soil is subsoiled 24 to 30 inches deep, 3 feet apart in two directions and then plowed about 12 inches deep. This plowed soil lays over the winter and is disced and planted as early as possible in the spring. We prefer 7 to 8 feet size whips or branched shade and ornamental trees for transplanting. The rows are spaced 9 feet apart with the trees set 3 feet apart in the rows. This spacing allows ample room for digging with hydraulic 24 to 30 inch tree spades mounted on a Vermeer T30 tractor or a "Bob Cat" skid loader.

In June we side dress the trees with a 20-5-10 fertilizer that has 50% immediately available nitrogen and 50% slow release nitrogen. This is applied at the rate of 500 pounds per acre, measuring the actual area fertilized, which is a band approximately 3 feet wide. This leaves a space 6 feet wide between the rows that is not fertilized except for the original application plowed under prior to planting the sudan grass. This 6 foot strip is allowed to grow into grass and is kept mowed. The 3 foot strip is kept free of weeds with pre-emergent herbicides (Caseron and Princep). If necessary a post emergent herbicide (Roundup) is also applied. All herbicides are applied in liquid form with a 100 gallon sprayer mounted on the rear of a 140 International tractor. A spray nozzle, which makes a flat spray pattern about 6 inches above the soil, is mounted behind the front right tractor wheel.

The fertilizer is applied through an International side dressing attachment on the 140 International tractor. The tube carrying the fertilizer from the hopper drops the fertilizer in front of a 13 inch disc, which throws the fertilizer in towards the tree and covers it. We go down each side of the row.

In early November, when fall colors are beginning to show, we again side dress with the same fertilizer at the same rate. This method and amount is continued each year until the trees are removed. The trees are harvested as 1-1/2 to 2 inch caliper to 2 to 2-1/2 inch caliper in 3 to 4 years following planting. The field is again planted into sudan grass before it is used for a new crop of trees.

We find the November application of fertilizer is extremely important. By the time the fall colors begin to show, the plants are going into a dormant stage, and there is no danger of getting excessive succulent growth that would probably freeze. However, the roots are still active enough to absorb the nutrients and store them in the plant where they are readily available for the big spring flush of growth. We believe spring-applied fertilizers are usually not available until the big growth period is over.

When applying fertilizer by this method, the disc will build up a ridge in the row. To correct this we use a hydraulic vineyard hoe purchased from Timm Enterprises, Toronto, Canada. This hoe automatically goes in and out between the trees pulling the ridge down and cultivating the soil.

When one-year seedlings are planted in the nursery row, they are spaced 2 feet apart in rows 3 feet apart. These are planted in early spring. The following November, a 20-5-10 fertilizer is applied at the rate of 500 pounds per acre by the use of a cyclone fertilizer mounted on the rear of the tractor. In February or early March these seedlings are cut to 1-1/2 to 2 inches above the soil. As buds are formed in the spring all but one are removed in an attempt to promote one fast growing stem. These trees are cultivated and fertilized again in June at the same rate. At the end of the growing season we hope to have whips approximately 6 to 8 feet to transplant the next spring into 9 foot wide rows. We choose only the select trees to line out into the wide rows. Some types of trees such as pin oak and red oak may take an extra year in the close rows before they are of sufficient size to transplant into the wide rows.

We find it is a problem to get a clean straight trunk if a tree under 6 feet is lined out into the wider spaced rows. However, when we use the right size trees, properly pruned, this method of growing has given us top quality trees.

PHYSIOLOGY OF PLANT TOPS DURING WINTER

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The survival of plants during the winter, or their resistance to low temperatures, is not controlled by any one environmental or physiological factor. Rather it is the combination of a number of environmental factors, both past and present, as they each, or in combination, affect the many physiological processes that interact to produce a plant response. This paper will attempt to cover some of the physiological phenomena which operate in a plant as it acclimates to freezing temperature and resists injury during winter.

Acclimation of plants. Cold acclimation of overwintering plants generally follows a two stage pattern (21). The first stage of plant acclimation to freezing temperatures appears to be induced by short days in late summer and fall (18,19). The first stage of acclimation appears to involve two distinct events; growth cessation and the initiation of the metabolic changes which facilitate the plant's response to low temperatures during the second stage of acclimation. The increase in hardiness during the first stage of acclimation is relatively small, although it may be very significant since just a few degrees of resistance in the fall may make the difference between life and death. The second stage of acclimation is apparently induced by low temperatures. Frost appears to be the triggering stimulus (19), but concurrent metabolic or physiological changes probably are more important in producing a plant which is considerably more resistant to freeze injury than during the first stage of acclimation. Metabolic changes that occur during acclimation affect the level of total protein (2,3,11); the amounts of specific enzymes (6,7,8); the degree of tissue hydration (12); the content of polysaccharides (15,16), sugars (11,13,17), and nucleic acids (2); and the nature of the membranes (15,19).

Studies of the metabolic and physiological changes accompanying hardening have led to several hypotheses on the mechanism of acclimation. Some of the mechanisms proposed are the following: inhibition of the formation of intermolecular disulfide bonds between protein sulfhydryl groups as the cells become dehydrated during freezing (10); sugars replace water in forming protective shells around sensitive proteins (6,7,17); temperature-sensitive cellular components assume more stable configuration (1); specific proteins are synthesized which interact directly with other cell components to protect them from freezing stress (7); reduced hydration of the protoplasm in the autumn increases resistance by reducing the amount of free water available for destructive ice-crystal formation (12); and increased water permeability of membranes in the autumn which permits cellular water to escape to extracellular space (9,14). There are studies of metabolic changes in plants during acclimation which can be interpreted to support most any or all hypotheses which have been proposed. Regardless of the specific mechanism, it is obvious that many physiological changes are associated with acclimation and take place in overwintering plants at a time of the year when we would expect the metabolic machinery to be operating at substantially reduced levels.

Freezing mechanisms in plant tissue. The fact that most plants freeze when their tissue temperatures drop below 0°C is important. When this occurs in tender or herbaceous plants, death usually results; however, after acclimation, hardy plants are able to tolerate extracellular ice formation in their tissues. This ice formation creates a vapor pressure deficit outside the cell and causes water to be slowly withdrawn from the cell into extracellular spaces where it freezes. The more hardy the plant is, the better it is able to tolerate the dehydration or loss of water from the cell. Plants with this type of freezing pattern, such as paper birch, red-osier dogwood, willow, and trembling aspen, can survive experimental freezing temperatures of −196°C when fully acclimated (5). In the temperate climate in which we live, we find plants which can tolerate freezing without injury from the above extreme to only a few degrees below 0°C.

Another means by which plants or plant parts survive freezing temperatures is by avoiding freezing by a process called supercooling. In general, supercooling simply refers to a liquid system which is below its normal freezing point and thus in a metastable state. For example, pure water will supercool without freezing to −38°C in the absence of a heterogeneous nucleating substance on which ice crystals can begin to form. The xylem tissue water of many fully hardy deciduous species has been shown to supercool to −40°C before freezing, even with ice in adjacent bark tissue (4). Floral primordia in *Prunus*, *Rhododendron* and *Vaccinium* flower buds also survive freezing temperatures in this manner and may not freeze when fully hardened until temperatures reach −20 to −30°C (4). In contrast to tissues which survive freezing temperatures by tolerating ice formation in their tissues, ice formation is rapid, intracellular, and causes immediate death to supercooled tissues. Supercooling probably occurs in nature because of a lack of nucleating substances necessary for ice formation within plant cells and because of ice growth barriers of some unknown form between adjacent tissues containing ice crystals and the supercooled tissues.

Mechanisms of cellular injury to plants. *Extracellular ice formation* — Hardiness of most nursery plants is related to tolerance of extracellular ice formation and to the dehydration of particular tissues during this ice formation. In hardy plants the cellular water that is removed during freezing will be absorbed during thawing without loss of metabolic activity or injury. In sensitive tissues, injury is presumed to occur when irreversible changes occur at the cellular level when excessive amounts of water have been removed during extracellular freezing. A number of hypotheses on the exact cause of injury from extracellular ice formation have been proposed but to date no single one has been fully accepted. It must also be pointed out that damage caused by freezing cannot be attributed solely to desiccation. In part, it may result from the mechanical stresses induced by the presence of ice in the tissue or by other direct effects of low temperature such as protein denaturation.

Intracellular ice formation — Injury from intracellular freezing normally occurs as a result of rapid freezing and formation of ice crystals within the cell. This occurs in non-hardy plants and in plant parts that supercool. Mechanical destruction of cell membranes and organelles is probably the most likely result of intracellular ice formation. In any case, once ice has formed within a cell, it is normally killed.

Dessication injury — Probably more nursery plants are winter-killed each year from dehydration of the tops when the root ball is frozen than from either of the mechanisms previously mentioned. This is especially true for container-grown plants whose root ball may freeze readily when subfreezing temperatures are experienced for any length of time. Following this period of freezing temperature the air and leaf temperature may rise above freezing, creating a situation in which water will move from the interior of the leaf to the surrounding air. The movement of water from the leaf to the surrounding air occurs because of a difference in the humidity in intercellular spaces of the leaf (usually 100%) and the humidity of the air. The term ascribed to this difference is vapor pressure deficit (VPD). The greater the VPD the quicker the plant will dehydrate to the point of injury. Air temperature has a marked effect on the VPD since a temperature rise will be accompanied by a decrease in the relative humidity and therefore a greater VPD. Solar radiation will also affect the loss of water from the leaf since absorbed radiation can increase the leaf temperature and thus the immediate temperature surrounding the leaf. Humidity of the air will, of course, directly affect the VPD, but the magnitude of its effect will depend on the air and leaf temperature.

Wind can have a significant effect on the loss of water from the plant since it increases the evaporation from the leaf surface. Of the environmental factors present, wind probably has the greatest effect on water loss from plants. It should be noted that injury to plants due to dessication when the root ball is frozen is similar to injury to plants when extracellular ice formation causes dehydration of plant cells.

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FACTORS AFFECTING PHYSIOLOGY OF ROOTS IN WINTER

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Roots respond to their environment. The greatest response is to temperature with rapid expansion and translocation from 25 to 35°C. As the normal temperature decreases in fall and winter, root activity slows down. Water content of root cells decreases. Sugar and mineral content increases. Roots are easily damaged by freezing, but in November normal roots become more freeze resistant due to normal hormone changes and decreased root activity.

In the container nursery, roots are not in a normal environment — they are hotter in the winter day and colder at night. Most roots are against the side of the container where the temperature changes are most severe. Without examining roots in pots by upending them, you do not realize that two plants with the same size top may be supported in one case by half a root system and in the other by a quarter root system. In the field, roots are spread over a wide shallow area with a moderated air temperature. Freezing is delayed by earth heat. A long fall season aids in the change of root function. Less water and less nitrogen also aid in making roots more freezeproof (depress injury point temperature).

In some plants cool nights and normal short days have been shown to increase hardiness of roots and stems, but each genetic strain has a different response to temperature.

Before winter, other factors affect how many roots there are and how active they are. *Drainage* of field soil or landscape site or container mix is a major factor of root vigor. Adequate soil air and water holding capacity are vital. Slope and soil amendments change drainage and thus affect root physiology. With high organic soils, wettability is a problem if they ever get dry. Capillary flow is slower than in mineral soils from wet to dry soil. This can lead to winter dessication.

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Mulches can be misused on poorly drained soil by forcing a very shallow root system to develop, subject to winter drying or winter freezing. Use a soil probe in field soils to see how wet the root zone soil is. The *irrigation* regime is also vital. Many watering systems are left on too long. It is possible to overwater a soil during a summer or winter drought. Planting root balls too deep will result in the old roots death due to anoxia. If the temperature is moderate, a new root system may develop near the surface where there is a better soil water-air mixture. It is especially difficult not to overwater seedling trays.

Improper *weed control* can result in root injury. *After* the roots are injured and their function changed, you can see evidence of the injury in the leaves.

Fertilization affects root action. Acid soils impair root growth and root function. Over-fertilization results in high soluble salt injury. Damage can be shown from one day or one hour of salt concentration. Broadleaf evergreens lose considerable water on every sunny day. Dead or damaged roots cannot supply that water even in small quantitites. Thus, leaf injury follows root injury.

Root disease is a major factor in winter root disfunction. If a pathogen, a root host, and an environment favorable to the pathogen are present, root injury will result. I like to examine the roots of plant samples once a month. Upend the pot or dig in the bed. The grower cannot tolerate root-diseased plants. He must change the environment (usually less water, less pathogen).

In intensive irrigation culture, plants can exist with very few roots, but after placing in the landscape, they die from drought (few roots).

Winter protection — We must remove some of the stress from plants. Reduce their exposure to sun and wind. Insulate from severe temperature drops.

A snow machine may be ideal. Many alpine plants covered with snow do not suffer drought or cold. In a no-snow year they are killed. Sometimes a band of brown paper or saran cloth around the bed of cans will be enough insulation to prevent heat of the soil from blowing away. It is well known that a dry soil will freeze first. Roots on the exposed side of the can will freeze first.

Root growth and root function are related. If a plant is dropped into a can in December, very little root growth will result and tops may dry out. It is important to shade the tops. If dropped in March, roots grow due to higher soil temperature, and can pump water rapidly.

The root function in winter is slower than it is in summer. But many factors work together to affect root efficiency or root damage. Landscaping near a downspout may cause a wet soil in fall. This results in shallow roots forming, which can be injured in winter by winter drought. Shallow roots will not re-grow due to lower soil temperature. They may be injured by winter cold, which will penetrate to the 4 cm deep roots more readily than to normal 8 cm deep roots.

Root physiology is a complex subject. The total present environment affects it (too wet-too dry-too cold). The total past environment also influences winter root function (root rot-high salts-nutrient hunger).

NUTRITION PRACTICES AND MEDIA CONTROLS FOR WINTER PROTECTION

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Media Controls for Winter Protection. Information on the influence of the soil medium on winter protection is not very plentiful. Work done by Self (6) in 1963 showed that, after artificial freezing and thawing of containers filled with several media, those containers with sandy clay as an ingredient were the first to freeze. Containers with charcoal or peatmoss had slower freeze rates. Some work done in Georgia showed that media with pine bark were 2 to 8°F warmer than identical mixes with peatmoss as the organic ingredient (4). Both studies indicate that winter protection of containers can be influenced by the medium used.

The most important factors of a medium that influence cold protecion are its: (a) percent air filled pore space or porosity, (b) moisture, and (c) organic matter content (1).

Air space within a container minimizes heat loss through conductance by serving as an insulator. Potting mixes with a large percentage of ingredients that are fine in particle size, such as the sandy clay and other mineral soils, contain little air space. Ideally, a soil mix should contain 20 to 35% air space for adequate drainage and root development (8). This will also provide adequate insulation for winter protection. Most soil mixes have adequate air capacity at the time of potting but, by winter, there has been a drastic reduction in air capacity due to compaction, shrinkage, and decomposition of organic matter. In order to prevent this, one should use shale, haydite, perlite, The root function in winter is slower than it is in summer. But many factors work together to affect root efficiency or root damage. Landscaping near a downspout may cause a wet soil in fall. This results in shallow roots forming, which can be injured in winter by winter drought. Shallow roots will not re-grow due to lower soil temperature. They may be injured by winter cold, which will penetrate to the 4 cm deep roots more readily than to normal 8 cm deep roots.

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Moisture or water content of the soil mix is a factor nurserymen should constantly be aware of during the winter season. One question nurserymen commonly ask is "Do you water container plots before a hard freeze?" Yes, if the plants are in a stress situation or will be without a regular watering. One should be careful though, not to waterlog the containers because when there is excess water it replaces available air space and serves as a conductor for heat loss from the container.

Most container potting mixes contain some organic matter such as bark and peat. In terms of cold protection it is an advantage to have a high organic content in potting mixes. Organic matter does not transfer heat as readily as mineral soils, which means there would be more heat retention in the container during freeze conditions. Even though organic materials decompose with time and reduce available air, the insulating property is still retained.

At our Experiment Station, the recommended soil mix for general ornamentals is 3 parts pine bark, 1 part sandy clay, and 1 part shale. This mix, in combination with other cold protection measures such as jamming containers and a north wind barrier on outer rows, has given excellent root protection at the Station. This mix contains adequate air space, organic matter, and retains moisture and nutrients.

Even though I've emphasized the medium's influence on protection, without one or, preferably, both of the above protection measures, effectiveness of the soil mix in reducing root injury will be negated.

Nutritional Practices for Winter Protection. Nutrition's relationship to cold hardiness has been a source of controversy for many years. Numerous reports can be found in the literature concerning nitrogen's and potassium's effect on cold hardiness. Early workers reported high nitrogen levels reduced cold hardiness. Potassium was reported to increase cold hardiness and it became an established cultural practice to increase potassium during winter fertilization.

Some nurserymen for years believed that any fertilizer at all during the winter months would render their plants susceptible to cold injury. It is true that excessive fertilization, especially with readily available nitrogen sources, will result in more cold damage. During the growing season both roots and shoots are actively growing, and a high level of fertility needs to be maintained, whereas in winter only roots are actively growing. This means there is a requirement for fertilizers, but at lower rates.

Early work by researchers in the south showed that early winter and subsequent fertilizations decreased leaf drop, improved leaf color, and decreased root and shoot damage on several ornamental plants (2,5,10). An improvement in spring growth has also been shown to result from winter fertilizations. It appears that roots actively absorb fertilizer elements during winter and some elements are transported to leaves and shoots.

It is very important for nurserymen to realize that the key to using fertilizers during winter is to use a balanced fertilizer, one that contains adequate nutrients to supply plants with optimum levels of the elements that are essential to plant growth. In 1940, Lawless (3) observed that after a hard freeze in Florida citrus groves, those trees receiving a complete nutritional program consisting of proper ratios of N, P, K, Mg, Fe, Mn, Cu, and Zn along with proper pH control, showed adequate cold resistance. A deficiency of one of these elements seemed to predispose the tree to greater cold injury. He concluded that there is no magical virtue in any single element that will change the physical complex of the tree, for it is dependent upon the proper use of all nutrients known to be essential to proper tree growth. This does not agree with the practice of some nurserymen who apply single fertilizer elements, such as nitrogen or potassium alone for increased cold hardiness.

Nutritional practices that render protection must begin early in the growing cycle, preferably 4 to 8 months before winter arrives and continue during the winter season. There are three basic means by which nurserymen can achieve optimum fertility levels in container-grown plants. Regardless of the method chosen, one should include a preplant fertilizer in the potting medium. This preplant fertilizer should contain sufficient lime, superphosphate, minor elements and, preferably, some slowly available source of nitrogen and potassium. Lime is added to adjust the pH between 5.0 and 6.5 and if dolomitic lime is used, it also serves as a source of magnesium. Superphosphate is added because phosphorus is very immobile in soil and needs to be uniformly available to plant roots. Trace elements are addd to provide adequate amounts of iron, manganese, copper, zinc, and molybdenum. Care should be taken in choosing the right source; all trace element mixes are not the same. In order to supplement the basic nitrogen and potassium program, it is an advantage to have some N and K in your preplant fertilizer.

The three basic methods of fertilizing containers today are (a) topdressing with granular fertilizer, (b) liquid fertilization with water-soluble fertilizer, and (c) incorporation of Osmocote-type fertilizers. Most nurserymen use one or some combination of these methods to produce their container plants.

These methods mainly supply the major plant elements nitrogen, phosphorus, and potassium.

Research at the Auburn University Agricultural Experiment Station in recent years has revolved around perfecting the third method (7,9). Salable container plants have been produced in 4 to 8 months without additional fertilizers by incorporating 10 to 15 *pounds of 18-5-11 Osmocote per cubic yard at the time of* planting. The research has also shown that this method of fertilizing can be used during seed and cutting propagation. Generally, 18-5-11 will have enough nutrients left at the end of the growing season for winter nutrition. If not, a balanced topdress or liquid material should be used to supplement.

In conclusion, one should know that no single factor or a small group of factors are involved in cold protection. Nutrition practices and media control should be part of a total protection scheme, because freezing itself involves multiple events. From field observations and experimentation it is our believe that a well-fed, disease-free plant with an extensive root system will sustain less cold injury than one suffering from a deficiency.

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WINTER PLANT PROTECTION AT FAIRVIEW NURSERY

PHIL BEAUMONT

Fairview Nursery
Wilson, North Carolina

At Fairview Nursery we grow azaleas, hollies, photinias and some junipers in containers. We grow only one, two, and three gallon material. We are a bread-and-butter nursery and do not grow anything out of the ordinary. All our plants are grown in a bark and German peat mix. Our bark is green and runs from 1/4 inch to 50-cent piece size. All 2 and 3 gallon plants are fertilized with 16-4-8 formulation. At the time they are containerized, one gallon material and azaleas are fertilized with 18-6-12 Osmocote at the rate of 1 teaspoon per gallon. All plants are fertilized with 10-20-10 through the irrigation system several times during the summer. They are grown in full sun on black plastic.

Previous years, during the latter part of November and early December, all 2 and 3-gallon containers were pushed can tight, except for the azaleas. We jammed at this time for several reasons. One is that we ship on into mid-November and we find it difficult to pick out orders from can-tight stock. Another reason is that the cooler air flowing around the cans really slows down the growth and hardens it off before jamming. It may also be that our bark:peat mix is staying warmer than a mix containing sand.

All one gallon plants, except azaleas, are placed can-tight when they go to the field, and any of these left spaced after shipping are pushed together in the same manner as the 3-gallon material. No sawdust or bark is placed around these beds.

Azaleas are handled somewhat differently. All 1-gallon material is spaced on 10 to 12-inch centers as it goes into the container area after potting in the spring. The cans are left on this spacing until sold. We are not growing forcing grade azaleas.

The 3-gallon material has been handled differently until this year. In the past, it was placed can-tight, as it was potted in the winter and spring. This year, all 2 and 3-gallon material is placed on 18 to 20-inch centers as it goes into the field. This early spacing is being done due to our lack of labor during the shipping season in the spring when these cans need to be spaced. All 3-gallon material left from the fall season is reorganized to make room for new canning. We try not to get these cans spaced any closer than they were spaced before.

We do not use water as a method of winter protection. We water before each cold snap, but do not coat the plants with ice.

At Fairview we grow most of the hardier cultivars of azaleas since our market is north of our location. We do grow some Indica cultivars but gamble on the winter we may have.

This open method has worked for us. We feel that we get more hardening off and tougher plants by allowing cool air around the containers. We do suffer some losses, but do not feel that they justify the added expense of winter protection.

WINTER PLANT PROTECTION AT GREENLEAF NURSERY COMPANY, OKLAHOMA DIVISION

STANLEY FOSTER

Greenleaf Nursery Company
Park Hill, Oklahoma

Over the past 15 years Greenleaf Nursery has spent a great deal of money on its overwintering process. The winter of 1961 taught us some rather severe lessons that resulted in such extensive steps being taken. In the winter of 1976-77, all of the extra effort paid off.

In January of 1977, we had a low temperature of near −20°F, and the temperature did not get above 10°F for three days. Had we not had the system of overwintering that we have used for the last several years, our losses would have been devastating. As it was, our losses were basically limited to 5-gallon pyracantha that were outside and 5-gallon sweetgum. All items that were in our overwintering houses were spared, including azaleas that we had brought in from Alabama and hollies from our nursery in Texas. Thus, we feel like our system had the ultimate test and came through in relatively good condition.

Our overwintering system is divided into four basic procedures:

(1) Bunching for mutual protection.
(2) Mulching with wheat straw.
(3) Constructing overwintering houses.
(4) Protecting from dessication by watering before and after sub-freezing weather.

We bunch basically all our plant material for winter, since our operation is totally containerized. Deciduous trees and broadleaf evergreens are bunched for mutual protection. We place containers "can-tight", where the type of plant material will allow but, out of necessity, must leave limited space between containers on some cultivars due to the possibility of foliage discoloration and disease. Conifer cultivars are also

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Following the bunching, we then mulch all deciduous shrubs and trees with wheat straw. Most of the shrubs are mulched around the perimeter to cut down on air circulation and to protect the perimeters from freezing. The trees are completely mulched in, with both the perimeters and the tops covered. Straw mulching greatly reduces the frequency and the degree to which the medium in the containers will freeze. We will normally use about 6500 bales of wheat straw in accomplishing our strawing.

We construct 'A' frame overwintering houses over all of our broadleaf evergreens. The houses may vary in length from 150 feet to over 400 feet. The houses are built from a series of prefabbed "A-frames". Each frame is constructed of two 20-foot 2 by 6's, a 2 by 4 inch brace, and three triangular gussets of 1/2 inch exterior plywood. The prefabbed "A frames" are then strung together in place at 8 foot intervals with 2 by 4 inch stringers along the top, middle and bottom. A six man crew can erect about 800 linear feet of house in a day. After the house is erected, the ends are covered with plastic, the house is staked down (to prevent wind lift), and stiff legs are put under each bow to support snow load. The house is then covered with plastic, lathed down, and railroad ties are placed at the corners for weight. The process may sound somewhat lengthy, but it really moves fast and systematically when put into operation. This year, we will have 52 overwintering houses with about three linear miles of house space.

Without a doubt, we consider protection from dessication to be one of our primary responsibilities during the winter months. We try to go into every cold wave of sub-freezing temperatures with plenty of moisture in the medium in our containers. We are not terribly concerned when the medium freezes in those containers outside the houses, if there is adequate moisture going into that weather. As soon as the air temperature gets above freezing, we make it a point to overhead water any plant material with frozen medium. This helps to insure that the plants will have moisture around the roots when they again start transpiring. Dessication is especially a problem after lengthy cold spells which seem to freeze-dry the medium.

This is just a brief outline of the winter protection at Greenleaf Nursery. There are a number of exceptions and specialized cases involved in the process that I have not discussed. The main point to stress is that we strongly believe in our very regimented overwintering procedure. Despite the fact that it is an expensive process, it has proven to be a cheap insurance policy.

COLD PROTECTION AT WIGHT NURSERIES

JOHN B. WIGHT, JR.

Wight Nurseries
Cairo, Georgia

Wight Nurseries is in climatic zone 9 where normally lowest temperatures are in the range of 20° to 25°F. We have potentially damaging weather about 1 in 5 years. We have had snow one time since 1954, but we had 6°F weather in January, 1977.

We produce about 4 million container-grown plants per year, approximately 1/3 conifer and the balance broadleaf. We have never had damage to coniferous evergreens and have never made any effort to jam or space these plants. We do not jam azaleas but do put a polyethylene windbreak around the shade houses. Quite frankly I would hate to be growing a large quantity of container plants in a colder zone than this, particularly if the production were in broadleaves.

We have found that our biggest crop, *Ilex*, starts having severe root damage at around 12°F and sustained temperatures of 10°F or lower will kill them if some protection is not given.

Our protection at Wight Nurseries is very simple. As a preventive each year, all plants that do not have large tops and that will not be damaged by prolonged periods of jamming, are jammed together in beds 100 feet long and 10 cans wide. The beds are then wrapped with a Kraft paper that we buy from Union Camp Corporation (minimum order is 10,000 pounds). This paper lasts one season only. We make no effort to re-use it. We have obtained dramatic results from this paper which simply acts as a windbreak to the bed of cans. In years when we did not use paper, but jammed only, we lost the outside row of plants all the way around and occasionally the second row if the cold were severe. We have a policy at the nursery that we do not take Thanksgiving vacation unless this cold protection is completed.

The only other cold protection is the covering of our 76 plastic houses. For the propagation crew this is required for them to get a Thanksgiving vacation. That seems to be motivation enough to have it completed each year on time. As long as records have been kept, there has never been a cold in Cairo, Georgia, that would damage plants prior to Thanksgiving.

The hard part is the jamming together of the big finished plants, the salable choice ones that cannot be jammed over long periods because of damage to the plants. We jam these only when cold weather is coming and predictions are for mid- to low teen temperatures.

It is our policy to require all employees to work at this and the pay is double the normal rates. There is no effort to jam in pretty uniform beds; simply push everything together as tightly as possible. Because of the large tops on cultivars like *Ilex crenata* 'Helleri' or *Ilex vomitoria* 'Nana', jamming cannot be accomplished tightly. Therefore, these plants tend to sustain the greater losses. We do know that the larger the beds, the less damage we have because the severest damage is on the outside edges.

"Unjamming" is also important because winter temperatures can be high in our zone; we have 80°F days in January.

We think the younger plants, and plants with smaller heads, that can be jammed tightly and wrapped with paper receive about a 10°F benefit from this paper. Plants wrapped like this had no damage at 6°F last winter, although I am sure if temperatures stayed at 6°F a long period of time, the damage would have been great. Heavy finished plants that could not be jammed tightly were severely damaged at 6°F in January, 1977. I suspect we had as high as 50% mortality in some holly cultivars, with the highest mortality occurring in *Ilex vomitoria* 'Nana' and *Ilex crenata* 'Helleri.'

Some of the reasons there is benefit from Kraft paper around the cans is given in Table 1, which shows the effects of the "chill factor" when temperatures are at 20°F, 10°F and 0°F, with winds of 5, 10, 15, 20 and 25 mph. High winds are often associated with low temperatures.

Table 1. Wind Chill Factors.[1]

Estimated Wind Speed MPH	Actual Thermometer Reading, °F 20	10	0	−10	−20
	EQUIVALENT TEMPERATURE, °F				
Calm	20	10	0	−10	−20
5	16	6	− 5	−15	−26
10	4	− 9	−21	−33	−46
15	− 5	−18	−36	−45	−58
20	−10	−25	−39	−53	−67
25	−15	−29	−44	−59	−74

[1] Taken from a publication of the Grady County Electric Membership Corporation.

We are growing between 4 million and 5 million plants in containers. A major activity at Wight Nurseries, or any other nursery in our area, is devising the very best plan of cold protection that is economically feasible — treat the plan like insurance — consider the cost like an annual premium, and then make sure that the plan is implemented prior to the date of the first possible damaging freeze. Our plan simply involves:

1. Placing windbreaks around azaleas in shade houses.
2. Jamming when we can; making beds as large as possible.
3. Wrapping with Kraft paper on the north and west sides only.

Knowing what to do, but not doing it, will not save your plants.

WINTER PROTECTION FOR CONTAINER-GROWN RHODODENDRONS

TED RICHARDSON

Rhododendron Farm
Mountain Home, North Carolina

A great hazard of growing container rhododendrons is that of loss due to winter cold. Young plants have been a very serious problem as the wood is more susceptible to tissue injury. In the absence of protection large numbers with one or two flushes of growth are either fully lost or highly depreciated in value due to bark splitting. Hardy cultivars with 4 or more flushes of growth do not have this problem in our operation but do suffer from tissue water deficiency if exposed to direct sunlight when the roots are frozen. The degree of this type of injury varies with cultivar and exposure. Older plants may also suffer from root damage. A fourth problem is that of frost injury to actively growing tissue on both young and older plants.

I have attempted to solve the first mentioned problem by having no plants with less than four flushes of growth to carry through the winter. My propagation is done in late June. In early November the rooted cuttings are potted out in South Florida and two or three flushes of growth occur by the end of April. The plants then return to North Carolina, hopefully after frost damage is past, and two or three additional flushes are added during the summer. This leaves only mature plants to be carried through the winter.

Rhododendrons tend to roll their leaves when temperatures are low. It seems that leaves of the more tender cultivars unroll before those of the hardier ones. As soon as the sun hits, the leaves unroll and begin transpiring rapidly while the stem and root are still frozen. Protection from direct sunlight is, therefore, essential and is provided by a six foot high snow fence mounted vertically and oriented east and west. During late November, December, January, and early February, a 12-foot shadow is cast on the north side of the fence. The plants in each bay are pushed up tight into the shadow. This has proven

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Root kill had not been a problem for the past 15 years until the winter of 1977. There have been winters with lower temperatures (−3°F) but none with as long a period when the roots were frozen. Few times have the root balls frozen solid. In 1977 they were frozen for 10 consecutive weeks. I have no solution for this problem without going to plastic house protection or mulching around the containers. Both are costly and are contrary to my method of operation.

Frost protection is provided by Rainbird sprinklers. At the Florida nursery the pump is actuated by a heating thermostat set at 33°F. During the winter of 1977 this functioned several times. During the worst freeze, the temperature was 27°F for 10 hours and 1/2 inch of ice was formed on the plants with no observable damage. In North Carolina the pumps are operated manually for frost protection.

Last year we also tried covering the plants with burlap. However, this was not too successful. We may have been late putting it on or may have left it on too long (mid-March). At any rate, it was not as effective as we had expected.

One additional problem we seem to have is that of hiring people who are conscientious about helping implement some of our procedures. Unfortunately, none of our methods prevented serious losses last winter.

WINTER PROTECTION OF NURSERY PLANTS: 1956-1977 SUMMARY

RAYMOND L. SELF

Ornamental Horticulture Field Station of Auburn University
Agricultural Experiment Station
Mobile, Alabama

Disastrous effects of freezes in the South in 1950, 1962-1963, and 1977, have stimulated research at the Ornamental Horticulture Field Station in Mobile. Results have often been skimpy due to lack of freezes. Usually, the experiments have been set up hastily when severe freezes were predicated or immediately thereafter.

The results of numerous laboratory and field tests have revealed the following facts regarding protection of container-grown plants from freeze injury:

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1. The freeze rate varies with the type of potting mixture ingredients. The rate of freeze is fastest for sandy clay, inter-

mediate for spent wood (charcoal and sand from burned pine stumps), and slowest for German peat moss. By incorporating generous quantities of peat moss or charcoal with the potting mixture, many additional hours of freeze protection can be built into a potting mixture (6). The mixtures that freeze fastest also thaw fastest, causing undue rupturing of roots, which kills the plants (8).

2. Freeze and thaw is fastest inside the can, near the top and at the outer edges, and slowest in the center of the can near the bottom (7).

3. The rate of thaw following a freeze is affected by the color of the container. *Ilex crenata* 'Helleri' liners were grown from July, 1959, to August, 1960. Plants in white cans had the greatest survival, followed closely by aluminum and green cans. Survival was poorest in black cans with half of the plants being lost to cold injury. The percent increase in growth over that of plants in black cans for each of the other colors was as follows: white, 87; aluminum, 57; and green, 36 (4). In a previous test from September, 1958 through spring, 1959, root injury was greater on *Ilex crenata* 'Rotundifolia' growing in black cans set on 3 inches of shavings, than on those set directly on the ground. Greatest winter injury occurred in black cans, followed by green, aluminum, and least in white (3).

One-year loquat seedlings grown in green, black, and unpainted cans under nursery conditions in the field indicated container temperatures were affected by can color, position of can in beds, exposure to solar radiation, and soil moisture content. The highest soil temperatures occurred in the western side of cans that were in the outer rows of beds and in the rows having western and southwestern exposures. Soil temperatures in cans in the middle of the beds and in outer rows facing north were near air temperatures or several degrees cooler. Soil temperatures on the western side of fully-exposed cans were highest (10° to 15°C above air temperatures) in black containers, lowest (2° to 5°C above air temperatures) in unpainted containers, and intermediate (4° to 10°C above air temperatures) in green containers. Temperatures in dry soils were 4° to 7°C warmer than temperatures in soils of optimum moisture content (12).

A test in the summer of 1972 revealed soil temperatures were influenced by color, composition, and size of the container. A black plastic Lerio 7-in. can was 9.3°F cooler on the hot side in the a.m. and 1.4° hotter in the p.m. than a comparable 6-in. can. In the a.m., a white 6-in. metal can was 7° cooler than a green, and 11.4° cooler than a black metal can. The coolest pots were 8-in. Pullen papermache pots, which were

8.3° cooler for a light brown pot and 6.6° cooler for a dark brown pot (11).

4. Polystyrene liners used inside the can retarded both freezing and thawing of the root ball of plants. In a field test, the liners increased survival by 17.8, 24.4, and 31 percent, respectively, for *Ilex crenata* 'Rotundifolia', *I. cornuta* 'Burfordii', and *I. crenata* 'Helleri'.

5. Shavings mulches under the containers were responsible for much of the freeze injury to nursery stock during the 1961-1962 freezes. A 3-inch shavings mulch on a morning when the low was only 25°F reduced the soil temperature at the bottom of the can to that of the air temperature, whereas the temperature under the cans sitting directly on the soil was 36°F, or 11°F higher than the temperature under the cans sitting on shavings. A 3-inch shavings mulch inside a double-lined plastic house lowered the temperature 5°F below that in an identical house having no shavings mulch (3). Plastic or roofing paper also serves as a barrier.

6. A mulch over the cans retains ground heat and gives some winter protection. However, this same mulch results in increased frost damage on clear nights when the air temperature is in the neighborhood at 32°F. The mulch prevents upward radiation of heat from the soil to replace that lost from above the shavings (9).

7. Leafdrop of azaleas and other ornamentals was prevented with monthly applications of 6-8-8 complete fertilizer into the winter, and resulted in no winter injury (2).

8. Dolomitic lime at 6 pounds per cubic yard improved growth and winter hardiness of 8 species of plants treated; 12 pounds had no apparent ill effect on azaleas. Omission of lime resulted in tip burn of *Ilex crenata* 'Rotundifolia' and complete kill of *Buxus* sp., *Cornus florida*, *Gardenia* sp., *Pittsporum* sp., *Podocarpus* sp., and *Rhododendron* sp. (5). The newer slow-release fertilizers, plus complete preplant mix, should be the best approach.

9. Cold damage to camellias was greater in mixes of 3 bark: 1 shale amended with soil rather than sand (13).

10. Ten pounds of Osmocote 18-5-11, plus a potting soil mix (Special 8) containing 10 pounds dolomite, 2 pounds gypsum, 1/4 pound of 008 micronutrients, and 1/4 pound of Chlordane 10G, gave adequate growth and comparable cold protection to camellias in the mixes containing 15 and 20 pounds of 18-5-11 (13).

11. Antitranspirants (antidessicants) have given variable results when used for winter protection under mild winter condi-

tions. Responses have varied from slight retardation of growth to increases up to 50 percent with 12.5% WiltPruf. They have given considerable protection from severe, sudden freezes or from the after-effects of these freezes resulting from top dessication before new roots can be regenerated.

Several other antidessicants improved growth of *Photinia* × *fraseri* from 10 to 60% when applied 3 weeks before a sudden freeze (10).

In 1977, Exhalt 800 (1:10), WiltPruf (1:10), and Exhault 410 (1:5) all gave protection of the tops of dwarf burford holly until new roots could be regenerated. Best results were associated with transplanting to larger containers (14).

12. Chemical treatments other than antitranspirants have given some winter protection. Effects of a particular treatment have varied with the plant species. A combination of potassium bromide, calcium chloride, and potassium nitrate, plus naphthaleneacetic acid and Cycocel sprays, increased top growth of Coral Bell azalea 60 and 20%, respectively. B-9, KNO_3, and Sul-Po-Mag gave increases of 50, 50, and 66.6% on Pink Supreme azalea. Additional research is needed on the possible winter protection from various chemical treatments (1).

13. The best approach to winter protection of container plants appears to be to jam the cans together, put a protective border (soil-filled container, paper or plastic barrier, shavings, or straw mulch) around them, treat with one of the antidessicants, transplant to larger containers if plants are extremely root-bound, preferably before a freeze. Transplanting after the freeze will allow regeneration of new roots from within the old rootball (14). Fertilize adequately, but not excessively, as excess amounts burn the roots, and shade the plants if at all practical. Wind barriers are also very beneficial.

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QUESTION BOX

The Southern Region Question Box was moderated by Dr. Richard Stadtherr.

MODERATOR STADTHERR: Which is more harmful to plants after a 6°F temperature, a fast thaw or a slow thaw?

DR. JAKE TINGA: If the root ball is frozen, slow thawing of the shoots would be more compatible with the slow thaw of the roots. If you could thaw the roots as fast as the shoots, there would be no problem. Slow thawing of the shoots would reduce transpiration. Turn the water on before freezing starts; keep the water on until all ice has melted. This layer keeps the surface at 32°F (cell damage begins at 28°F) and also prevents dessication. If the sun hits a dry leaf and it transpires, and there is no available liquid water to come through the frozen root and stem, the leaf dessicates and dies. However, I do not think you can hold a plant at 6°F. I think the limit is about 20°.

CHARLIE PARKERSON: Dr. Robert Wright told us today that roots freeze before the tops. How can roots freeze first?

MODERATOR STADTHERR: Roots do not have the ability to go into rest. They do not withstand as low temperatures as the tops, but in the ground they have protection from the soil warmth. Roots of canned plants have less protection.

GARY HUTT: Is it better to leave plants jammed or leave them apart to thaw out quickly?

KERMIT NORRIS: In the Mobile area the temperature went down to 10°F. I didn't jam anything except young material that was potted up early in the fall. Winter damage was noted on this young material. Other plants that were left spaced came

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KERMIT NORRIS: In the Mobile area the temperature went down to 10°F. I didn't jam anything except young material that was potted up early in the fall. Winter damage was noted on this young material. Other plants that were left spaced came through with very little damage except on the north side where the wind hit.

DR. RAY SELF: What was the soil mix and treatment of plants before the freeze? Did you have windbreaks?

KERMIT NORRIS: We did not have any windbreaks. We have a very porous mix: 3 parts pine bark, 1 part shavings and 1 part topsoil. We had a very high nutrient level in the soil and also applied KNO_3 in October and Ureamide in November.

BRAD MAY: Ray Self, I understand you apply lime to help prepare plants for winter. Do you apply lime to azaleas and rhododendrons also?

DR. RAY SELF: We are now using dolomitic lime on azaleas and have no trouble. In the early sixties we believed that you should not use lime on azaleas, but now we believe that was a large part of the trouble with growing them. The pH will start at 6 or 6.5 but will drop as the calcium and magnesium are leached out.

ROB HOLLINGS: What is the physiological explanation for stem splitting?

DR. JAKE TINGA: With the ordinary onset of fall, temperatures become cooler and cooler. Water content goes down and sugar content goes up in the cells. If temperatures do not go down gradually, the stem remains high in water content. The cambial area contains the most water. Therefore, when a freeze comes, water in the cambium expands, the cambium ruptures and pulls away from the xylem. When everything thaws, the cambium collapses leaving a split; splitting occurs on the sunny side as it was warmer and the least hardened. It is not that the sun hits that side of the stem first, the damage is done when the ice crystals form. Twenty years ago at the Arnold Arboretum there was an experiment with mulches. It was found that when the mulch was scratched away the first of October and the ground heat could get to the lower branches, there was no stem split. When the mulch was there, it insulated the ground heat from the stems, and the stems above the mulch split.

MODERATOR STADTHERR: I would also like to comment on that. In North Carolina, sawdust mulch was being used in azalea cuttings. I believe the heat from the mulch kept the plants from going into the rest. The cells close to the ground and those in the cambium are always the last ones to go into rest. When they removed the mulch, there was no problem. I definitely think the stems split because they had not gone into rest.

DR. RAY SELF: We grow most of our azaleas without mulch and we find that bark splitting is usually a varietal situation; 'Mrs. G.G. Gerbing' azalea splits most readily.

CHARLIE PARKERSON: John Wight, would you turn water on plants as soon coming out of a period at 6°F as after 32°F?

JOHN WIGHT: We ordinarily do not use icing. We had a group of high quality *Ilex crenata* 'Helleri' plants in containers that we could not jam together without breaking them so we lost 50 to 60% of the root system from freezing. We found that it helped to syringe them frequently on windy days following the freeze. We did not keep them soggy. The Kraft paper around the plants may keep temperatures about 15° higher than the surrounding air for short periods.

RONALD COPELAND: One year we did not jam a block of *Ilex crenata* 'Helleri' holly plants and I was prepared to accept 100 per cent loss. However, that particular block had a higher survival percentage than the blocks that had been jammed with a plastic strip around them. I think the plants could thaw more rapidly with the air movement around them. We found the same situation with rhododendrons. The leaves were yellow, but we did not lose many that were not jammed.

DAVID TANKARD: Does it do any good to put anti-transpirants on plants? How late in the fall can you apply these materials and still get the effect?

DR. RAY SELF: When I put anti-transpirants on in one experiment in early November, I did not get as good response as when I put them on just a few days before the predicted freeze.

DR. JAKE TINGA: David, we think that the anti-transpirants flake off in a short time and that the effect is really short term. I do not have confidence in them; but if you do, you should spray several times, beginning as soon as a bad freeze is predicted and continuing until just preceding it.

JOHN WIGHT: I furnished 100 camellias for a test of anti-transpirants on Long Island. The check, with nothing applied, did better than those sprayed with anti-transpirants.

RICHARD VAN LANDINGHAM: Stanley Foster, how cold does it get in your over-wintering houses in Oklahoma?

STANLEY FOSTER: Most of them do not go below freezing. The houses basically are not heated, but if we have a prediction of extremely cold weather, we use kerosene in "Salamander" heaters. Even with temperatures of 20°F below zero, the houses went only down to 15°F above zero. This was partly because we had 15 inches of snow. The amount of damage would depend upon how long the temperatures remained low.

CHARLIE PARKERSON: Is anyone using a plant with quick growth to block some of the wind? I don't have much room and would rather not purchase snow fencing and then have to drive it into the ground and then remove it. A quick growing plant could be mowed down in the spring.

ROB HOLLINGS: We, at one time, planted sorghum to protext our azaleas and broke it over for winter protection.

RANDY HEFNER: I planted sudex the last of August to protect late-planted liners. We broke it down about halfway. Half of the block has sudex planted and half does not, which will provide a good test of protection.

RICHARD AMMON: Should we wait until the first frost to cover structures with plastic? My argument is that frost is important to temper the plants, but another nurseryman told me he covers before frost and has no problem.

DR. JAKE TINGA: Can you guarantee the first frost is going to be a gentle frost? The air space under the plastic will be a gradualizing influence for hardening.

BILL CURTIS: I have a small operation and a small crew. When the temperature drops to 28°F, with a prediction of 20°F, we cover immediately. When the temperature goes back up, we open the house.

LES CLAY: Early this fall we had Japanese azaleas in two houses. One was not quite sealed when the temperature dropped to 26°F. Everything came through perfectly in the sealed house, while we had tip damage on all the young azaleas in the unsealed. house.

RICHARD AMMON: Then the conclusion is that we don't need the frost?

MODERATOR STADTHERR: You do not need conditioning temperatures. You cannot drop from 60° and 70°F to 22°F without having some damage. Dry conditions will also help bring on rest, while excess nitrogen will delay the process.

GERALD SMITH: What are the maximum and minimum rates of Osmocote 18-6-12 on one gallon containers, surface applied, for a cubic yard of potting mix — and for a propagating mix? Some growers say it is too expensive and want to us minimal quantities.

DR. RAY SELF: You can achieve the same results without using Osmocote; there are other slow release methods. But for Osmocote, I would suggest 5 pounds per cubic yard for greenhouse production, or 7-1/2 pounds for outside. The 18-5-11 formulation would last longer but would require 10 pounds inside and 15 pounds outside per cubic yard. We suggest you use a preplant mix along with Osmocote to give a complete program. Then you would not need to add minor elements later.

OLIVER WASHINGTON: The recommended rate on the bag for one gallon, surface applied, is 5 grams — about 1 teaspoon.

GERALD SMITH: Is there general agreement with these rates?

DR. RAY SELF: We do not always agree with other recommendations, including those on the bag.

DR. JAKE TINGA: I would use less and liquid feed since Osmocote is expensive.

MODERATOR STADTHERR: John Machen, please comment on your observation of callus formation as affected by hormone treatment.

JOHN MACHEN: It seemed to us that when we got maximum root production we got very little callus formation and, on the contrary, when we got a great deal of callus, we got very little rooting. We feel hormone concentration in an alcohol dip should be increased until there is slight tissue burn. Then roots will form above the burned tissue instead of callus.

VIVIAN MUNDAY: Then you believe it is the hormone and not water relationships that affect callus formation?

JOHN MACHEN: Based on what we have seen — yes. The camellias which callused heavily were definitely not too wet.

DR. BRYSON JAMES: I disagree with you. I think water relationship has a lot more to do with callus formation than hormone concentration.

MODERATOR STADTHERR: It is really difficult to say just what causes callus. Callus and root formation compete for the same materials. I have seen instances when high concentrations of IBA in a talc preparation on wet plant material gave a tremendous amount of callus, but no root formation whatever. If there are optimum amounts of hormone and proper environmental conditions, including aeration, roots may appear ahead of callus. If aeration is poor, callus will often form.

JOHN MACHEN: Did you get tissue burn?

MODERATOR STADTHERR: No, not at all.

JOHN MACHEN: I'm suggesting that you were not at the upper level of this hormone.

HUNTER BUOLO: There was some fertility work on photinia, in which some cuttings callused without rooting, but at higher fertility levels, rooting improved.

OLIVER WASHINGTON: It is difficult to say that improved rooting was due only to fertility. It is very difficult to get root formation on photinia in an alkaline mix such as vermiculite or perlite. I get rooting when I go to a lower pH mix. The addition of fertilizer would lower pH, so it is hard to say whether it is the pH or fertility.

DR. BRYSON JAMES: I doubt that the increased fertility in the medium is affecting root formation. It may be affecting root growth once roots are initiated.

HUNTER BOULO: We've decreased propagation time two weeks by fertilizing the medium. However, the percentage of rooting has not increased.

LES CLAY: We have had some heavy callus problems with *Prunus laurocerasus* 'Otto Luyken'. However, when we increased bottom heat, callus formation was less, indicating that temperature might be a factor.

DICK AMMON: Would Charlie Parkerson give his results of propagation in the greenhouse with plastic heating pipe in the floor?

CHARLIE PARKERSON: We did not root there, just carried plants over the winter. However, it is quite efficient for heating. It took approximately half as much fuel as it did to heat a similar size house using hot air. I think providing bottom heat with CPVC pipe in porous concrete plus plastic skirts around the benches would give an ideal method for heating a propagation or grafting bench.

LES CLAY: We get very uniform heat using "PVC 40" in concrete benches.

CHARLIE PARKERSON: We are using CPVC, a hot water pipe, to avoid any chance of deterioration, since we send 150°F water into the pipe. We did have trouble with expansion of the pipe.

RICHARD AMMON: What is the advantage of cement covered pipe over gravel covered pipe?

LES CLAY: We are using both as a comparison. We get a much more uniform heat with the concrete and have cut our rooting period by a week to 10 days. The pipes were covered 3 inches and are about 8 inches apart.

DR. JAKE TINGA: If the sand is left out of an ordinary concrete mix (3 parts gravel, 2 parts sand, 1 part cement), the finished material is drainable. Simply use 3 parts gravel and 1 part cement.

JERRY HODGES: The Van Wingerten Greenhouses have about 12 acres of porous concrete floor 3-1/2 inches deep imbedded with poly pipe. Van Wingerten uses styrofoam below the pipe and provides a 4 inch drainage line below the insulation. He avoids pipe expansion by arranging a cold water injection valve to maintain a water temperature of 90°F.

MODERATOR STADTHERR: Will 50% isopropyl alcohol surface sterilize the stems of cuttings dipped into it?

DR. ROBERT LAMBE: Seventy per cent is the concentration used as a surface disinfectant for eradicating bacteria, and it will probably work on fungi. Any higher concentration may give leaf damage and even 70 per cent could give some leaf damage. However, it does not penetrate very deep and you would probably not really hurt tissue as the dip is usually for 1 or 2 seconds.

MODERATOR STADTHERR: Hugh Strain, could you describe your method of fertilizer injection.

HUGH STRAIN: The equipment company installed and calibrated our injector for us. We are using 2 tanks and a small pump to inject 8-4-4 and liquid nitrogen into the water line. We use 8-4-4 twice a week for three weeks and then nitrogen twice a week for one week each 4-week period. In addition we use Sta-green #3, lime and gypsum in our soil mix. We feel we cannot afford the labor cost of top dressing with dry fertilizer.

SUE CURD: We have a problem with algae on the cement floor of our propagating house at Callaway Gardens.

CHARLIE PARKERSON: The fungicide "Cyprex" does a good job on controlling algae.

MODERATOR STADTHERR: We have used just lime, but Clorox does a good job, too.

DR. BRYSON JAMES: Any of the standard household bleach preparation could be used. The bleach is 5% sodium hypochlorite and can be diluted to 5 or 10% concentration.

LYNN TABOR: If you have a high calcium content and low pH, how do you bring up the pH?

DR. GEORGE McVEY: I think this is a rare situation. First check the basic ingredients of your potting medium.

DR. BRYSON JAMES: If you run a buffered pH, I believe you will find you do not need lime. "Buffered pH" gives a measure of total soil acidity rather than just active acidity. A salt solution is used rather than water to make the measurement.

JOHN MACHEN: "Buffered pH" is a measurement of the soil's resistance to pH change. The active pH reading does not tell this.

WYLIE ROACH: I have a tremendous amount of 3 year old bark compost with a pH of about 8. Would adding fertilizer such as 13-13-13, with a high potassium content, cause more problems?

DR. GEORGE AVERY: It is very difficult to bring down the pH of hardwood bark. Using sulfur is one method.

GROWTH REGULATORS FOR POT PLANTS

J.P. SALINGER
Massey University, Palmerston North, New Zealand

Although a wide range of foliage plants are grown for house plant sale, only recently have specifications been drawn up indicating the factors to be considered in evaluating a plant for this purpose (6). The action and use of growth regulators on pot plants have been widely considered (1,3,7) and also tabulated for extension purposes (5). These regulators can assist in the production of desirable pot plants by manipulating the vegetative growth, inducing flowering, or a combination of both aspects.

Growth Retardants. Vegetative growth manipulation, especially height control, is achieved by the use of dwarf-inducing compounds. Desirable house plants should be relatively wide in relation to height; the most suitable height to diameter ratio is 1 to 1.62 (6). This is difficult to obtain without control in many pot plants due to the natural growth habit of the cultivar and the environmental conditions imposed on the plants; frequently several plants are placed in one container to rapidly produce a marketable product and the congestion of the plants in the container will induce shoot elongation. The selection of the appropriate growth regulator to produce a compact plant will be decided by the response of the species or cultivar to a particular chemical; *Hibiscus*, for example, responds to chlormequat but not to daminozide (3) while ancymidol, normally a very reactive compound, reduced the height of only certain cultivars of dahlias grown from tubers (2).

The persistence of the plant response and the ease of application — whether incorporated in the growing medium, applied as a drench to the medium, or applied as a spray to the foliage may determine which material is selected. In general, a higher concentration of material is required as a spray than if it is incorporated into the medium. When chlorphonium was originally used as a medium-incorporated material, it caused excessive dwarfing in chrysanthemums and was too persistent; more recent formulations appear to have overcome this problem and it is now an accepted compound to use in the medium for "pot mums".. Finally, it is essential that the product should produce no undesirable effects on flowers or foliage, consumers and producers both requiring an unblemished plant.

Induction of Flowering. In an efficient nursery producing a succession of crops, it is essential to time correctly the maturity and marketing date of specific plants. With those to be sold in flower, flowering time may be affected by many factors including the maturity of the plants, (Kreb's "ripeness to flower"), temperature, daylength or natural flowering period.

The use of appropriate growth regulators can induce flowering in certain pot plants. The flowering of bromeliads, e.g. *Vriesia* and *Aechmea*, has been induced by the application to the central apex or "vase" of the plant of betahydroxyethylhydrazine (BOH) (10 mg per plant), and ethephon (250 ppm), while Goldie, at the Horticultural Research Centre, Levin, has dissolved acetylene gas in water and filled the "vases" twice at one week intervals with the solution. With these plants, it is essential that they have produced sufficient mature leaves; in addition, time to flowering is more rapid when applications are made in late spring or summer than in autumn or winter.

The application of gibberellic acid (GA_3) at 10 to 25 ppm to cyclamen includes rapid and simultaneous flowering, thus allowing the timing of the crop for a specific date, such as Mother's Day in New Zealand, or offering the possibility of extending the flowering season.

Finally, a good example of growth manipulation by a combination of cultural operations and the use of growth regulators has been shown in the production of *Bougainvillea* as a pot plant (4). This can be tabulated in relation to plant growth:

Growth Stage	**Treatment**	**Purpose**
Cuttings	Synthetic auxins	Root induction
Young plants	Pinching	Branch induction
Developing plants	Short days	Rapid prolific flowering
Maturing plants	Chlormequat or Ancymidol	Height control, flower induction
50% bracts opened	NAA to mature flowers	Flower retention

In addition to natural or synthetic auxins, the use of growth retardants can assist in planned production or the introduction of new plants which otherwise have undesirable qualities when evaluated as house plants.

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METHODS OF GRAFTING TAMARILLOS (TREE TOMATOES) (*CYPHOMANDRA BETACEA*)

DICK J.W. ENDT, Dip. Hort. (M.A.C.)
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History. During 1964, experimental work was carried out at Plant Diseases Division, D.S.I.R., Auckland, on tomatoes. This involved grafting tomatoes on resistant rootstocks for nematode control. As a matter of private interest a few tamarillos were grafted. These few trees were later given to me to study their resistance to root-rot diseases in my tree nursery. The stock used for these trees were *Solanum aviculare* and *Solanum mauritianum*. These grafted plants were planted at random in my tamarillo plant nursery in the field.

During the following winter months disaster overtook this nursery block as 80 percent of the seedlings succumbed to *Phytophthora* root rot, owing to extremely wet soil conditions. The surprising result was that none of the grafted trees were effected.

On the strength of these results I was convinced that grafting tamarillo plants on these rootstocks would solve the *Phytophthora* problem. My property has a clay soil and 60″ of rainfall per annum, where seedlings die after a few years of heavy cropping.

Propagation procedures.

Seed Collection. Two stocks were considered, namely *Solanum aviculare*, a native shrub growing in the bush in our area; secondly, *Solanum mauritianum*, a common treelike plant considered to be a noxious weed in the northern parts of New Zealand. Seed of both these species were readily available in our area.

Seed Sowing. Seeds are sown in August under glass in heated soil beds with emergence usually in about 4 weeks.

Potting of seedlings. Late October for *S. aviculare* and mid-November for *S. mauritianum* is when the seedlings are potted. Growth rate varies between the two species. All plants are potted into 5″ plastic pots. Once the seedlings have been potted, they are placed in a shadehouse for growing on. One has to be careful not to use too much nitrogen in the potting mix as too rapid growth of the stock plants results in excessive

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The S. *aviculare* seedlings attain grafting size by late November. This stage occurs when the stems are of pencil thickness. The total height of the plants above soil level will reach about 12" at this time. The seedlings S. *mauritianum* reach grafting size at least a month later.

Preparation for Grafting. Tools required: Razor blades, 3/4" packaging tape and tape dispenser, secateurs, clothes pegs.

Collection of scion wood. Scion wood is taken from softwood terminal growth of mature tamarillo trees. Trees selected are those producing large fruits of desirable shape and quality. Wherever possible trees should be selected free from virus disease. Scion pieces used are about 2" long with three or four leaves attached. During preparation all but the terminal leaves should be removed. Collected scion wood is kept in a plastic bag.

Grafting Operation. Potted stock plants are brought into the glasshouse. Using a razor blade all leaves are removed from the stem; the top of the plant is cut off about 6" above soil level. Using the razor a vertical incision is made into the stem to receive the scion. The scion piece is then prepared making a pointed V cut about 3/4" long. The scion is then wedged into the cut made into the stock. To hold the graft into place, packaging tape is used, just wrapped around once, the sticky surface on each end of the strip just held together by itself. The two ends so glued together are clamped by a clothespeg to give extra holding strength. The idea of this is to prevent the tendency of the stock to curl back away from the scion wedge. The adhesive strength of the tape is not strong enough to prevent this from happening.

After care. The newly-grafted plants are placed under intermittent mist in shade under glass. The mist is set to run on high moisture output for three weeks. At the end of this time growth will have started on the scion and shoots will develop from the stock — these should be removed. At this stage, the plants can be slowly weaned off the mist for a period of about 10 days. Leaf development is rapid at this stage and plants may be moved to an outside shade house. When suitable conditions prevail plants are lined out in the field or nursery in the open.

Nursery Care. After lining out in the field the young plants are staked to encourage upright growth. Prune off lateral growth, as branches that form in the early growth phase result in weak crotches and later breakages.

Discussion. Over a 12-year period 8,000 grafted tamarillo plants have been planted. The ultimate production of the grafted trees is superior to seedling trees. Spectacular resistance to *Phytophthora* root rots has resulted. Not all my problems were solved, however, as other diseases, such as verticillium, have taken their toll of trees in the orchard. Further work is being carried out to find stocks resistant to the other diseases encountered.

PHYSIOLOGICAL FACTORS LIMITING THE PROPAGATION OF DECIDUOUS ORNAMENTALS BY HARDWOOD CUTTINGS

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Since the initial breakthrough with hardwood cutting propagation of fruit tree rootstocks (2,4,5), the logical progression of research has extended towards the evaluation of such techniques on deciduous ornamental species. Most of such work has been done by the research groups who were involved with fruit tree rootstock hardwood propagation, and a similar trend in emphasis has been true with the N.Z. Nursery Research Centre, where extensive trials are continuing with hardwood cutting propagation of deciduous ornamentals.

The initial approach to the propagation of deciduous ornamentals by hardwood cuttings has been to impose those treatments which were successful on genera such as *Malus* and *Prunus*, to a wide range of ornamental species. Although some species have responded well to the standard treatment, others have not. Subsequent research has established a broad base from which more detailed studies can be developed. Many of the factors limiting the successful hardwood propagation of deciduous ornamentals are similar to those which were found with studies of fruit tree rootstock propagation. When evaluating the factors which limit the propagation by hardwood cuttings, it is essential that all influences are considered in combination rather than each one in isolation.

Juvenility. Although very little is understood about the components of juvenility in plants, the importance of using juvenile plant material for cutting propagation has long been recognized (6). From our recent trials, it has become apparent that the use of juvenile plant material for hardwood cutting propagation is of paramount importance. Other methods of cutting propagation can utilize material which may be temporarily juvenile because of the timing of collection, summer cutting

Discussion. Over a 12-year period 8,000 grafted tamarillo plants have been planted. The ultimate production of the grafted trees is superior to seedling trees. Spectacular resistance to *Phytophthora* root rots has resulted. Not all my problems were solved, however, as other diseases, such as verticillium, have taken their toll of trees in the orchard. Further work is being carried out to find stocks resistant to the other diseases encountered.

PHYSIOLOGICAL FACTORS LIMITING THE PROPAGATION OF DECIDUOUS ORNAMENTALS BY HARDWOOD CUTTINGS

D.S. TUSTIN

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Juvenility. Although very little is understood about the components of juvenility in plants, the importance of using juvenile plant material for cutting propagation has long been recognized (6). From our recent trials, it has become apparent that the use of juvenile plant material for hardwood cutting propagation is of paramount importance. Other methods of cutting propagation can utilize material which may be temporarily juvenile because of the timing of collection, summer cutting propagation being the classical example. Because hardwood material is one-year-old and "hardened", totally juvenile stock plants must be established for successful propagation. It is this factor more than any other, that is the key to obtaining high rooting percentages. Initial propagation trials may be conducted using less juvenile material and useful indications of the potential of the technique can be obtained, but as juvenile plants are established, further improvements in rooting performance might be expected.

Reversion to, or reinduction of the juvenile growth phase on stock plants can be achieved in several ways (6). To date the easiest and most successful has been by severely pruning the plant, leading to the development of both adventitious shoots and vigorous vegetative growth. The process of reversion to the juvenile phase may take from one to several years and appears to be species dependent. Once the mother stock plants are established, annual removal of cutting material can serve to keep the plant in the juvenile growth phase.

Expression of juvenility can be observed from several features and it is important that these can be recognized by growers contemplating hardwood cutting propagation. Plants in a juvenile growth phase produce long, strong, vegetative shoots and individual leaves may be larger than those on adult plants. With some species, leaf shape can be quite different, usually deeply lobed leaves become less lobed or even ovate (e.g. *Quercus coccinea*). Leaf senescence and shedding is usually delayed when compared with adult plants. The absence of short adult shoots bearing floral buds also indicates that reversion to the juvenile phase has been achieved.

Rooting Hormone Treatments. Most research into rooting hormone treatments for hardwood cuttings has utilized the concentrated alcohol-quick-dip technique using indolebutyric acid (IBA). It remains to be established whether this method of application is suitable for all deciduous ornamentals, especially those with tender bark and buds.

Concentrations of approximately 2,500 ppm IBA, which were optimum for some fruit tree rootstocks, have been found to be excessive for many deciduous ornamentals, consequently the re-evaluation of the basal hormone treatments constitutes one large area of current research. Problems of basal deterioration on cuttings prior to root formation have been found to be, in part, associated with excessive IBA concentrations. Therefore, when a previously untried species is treated, an IBA application of 1250 ppm might be a more satisfactory starting concentration (9).

At present, very little is known about the mode of action of IBA in promoting root formation. Traditionally it has been thought that IBA increases the total auxin content of a cutting to a threshold level required for root formation. It has also been postulated that IBA breaks down to produce IAA which is the endogenous active auxin within the plant (3). When one considers that IBA is physiologically very inactive, and that IBA is used for propagation because it is relatively stable within the plant cell (i.e. resistant to breakdown), the explanations for IBA actively in rooting promotion are in conflict with the apparent benefits of using IBA compared with IAA which is unstable. Furthermore, many cuttings will not root simply by applying IBA to the cutting base, although it has been found that if the endogenous IAA level of a cutting increases, IBA can then promote root formation (8). This suggests that IBA may have another function rather than simply elevating the total auxin level to that which is required for root formation. There is a need for basic physiological research into the mode of action of IBA in root promotion, because until this process is more clearly understood, further developments in hormone stimulated root formation may be restricted.

Basal Temperature. The combination of high basal temperatures and high IBA concentrations has been found to be the two essential stimuli for rapid root formation on fruit tree hardwood cuttings. As has been found with IBA concentrations, each species of deciduous ornamentals may have differing optimum basal temperature requirements. Excessively high basal temperatures have been found to induce basal decay prior to root formation. Prolonged high temperature storage will also deplete carbohydrate reserves within the cutting (1). While root formation may ultimately be achieved, the subsequent establishment of rooted cuttings may be poor owing to the depleted food reserves.

From studies at the N.Z. Nursery Research Centre (7), lower basal temperatures of 18°C (64°F) compared with 22°C (72°F) have shown promise with cultivars which root readily provided basal decay can be avoided. When lower basal temperatures have been associated with lower hormone concentrations, basal decay has largely been diminished and rapid root formation has been achieved.

The Time of Taking Cuttings. The timing of taking cuttings has always been an important feature of successful propagation and has a considerable influence on hardwood cutting propagation. Generally hardwood cuttings have been found to root most readily in late autumn or early spring (4,7,8). The time when cuttings are taken will also influence the subsequent IBA and the temperature response due to the interaction of these treatments with endogenous factors affecting root formation. When considering deciduous ornamentals, quite different seasonal rooting responses are evident between species (see Table 1).

Table 1. Seasonal Changes in Root Formation on Hardwood Cuttings of *Betula pendula* and *Ulmus procera* 'Van Houttei'.

Species	Percent of Cuttings Rooted			
	April	June	July	August
B. pendula	70.0	75.0	37.5	12.5
U. procera 'Van Houttei'	0.0	0.0	55.0	50.0

Clearly, the optimum time for taking cuttings must be established for each species, a process which requires considerable reserves of stock material. Consequently, studies of the effect of the time of taking cuttings on root formation have been restricted but will continue as sufficient juvenile plant material becomes available.

In summary, developing hardwood cutting propagation techniques for deciduous ornamentals involves establishing juvenile stock sources and evaluating interactions among temperature, hormone, and timing treatments. As research progresses more data is being accumulated and recommendations for particular species will soon be available for growers contemplating using this propagating technique.

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ASPECTS OF PROPAGATION HYGIENE

J.M. RUMBAL

Duncan and Davies

New Plymouth, New Zealand

Hygiene in a propagation unit really begins with the stock plants. Duncan and Davies have extensive stock areas, about 20 acres. These require regular spraying and pruning to keep them in good order; propagation hygiene must start with clean healthy cutting material. A general spray programme, consisting of the following, is applied with a motor blower sprayer to all stock plants: 2-1/2 oz Lorsban insecticide, 6 oz Dithan M45 fungicide, 1-1/2 oz Topsin M fungicide. These are put into a 3 gal motor-blown sprayer.

Any specific pest or disease not controlled by this combination is picked up with routine checks and the following sprays are usually used to combat these: 3/4 oz Plictran for mites; 3 oz Cuproxide + 1/2 oz Agrimycin for fungous diseases. All of these again in 3 gallons of water. This programme outlined controls most pests and diseases, but other controls are used for specific pests. Recently the nursery has undertaken the spraying of stock plants and nursery crops with a helicopter with some success.

The next stage is to get clean healthy cutting material through a fungicidal wash prior to going to the cutting bench to eliminate further fungus troubles that we may introduce into the propagation area. The collected cuttings are sent through a Captan dip, which we use because of its general fungicidal properties and its relative safeness. A rate of 10 oz in 20 gallons is used and changed twice a week.

Cutting benches are scrubbed each week with a Jeyes fluid wash at 2 tablespoons per gallon. We endeavour to get clean cuttings into clean houses and the following are the steps used to clean all our propagation areas, generally about twice a year, or when the house is emptied or space permits.

Firstly, a high pressure steam cleaning unit is used to remove all traces of algae, slime, dirt and any plant remnants. Even the most stubborn algae is literally blasted off and washed away. The P.V.C. ceiling is then sprayed with Solar Sunclear, applied with force to enable the ionized particles to adhere. This eliminates excessive condensation drip and is used at a rate of 1 pint in 7 gallons of water for 2,000 sq. ft.

The walls, which the mist jets spray against, are treated next with a Dentolite sterilizing solution. This is an anti-fungicidal and bacterial wash. We use a paste brush and paint on the 'Dentolite' wash. This prevents any algae or slime from growing on the P.V.C. or polythene cover for several months.

The propagation beds are treated with Dinamin-A where cutting trays are to sit. This controls algae, slime, moulds, bacteria, mosses and liverworts. It is residual and does last for a worthwhile period keeping the surface clean. If algae builds up on the paths, copper sulphate crystals are dissolved and watered onto the concrete. This is most effective. Dinamin-A is used on sand beds, but Jeyes fluid, at 2 tablespoons per gallon watered on, is also effective and may be watered over cuttings if the need arises.

At present neither our cutting trays, (plastic plixie trays) nor our cutting media is sterilized. Media consist of fresh (1 to 3 months old) untanalized *Pinus radiata* sawdust, Irish peat, sand and perlite, all relatively uncontaminated ingredients. Terrazole is incorporated in all propagating and growing media at the rate of 2 oz per cubic yard to control *Pythium* and *Phytophthora*. We hope to have in the near future, a fumigating shed for methyl bromide for use with all pots, trays and media. Although we do not sterilize these at present, we have not met with any buildup of troublesome diseases.

When the cuttings are placed in the houses we undertake regular spraying every 10 days using the following therapeutants:

Orthocide 80W — Captan: for its general fungicidal properties and also, perhaps, for beneficial cutting stimulation.

Lorsban 50: for general control of caterpillars, some scales and mites.

Topsin M: for control of *botrytis*, fungus spots and powdery mildew.

These treatments generally keep the cuttings free from pests and diseases while they are in the propagating houses and, except for specific problems that may arise, are usually all that is given. Generally daily checking is carried out; picking off dead and diseased leaves, removing collapsed cuttings, and keeping beds free of weeds is a routine job. Paths are washed down daily when the house is being filled and tidyness is encouraged.

There are probably many other ways of maintaining hygiene standards, but these are the general steps followed at Duncan and Davies and we find that they enable us to keep our houses and cuttings reasonably clean and disease-free.

GROWING *EUCALYPTUS* SPECIES IN THE SOUTH OF NEW ZEALAND

C. LESTER DIACK

Diacks Nurseries Limited
Invercargill, Southland, New Zealand

Within the last few years poplar rust has made its presence felt here in New Zealand and has taken its toll. With this happening, the demand has been greater for fast growing trees such as the eucalyptus. Of all the trees, I know of no species other than eucalyptus which grows from the coast to the mountains, desert, swamp, and in all types of soil conditions.

Seed Selection. For the growing of eucalyptus in very cold areas such as we are in (Southland), it is very important that seed be selected from a cold locality; this will give resistance to frost. Seed should only be selected from trees of good form and true to the species.

Seed sowing

Hardy, cold tolerant species. (e.g., *Eucalyptus delegatensis, E. niphophila, E. gunnii, E. coccifera, E. perriniana*, etc.) Seeds of species that are cold tolerant are best sown in seed boxes and stacked outside in a cold, shaded position during the winter; this provides stratification of the seed. Keep turning the stack over and water any boxes that become dry. Remove any trays where the seeds have germinated by early spring and place them under shade frames outside, well protected from heavy frost and birds, but do not over-water or let them become too dry.

Tender and fine seeded species. (e.g., *Eucalyptus ficifolia, E. forrestiana, E. grossa, E. pressiana, E. nicholii*, etc.) Seed is sown very thinly in the spring. Before sowing, mix the seed with Captan dust and firm the seed in. Fine seed must be covered with a very light covering of a sand mixture; the larger the seed the thicker the covering. The sand mixture for covering consists of 2 parts river sand and 1 part peat. Sand alone tends to pack too hard on the seed, whereas the peat alone dries out too readily. Place these boxes on heated benches in the glasshouse and cover with a sheet of black polythene. Within 3 to 7 days the seed should be germinated. Remove the polythene, then water lightly, no more than necessary. Dust with Captan and try to keep the humidity as low as possible, otherwise "damp off" due to fungus diseases will start. As the seedlings develop, remove the boxes to a cold glasshouse with no heating but with good ventilation. When the seedlings reach the four-leaf stage place them outside to harden off, in an area free from frost and birds.

Tubing Up. The mixture used is 2 peat, 3 soil, 1 river sand, 1 coke breeze (screened) plus Osmocote (or Magamp). Seedlings are then pricked out into tubes 5 × 9 cm. This takes place usually in late spring or early summer. Place the tubed seedlings outside in semi-shade until they are established before placing in full sun.

Topdress with superphosphate and dolomite, then spray with Euparen for fungus control and Menazon for insects. This usually gives plants 25 to 40 cm in height when fully grown in tubes. They then can be grown on in containers or open ground. I find it a good policy not to grow eucalyptus in glasshouses or tunnel houses on account of the development of fungus diseases, except for seed germination of some species in early spring to maintain an even growth.

Eucalyptus suited for Southland's Climate. Southland has a rainfall of approximately 110 cm on the coast and 62 cm inland per year and a good number of frosts, sometimes down to −6°C (21°F). But frosts can be very consistent from autumn until late spring, with heavy falls of snow inland in some years.

Eucalyptus species that are growing in Southland are:

E. amygdalina	*E. johnstonii*	*E. polyanthemos*
E. archeri	*E. leucoxylon* 'Rosea'	*E. pulchella*
E. barberi	*E. macarthuri*	*E. pulverulenta*
E. cinerea	*E. maidenii*	*E. regnans*
E. coccifera	*E. morrisbyi*	*E. rodwayi*
E. cordata	*E. nicholii*	*E. rubida*
E. crenulata	*E. niphophila*	*E. smithii*
E. dalrympleana	*E. nitens*	*E. stellulata*
E. delegatensis	*E. nitida*	*E. st. johnii*
E. fastigiata	*E. nova-anglica*	*E. subcrenulata*
E. fraxinoides	*E. ovata*	*E. tenuiramis*
E. glaucescens	*E. pauciflora*	*E. urnigera*
E. globulus	*E. pauciflora* var. *nana*	*E. vernicosa*
E. globulus 'Compacta'	*E. perriniana*	*E. viminalis*
E. gunnii		

DEVELOPING A TREE AND SHRUB PROPAGATION UNIT IN THE "DEEP SOUTH"

NEVILLE L. JONES

Bales Nurseries Limited
Invercargill, New Zealand

At the beginning of this year we brought out an established nursery at Lorneville, a few kilometres north of the Invercargill city boundary. Because it was obvious that we needed more room for propagating, owing to the increasing demand for trees

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E. delegatensis
E. fastigiata
E. fraxinoides
E. glaucescens
E. globulus
E. globulus 'Compacta'
E. gunnii
E. johnstonii
E. leucoxylon 'Rosea'
E. macarthuri
E. maidenii
E. morrisbyi
E. nicholii
E. niphophila
E. nitens
E. nitida
E. nova-anglica
E. ovata
E. pauciflora
E. pauciflora var. *nana*
E. perriniana
E. polyanthemos
E. pulchella
E. pulverulenta
E. regnans
E. rodwayi
E. rubida
E. smithii
E. stellulata
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At the beginning of this year we brought out an established nursery at Lorneville, a few kilometres north of the Invercargill city boundary. Because it was obvious that we needed more room for propagating, owing to the increasing demand for trees and shrubs, this appeared to be the ideal location to build an entirely new propagation unit where we had room to expand as required. The main advantages offered at this new site were the excellent water supply, the existing good hedge shelter belts, and the extra acreage which would allow for proposed container blocks as well as additional glasshouses for propagation, etc. I will discuss the initial development stage that has already taken place and the further proposed stages.

Stage I. This started with choosing and clearing a site for our propagation unit, and then drilling for a new water well. The existing two bores were not sufficient for our plants. A good water supply was found and a six-inch Aturia submersible pump was chosen with a pumping flow of 51 psi, at 3900 gallons per hour (62 gallons per minute).

Choosing the Greenhouse. An important factor in a greenhouse is the retention of the "glasshouse effect". To achieve this the sheathing used on the Fletcher greenhouse gives ample visible light during the day and resists the passage of heat during the night or during cold periods. So, after careful consideration, a 60 × 80-foot two-span Fletcher Brownbuilt greenhouse was chosen. The modular basis system of construction was also favoured for its galvanized steel framework, completely eliminating the chore of painting.

The greenhouse is covered with "*Durolite* f" panels (a surface-protected glass fibre reinforced translucent sheeting). "Durolite f" resists the passage of heat better than glass for two reasons. Firstly, "Durolite f" allows only half as much heat through as a sheet of horticulture grade glass, which means the cost of winter heating will be lower. The "Durolite f" sheeting used on the Fletcher greenhouse is shatterproof and impact resistant and its use has eliminated the most common hazard associated with glasshouses — wind damage caused by negative pressure. Also, "Duroflite f" admits less ultraviolet light than glass, so the need for shading in summer is eliminated.

Heating and Ventilation. The greenhouse is heated by a hot air "Tropical Vented Space Heater" with a heat output of 208,000 BTU per hour. This unit is run by electricity and fueled by either diesel or kerosene oil.

The greenhouse has its own side and ridge vents but we feel there is a need for extra ventilation as well. A fan ventilation system has been proposed for the future which would consist of two extractor fans, each 800 mm in diameter operating at 700 R.P.M. This pair of fans will give 15 changes of air per hour. At present we can cool the greenhouse with the space heater on a cooling cycle.

Propagation Heating Beds. After completion of the greenhouse construction, propagation heating beds were set out. These beds have been raised off the ground level about 12 inches. Three heat beds, plus a "weaner bed", have been constructed, each 80 feet in length and 3-1/2 feet in width. Each bed is divided into three sub areas for control purposes. These beds at present hold 41,000 cuttings in hygiene trays and when all beds of this Stage I are complete, they will hold approximately 56,000 cuttings.

On the basis of 10 watts per square foot of heating being necessary, we use 1050 watts per sub area. Each sub area is controlled by its own thermostat housed in a corrosion resistant box with cable terminal blocks, control switch and indicator lamp.

Reflective building paper was laid at the bottom of the beds for insulating, then Simplex type soil heating cables were embedded in six inches of coarse sand. Simplex type soil heating cables were used because of their reliability and low cost compared to the Pryotenax cable set in concrete which is expensive, particularly if a failure occurs. A large bed has been made in the middle of the greenhouse for our *Cedrus* grafting. This bed is filled with a mixture of sawdust and coarse sand into which we plunge the grafts.

Misting. Our mist line is electronically monitored by the "Aquatron Electronic Mist Controller" and associate sense electrode. This provides ideal mist values exactly in accordance with plant transpiration and evaporation.

Stage II. Fifteen irrigation blocks have been planned, six of which are completed and now in operation. We have based the sprinkler requirements on the "Perrot type ZA 30" fitted with the adjustable "jet breaker". While this sprinkler is smaller in terms of coverage than the type we use at our open ground nursery, we find that it is better suited to a wide range of plant sizes, with particular reference to smaller trees.

Electronic Control. To bring these 15 irrigation blocks into working order through the solenoid valves we have had an "automatic electronic irrigation controller" made which has provision for 15 channels, each channel representing one irrigation block. These channels may be pre-set to provide timing from 5 to 60 minutes, or they can be used manually if necessary. There is also a frost protection circuit which will bring one or two channels under frost conditions. The fertilizer irrigation control system allows liquid fertilizer to be mixed with the irrigating water on a separate 15 switches, one for each channel and selected as required.

Stages III & IV. This will see the completion of the irrigation blocks — the future addition of carbon dioxide enrichment to the plants in the greenhouse, controlled by our heating unit, and the construction of a large drive through the shade house. Future plans are laid down for the provision of a propagation room, bagging, packing and dispatch, office, etc., all contained within one building next to our greenhouses. So what appeared to be a major undertaking 9 to 10 months ago is now well on the way to being a productive and worthwhile venture.

PROPAGATION OF *ENSETE VENTRICOSUM* – (MUSA ENSETE) — PURPLE FORM

DONAL DUTHIE

Botanic Gardens
Wellington, New Zealand

Plants of most *Musa* species are propagated by division, the exception being *Ensete ventricosum* (*Musa ensete*) which does not normally produce divisions, but does flower and set seed which germinates in prolific quantities if conditions are right. In New Zealand, however, a purple variety of *Ensete ventricosum* has not been known to flower and therefore the only known method of propagation is by mutilation of the bud tip which causes an artificial means of divisions or, in other words, meristem culture on a large scale.

Removing the Leaves. The parent plant must be of reasonable size and should have a stem not less than 10 cm diameter at the base. The top foliage should be removed by cutting through the stem about 30 cm up from the base. Then begins the delicate operation of removing all the leaf bases to expose the crown and the growing tip. In a plant with a 10 cm diameter stem, the crown would be about 3 to 4 cm high. The leaves are removed partially by tearing and partially by cutting with a sharp knife. It is often difficult to tell where the leaf ends and where the crown begins and it is only by experience that this knowledge is gained. When all the leaf bases have been removed, the mound of the crown will be exposed with the small growing tip appearing as a sharp point in the centre.

Preparing the Crown. The crown should be scraped clean of any vestigal leaf bases and the growing tip removed. This involves cutting out a saucer shaped depression about 3 cm across and 2 cm deep. All soil should be carefully washed from the roots and any long or damaged roots trimmed back. The crown should then be placed in a container of sphagnum moss. The moss should not be packed down, otherwise it becomes too

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Preparing the Crown. The crown should be scraped clean of any vestigal leaf bases and the growing tip removed. This involves cutting out a saucer shaped depression about 3 cm across and 2 cm deep. All soil should be carefully washed from the roots and any long or damaged roots trimmed back. The crown should then be placed in a container of sphagnum moss. The moss should not be packed down, otherwise it becomes too wet. A light covering of moss over the crown is beneficial to the development of callus.

Position. The plant should now be placed in a glasshouse with average temperature between 20° and 25°C (68° and 77°F), preferably with bottom heat and high humidity, such as in a house with intermittent mist. A drench of benomyl will deter fungus infections. Sometimes removal of the growing tip may not have been successful, in which case the growing point breaks through the centre of the depression in the crown. If this happens the growth should again be removed, leaving a deeper depression.

Formation of a Callus. A callus will begin to appear in about two to three weeks. As the callus spreads it will develop nodules which will form small green buds. Each bud will then divide and grow into small clusters of plantlets and it is not long before each plantlet is producing its own foliage and roots, the latter spreading over the surface of the crown. A healthy crown about 10 cm across will produce about 100 plants on its first crop.

Removal of Plantlets. When the tallest of the plantlets is about 30 cm high the first crop should be removed and potted up. It is important that a small portion of the parent callus be removed with each plant. The young plants will visibly "flop" for a week or so but will soon pick up and produce new foliage. The temperature of 20° to 25°C should be maintained for several weeks to force growth into the young plants. After this they can be slowly hardened off at cooler temperatures.

Timing. Provided the temperature of 20° to 25°C is maintained, there appears to be no difference in the time of year that the propagation is done.

Follow Up. If some of the larger plantlets with developing foliage are left attached to the callus, it should go on producing plantlets for a second, third and even fourth batch although each succeeding batch will have fewer numbers and lower vigour.

Pests. Spider mite is the principal pest attacking *Ensete ventricosum* and, if left unchecked, it will soon disfigure a plant, leaving brown paper-like blotches mainly on the underside of the leaves. High humidity lessens the likelihood of infection and several applications of a miticide should soon eradicate the pest.

It is my belief that if this method of propagation were done under sterile laboratory conditions and if a nutrient solution were used, as is done with orchids, then vast numbers of this plant could be propagated in a very short time.

PROGRAMME OF THE PROPAGATION SYSTEM USED AT ARDMORE NURSERIES LTD.

D. ALLEN BEAUMONT

Papakura, New Zealand

Our nursery is 12.5 hectares in size. One hectare is used for containers and as a growing-on area and for buildings, the rest is open ground consisting of consolidated peat. We produce about 80 to 85 percent of our own plants from cuttings or seed.

Cutting Propagation. All our evergreen cuttings are made in March/April and are taken mostly from plants growing in the open ground which will be lifted for sale in June/July.

The genera of plants we propagate from cuttings are:

Azara	*Cytisus*	*Pittosporum*
Boronia	*Erica*	*Photinia*
Calluna	*Euonymus*	*Senecio*
Chamaecyparis	*Griselinia*	*Spiraea*
Choisya	*Hebe*	*Teucrium*
Coprosma	*Hypericum*	*Viburnum*
Corokia	*Juniperus*	*Weigela*
Cotoneaster	*Nerium*	*Westringia*
Cryptomeria	*Phebalium*	

All cuttings are treated the same way. We make heel cuttings or otherwise cut under a leaf node. Cuttings are made as large as is practical; for example, *Cryptomeria elegans* cuttings are up to 20 cm long. All cuttings are put in boxes of pumice and sand, the latter from the Waikato River. The trays we have used mostly are wooden boxes, 300 × 450 mm by 100 mm deep. One sheet of newspaper is put in the bottom to stop the sand going through the spaces. The sand is dusted with lindane to control nematodes. We put 160 cuttings to a tray using a prodder, which is a piece of 25 mm thick wood having one hundred sixty 150 mm nails sticking out of it. This is pressed into the tray of sand leaving 160 holes ready to put the cuttings into at the right depth. After insertion of the cuttings the trays are then watered down and tapped at the same time; this firms the sand down around the cuttings. Most of the conifers, *Photinia*, and *Pittosporum* go into a tunnel house, 35 m long and 4.5 m wide, with Sarlon cloth at each end to allow for air circulation. The tunnel house has a sand floor and all trays are placed on this. There is one 50 mm pipeline down the middle of the tunnel house with a 25 mm upstand every 2 m which is 1 m high, having a winspray sprinkler on top.

Watering is controlled by a time-clock which can be set to come on from once an hour to 60 times an hour; one can water from 1 second to 60 seconds each time, depending on the setting. We have to alter our settings according to the weather.

Also we have another clock which turns off all the time clocks at 5 p.m. and turns them on again at 8 a.m. We set this according to the time of year and adjust for daylight savings time.

Our hardy cuttings are made the same way but go into the Sarlon, or shade house, with the same watering system, but which is used a lot less in wet weather. Most cuttings will stay in that position through the winter until spring when they are brought out to harden before planting or potting.

All cuttings that are planted in the open ground are taken out of the trays and planted straight out. Hence the reason for making large cuttings. Cuttings which are not planted in open ground go into 6 cm square peat pots or 8 cm round peat pots and are grown in these until ready for putting in planter bags or, in the case of a slow grower, they may be left until the following autumn or spring to be planted in the open ground.

We get 90 to 100% success in rooting cuttings of most plants with our system of propagation but we are growing mostly the hardy type plants.

Seed Sowing. The main genera we grow from seed are:

Acer	*Cryptomeria*	*Metrosideros*
Agonis	*Cupressus*	*Nandina*
Albizzia	*Dodonaea*	*Neopanax*
Banksia	*Eugenia*	*Phormium*
Betula	*Feijoa*	*Pittosporum*
Boronia	*Grevillea*	*Pseudopanax*
Callistemon	*Hoheria*	*Rhus*
Casuarina	*Liquidambar*	*Schinus*
Cordyline	*Liriodendron*	*Taxodium*
	Melia	*Virgilia*

Our seed comes from New Zealand, Australia, and Italy. We use mainly hygiene trays for sowing the seed, except for the larger seeds for which we use a deep plastic tray, 150 mm deep. We use our potting mix which is a 1:1 peat/sand mix, with added manures. This mix is used for all our potting, etc. The mix is firmed in the tray and the seed is sown on top with grade 2.5 vermiculite used to cover the seed. The tray of seed is then watered with a watering can. Terrozole is mixed into the water to control "damping off". The trays then go into a tunnel house. Frequency of watering is controlled by a time switch. After the seed has been germinated for a few weeks, depending on the cultivar, the trays are moved outside for a week then the seedlings are pricked out into other trays, using 80 plants to a tray.

The seedlings are grown until they are large enough to be put in 8 cm round peat pots. We are finding that this is the best way to grow our plants until they are ready to plant out or to be put in planter bags. This gives a saleable plant quickly with the least amount of growing area being used.

We are very concerned in avoiding plant roots going around in circles in containers and not getting out of this "merry-go-round" as the plants mature, hence our large use of peat pots and our practice of not leaving plants in plastic tubes when we receive them from another nursery.

"COSTING" A GROWING MEDIUM

M. RICHARDS

Massey University
Palmerston North, New Zealand

In general terms I am not keen on the process commonly called "costing", although I am happy to admit that cost-accounting, correctly applied, can make a valuable contribution to business management. Too often, however, the process commonly referred to as "costing" is not carried out in accordance with sound cost-accounting principles, and the results so obtained are frequently misused to produce conclusions which may be economically unsound. This approach to costs has recently been focused on growing media for container grown plants.

The true costs of a growing medium are made up of a number of factors, some of which are not easy to measure. The most important of these are:

(a) *The raw materials.* The material costs of a growing medium are fairly easily determined. Table 1 sets out the on-site-cost per M^3 of some commonly used materials, while Table 2 sets out the materials cost of three mixtures made from these, including the costs of a fertilizer programme. These costs will vary from nursery to nursery, and are included here merely as an illustration.

Table 1. Material costs, per cubic meter, delivered on site to the New Zealand Nursery Research Centre.

Soil, good quality loam	$ 8.75
Sand, river, washed	$ 7.50
Sawdust, pine	$ 5.75
Peat, baled Hauraki	$23.00

To the casual observer the difference in price is considerable, with the most expensive mix raising growing media costs by 77% above the cheapest.

(b) *Storage.* When materials are delivered to the site they must be stored, and storage represents a cost. Soil needs to be put in planter bags. This gives a saleable plant quickly with the least amount of growing area being used.

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Table 2. Materials cost, per cubic meter, of three mixtures, commonly used in nurseries.

Mixture	50% sand 50% sawdust	7 soil 3 peat 2 sand	50% sand 50% peat
Cost	$ 6.65	$11.35	$15.25
Fertilizer	$ 4.50	$ 2.50	$ 4.50
Total	$11.15	$13.85	$19.75

stored under cover to avoid delays during wet weather; other materials may need bin storage if they are not to be dispersed by wind. Storage represents a real cost, the cost of tying up capital, which could only be determined for a particular nursery.

(c) *Preparation of the mixture.* Before use, the materials must be bought together, treated if necessary, and combined. Ease of handling can reduce the costs involved; the more that the materials can be secured in easily handled packages, the less will be the handling cost involved. If sterilization is required for materials handled, the cost of sterilization becomes a cost of using that material. Soil, for example, will normally require sterilization for both disease and pest control; this could cost $2 to $3 per cubic meter.

(d) *Bulk density of the mixture.* Media vary considerably in weight per unit volume. Heavier media increase handling costs in the nursery, both in preparation of the mixture, and in all subsequent operations. When the plants are dispatched from the nursery extra weight means increased freight costs. In one nursery, a 50% reduction in weight of plants brought about a saving in freight greater than the cost of all the growing media used.

(e) *Adaptability to automated systems.* Todays production technology is increasingly based upon automation of the production processes, e.g. automated watering systems. Only media with the correct physical characteristics are adaptable to these systems, which may not only save labour, but may also produce better "yields". The extra labour costs arising from not being able to use automated systems, and the costs of not securing the possible extra growth, are costs of using media not adaptable to these systems.

(f) *Crop yields.* Despite claims to the contrary, our work continues to indicate that the best possible growing medium tends to increase "yield" in three ways:

1. larger plants,
2. saleable plants in shorter time,
3. a higher percentage of saleable plants.

Items 1 and 2 may merely be manifestations of the same property. In some circumstances speed of growth may not be important in itself, but the larger plants produced in a season may command higher prices. In other cases, e.g. house-plants and bedding plants, quicker growth may mean quicker turn-around of crops, and increased output from a given installation.

A higher percentage of saleable plants from a given number potted may also make considerable differences in crop returns. Nurserymen often fail to appreciate what these differences may mean in terms of money.

Plants growing in P.B. 8s will pot at about 200 per M^3. If increased growth brings an additional 10 cents per plant, not difficult to achieve, the extra return could be about $17.50 per M^3, far more than the increased cost of the growing medium. If a better medium gives 5% more saleable plants, at $1.00 per plant, this represents $20.00 extra per M^3, again, far more than the increase in media cost. Quicker turn around may be even more effective. On one nursery, improved turn around gave increased profit in excess of the total media cost on that nursery for one year.

It is possible to overcome some of the effects of low yielding potential of a growing medium by using larger containers. This, however, increases cost in other ways, such as more media used per 100 plants, higher packing costs, and increased transportation costs.

I have endeavoured to point out areas where the less obvious costs can occur in using a particular growing medium. It is not possible to itemize these, because the individual items will vary from nursery to nursery. Growers would be wise, however, to compare any particular medium with the best medium which can be devised for their particular operation. They will then be in a position to evaluate many of the cost areas which I have discussed.

PLANT QUARANTINE PHILOSOPHY IN NEW ZEALAND

A.F. RAINBOW

Plant Health and Diagnostic Station
Ministry of Agriculture and Fisheries
Levin, New Zealand

Is Quarantine Justified? Two of the most important potato pests (cyst nematode and wart) have been found in New Zealand within the last few years; so have bacterial wilt of lucerne, *Sitona* weevils (pests of pasture legumes), and the blue-green lucerne-aphid, amongst others. However, New Zealand is still

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Table 1. Approximate Number of Crop Disease Pests.

	Known In	
Crop	New Zealand	World
Barley	15	50
Maize	15	70
Dwarf beans	20	90
Potatoes	40	100
Onions	20	35
Strawberries	20	70
Peaches	45	80

The figures in the table are an over-simplification but show that many crops in New Zealand are still at risk from the introduction of new pests from overseas and that quarantine is necessary.

Many factors must be taken into account, such as our country's natural isolation, the need to import plant material either for planting or consumption, the pest status of our own economic and/or aesthetic plants, and the effect that a serious new pest could have on our plant exports.

Plant Quarantine. Animal quarantine in New Zealand is successful as animal disease cannot spread naturally; only two animal species are of prime economic importance, smuggling of cattle or sheep is difficult, and New Zealand is not dependent on imports of animals other than for the introduction of new breeds. By comparison, the plant quarantine situation is almost exactly opposite:

1) Because their hosts are stationary, plant pests are adapted for natural spread, although relatively few spread hundreds of kilometres on the wind. Like animal pests, however, they are easily spread by man when he moves infested propagating material or produce.

2) Many hundreds of plant species are of economic or aesthetic significance in New Zealand but, with the possible exception of rye grass and white clover, the economic importance of any one species is comparatively small.

3) The introduction of a new pest, although possibly of serious consequence for the crop concerned, will generally be of limited economic significance to the country as a whole.

4) Almost all the economic and most aesthetic plant species in New Zealand are introduced and we still depend on imported supplies of some plant produce and seeds.

5) Many of the seed-transmitted pests of New Zealand's traditional annual crops were already introduced long before serious thought was given to quarantine.

It is, therefore, neither necessary nor desirable to apply similar quarantine measures to the introduction of both plants and animals.

Potential Benefits of Plant Quarantine. It is difficult to place a monetary value on the benefit of quarantine but the establishment of a new important pest will cause loss in crop production and/or quality and is likely to result in increased production costs through additional control measures. There may also be an effect on exports. Although not a major item, New Zealand does export significant quantities of plant products, seed and nursery stock, with considerable potential for more, but this potential would be reduced if serious new pests become established. Already we are in a somewhat privileged position in respect to the export of some crop seeds to Australia. Seed certified as being grown in New Zealand has assured entry into Australia, *provided the pest status in New Zealand does not deteriorate*. Similarly, we have very few of the serious pests listed by the countries of the European Economic Community and so there are few plant health restrictions on trade with those countries — *provided the pest status in New Zealand does not deteriorate.*

Quarantine Philosophy. New Zealand's philosophy seems to be:

1) Being at considerable risk from the introduction of new pests from overseas and having good natural isolation, it is worthwhile taking sensible plant quarantine precautions.

2) Economic crops should be protected against known serious exotic pests, by strict measures if necessary.

3) A prohibitive procedure in respect of all propagating material is not justified.

4) Planting material cannot be considered pest-free on the basis of visual inspection alone and detention for a period in post-entry quarantine is necessary.

5) The greatest risk is with imported nursery stock and seed, where a pest is already in contact with its host.

6) The risk of introducing a new pest increases with the quantity of plant material imported.

7) Fruit and vegetables for consumption should not be imported from regions that present a serious pest risk unless the produce can be effectively treated.

8) Exotic pests will continue to arrive in New Zealand either naturally, or by accident as "passengers" on imported goods; some of these may become established. Introductions of

this nature are largely unavoidable and contingency plans are necessary to eradicate or contain a new outbreak if practicable.

Quarantine Practice. New Zealand has put its philosophy into practice through the Introduction and Quarantine of Plants Regulations, 1973, issued in pursuance to the Plants Act, 1970. These regulations govern the importation of plant material into New Zealand and their main provisions are summarized in respect of the following classes of material:

Nursery Stock (whole plants, cuttings, budwood, etc. for growing) frequently carries pests which, being already in contact with their host, can easily establish when the host is moved to another area. Importation of nursery stock of economic plants such as berry fruits, citrus, many conifers, grapes, pip and stone fruits is therefore restricted to very small quantities of new cultivars which must pass through a period of strict post-entry quarantine (close quarantine). Most other classes of nursery stock (covering several thousand species of plants) present less of an economic risk and importation is subject to a less restrictive procedure (open quarantine). Nevertheless there is a limit on the number of plants that an importer may introduce in any one year and the plants are still required to be grown for a period in post-entry quarantine, usually on the importer's property. In theory this is not a very good precaution because conditions may not be suitable for a pest to manifest itself and it could escape detection or, alternatively, conditions may be so good that the pest builds up between inspections and has already spread by the time it has been detected. Nevertheless this system has been operating in New Zealand for about 25 years and very few new pests are known to have been introduced in this way.

Seeds of all annual economic crops can carry pests that are transmitted to the following crop but, because traditional crop seeds have been in international trade for so long, New Zealand already has many of the important seed-transmitted pests of these crops. Quarantine precautions therefore vary with the species of plant. There are almost no health restrictions on seeds of most common vegetables because all the important seed-transmitted pests are already in New Zealand. On the other hand we have few pests of newer crops such as maize and soya beans and seed import requirements are very strict, but vary with the pest situation in the country where the seed was produced.

Commercial crop seed often contains seeds of noxious plants as impurities and importations must also be officially sampled, usually in the country of export, and certified free from specified noxious plant impurities before entry will be permitted.

Fruit and Vegetables for consumption do not present such a risk as planting material; nevertheless they are usually infested to some extent with insect pests in particular and they are imported in relatively large quantities. New Zealand will not import these commodities from countries where a serious pest risk exists. For example, we are completely free from fruit flies (family *Tephritidae*) and will not import fruit from areas where the more serious species of this family occur unless an effective treatment such as fumigation is available.

SOIL-BORNE DISEASES AND THEIR ROLE IN PLANT PROPAGATION

A.J. McCULLY and M.B. THOMAS[1]

Lincoln College

Canterbury, New Zealand

Abstract. The effects of four genera of fungal plant pathogens on seedlings and cuttings are reviewed. Current control measures for these diseases are discussed.

Poor seed germination, seedling diseases, and failure of cuttings to grow are common problems. Many fungal disease organisms have been found to be associated with these disorders. All are soil-borne, while some are also carried on seed and may cause disease when seed is sown in moist soil.

Symptoms caused through invasion of plant tissue by these organisms may include seed rot, pre-emergence or post emergence seedling rot and collapse ("damping off"), and a root rot and/or stem dieback of cuttings.

Unfortunately, conditions required for propagation (i.e. misting, high humidity, etc.) often favour growth of disease organisms which are present. The cut base of cuttings and wounding may provide an entry point for disease organisms. In some cases, poor growing conditions may precede fungal invasion (e.g. with *Pythium* spp.).

The following fungal organisms can be important in preventing establishment of seedlings and/or cuttings:

Fusarium spp. A large number of *Fusarium* spp. are present in soil, often occupying a saprophytic role from where susceptible host tissue may be attacked.

Fusarium avenaceum, *F. culmorum*, *F. oxysporum* and *F. solani* are the more important species involved in diseases of seedlings and cuttings. These species are generally not host specific at the seedling stage and have a wide host range. *Fusarium* attack can result in seedling death, (34, and J.W. Ray,

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pers. comm.), failure of cuttings to become established, or it may produce a debilitating effect on older plants or cuttings by means of root and crown rots. Serious losses from *Fusarium* infection in cuttings have been reported (1).

Symptoms. Although some pre-emergence death of seedlings is often attributed to *Fusarium* attack, this is not a characteristic of the disease. Generally *Fusarium* infection result in ill-thrift, stunting and occasionally death of emerged seedlings. Unevenness of growth and associated leaf yellowing of stunted seedlings can be caused by *Fusarium*. Infection by this fungus occurs particularly in young plants (3) on the root tips at the point of attachment to the mother seed, or via wounds, particularly in 'soft' foliaged or 'succulent' plants (41).

Seedling infection is seen as a root discolouration, ranging from light tan to brown in colour. Often an associated orange-red colouration can be seen within cut roots.

Cuttings are frequently invaded by *Fusarium*, resulting in dieback of the stem from the cut base and infection and death of developing roots. Symptoms include dark brown or black external colouration, brown to orange-red staining within the stem of the cutting, and browning of the young emerging rootlets.

Environmental Conditions. A wide range of soil temperatures [i.e. 5 to 35°C (41 to 95°F); optimum: 15 to 30°C (59 to 86°F)] and low-moderate conditions of soil moisture (14) (i.e. soil above permanent wilting point but below field capacity) favour *Fusarium* attack. High temperatures may stress the plant and make it more susceptible to *Fusarium* (38). Very wet soil and poor aeration suppress *Fusarium* growth and attack.

High levels of available soil nitrogen have been shown to increase the severity of attack by *Fusarium*, partly due to increased growth by the pathogen and partly to increased susceptibility of the host because of additional root growth. Nitrate nitrogen produces this effect to a greater degree than does ammonium nitrogen (43).

Fusarium rarely grows on aerial parts of plants, except where the relative humidity is very high (i.e. almost 100%). Under these conditions, mycelia may grow over the plant and groups of conidia may be formed on stems or leaves of young plants.

Spread. Fusarium spp. are generally soil-borne although conidia are often detected on seed. Seedling infection can arise from the seed-borne source.

Saprophytic growth of *Fusarium* spp. occurs in soil on plant debris, from where the organism can grow to attack living tissue. Contaminating fungi grow much more rapidly through sterilized soil than through soil where other micro-organisms exist which compete with the pathogen. Any movement of soil on boots etc. can also contaminate previously sterilized soil.

Control. *Fusarium* can be controlled by a number of methods:

1) *Disinfection of soil*. The most effective, and most generally used methods of soil sterilization involve the use of steam, steam-air mixtures and chloropicrin/methyl bromide.

2) *Cultivation and hygiene*. Removal of plant debris and early cultivation to enable breakdown of any remaining plant debris will reduce the incidence of *Fusarium* infection. Good crop rotation practices will also assist in avoiding *Fusarium* infection.

Flooding has been used as a control measure for *Fusarium*, especially in the case of *F. oxysporum* f.sp. *cubense* on banana (banana wilt) where fields are flooded to a depth of 60-150 cm for up to 6 months (35). However, although this is not generally a practical method for curbing *Fusarium* infection in seedling/cutting material it illustrates its susceptibility to poor aeration.

Hygiene in hormone powders with cuttings is also important as infected cuttings can contaminate the hormone powder. Allowing the cut surface of cuttings to dry prior to planting is most important (41) as this results in less infection.

3) *Fungicide Application*. A number of fungicides have been used to control *Fusarium*:

(a) *Benzimidazoles*. The development of systemic benzimidazole fungicides has been important in the control of *Fusarium*. Benomyl (Benlate*), thiabendazole (Thibenzole*) and thiophanate (Topsin*) act as protectants (applied as a soil drench, coated on seed or used as a cutting or root dip), or eradicants (generally applied as a soil drench) to control *Fusarium*. Fuberidazole is used as a seed dressing, often in combination with captan.

Excellent control of *Fusarium* spp. has been achieved with these materials, although some reports of tolerance to the fungicide by *Fusarium* (15,30) may indicate a need for caution in the use of these chemicals. Benomyl appears particularly useful on rhododendron cuttings where it has been shown to increase rooting (20). Stevens *et al* (41) applied benomyl to stock plants prior to taking cuttings but this technique was not effective in preventing decay of the cuttings. Benomyl at concentrations of 5% or more (in talc) can be phytotoxic to cuttings and concentrations should be kept low (e.g. 2.5%) (Hocking and Thomas, unpubl.).

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* *Trade Name.*

(b) *Other Fungicides.* Captan, quintozene (or PCNB) and thiram have all been used in the past in control of *Fusarium*. However, they have all been largely superseded by the use of the benzimidazole fungicides. The main advantages of the non-systemic materials lies in their relatively low cost and low toxicity.

4) *Biological Control.* Attention is now focusing on the use of biological control of seedling diseases. Often this may be used in conjunction with chemical control; e.g. soil treatment with trichodermin (extracted from the fungus *Trichoderma viride*) combined with thiram seed treatment produced control of *Fusarium* in pine seedlings (18).

Pythium and Phytophthora species. A number of *Pythium* species are important pathogens in the early stages of seedling growth. *P. debaryanum*, *P. irregulare*, and *P. ultimum*, all of which are well recognized as seedling pathogens, have been isolated in New Zealand (7,31,32). Other *Pythium* species found in soil in New Zealand may be important pathogens on less frequent occasions.

Phytophthora megasperma, *P. cryptogea*, *P. cinnamomi*, *P. dreschleri* appear to be the most important species attacking seedlings/cuttings. Other species may also be important in some areas; e.g. *P. lateralis* on *Chamaecyparis lawsoniana* (25).

Pythium spp. readily attack young root tissue. However, seedlings have been observed to become resistant to attack by *Pythium* after a short period of time as the tissue begins to harden and lignify. *Phytophthora* can infect seedlings through to relatively mature plants, although as the plant ages, it becomes less susceptible to attack. For example, 2 week old lucerne seedlings sown into soil inoculated with *P. megasperma* had a higher incidence of infection than in 4 week old seedlings sown in the same soil, which in turn had a higher mortality than 8 week old seedlings similarly treated (29).

Symptoms. Infection of young seedlings by *Pythium* spp. occurs at two points on seedling plants — at the point of emergence from the seed, in which case the fungus appears to colonize the seed in a saprophytic role, and then move to the healthy seedling tissue of both root and shoot; or at the root tip from where infection moves up the plant.

Pre-emergence damping-off is caused by total infection of the seedling prior to emergence. Post-emergence damping-off is characterized by a later or, perhaps, slower infection which eventually engulfs the stem of the seedling above ground level and produces collapse of the seedling.

Pythium infection normally produces a soft wet rot of the roots and/or stem, which turn tan to mid-brown in colour. If drier conditions prevail following a late infection of a seedling, the lesion on the stem may appear drier, and collapse of the cell walls give the lower stem a slightly constricted appearance.

In a seed-box or seed bed, *Pythium* infection is usually seen in patches of plants which may develop symptoms, often in a wetter area of the box. Alternatively, individual plants with slight infections may remain stunted.

Phytophthora spp. generally attacks roots, often entering at injury points (10). As with *Pythium*, a soft wet rot may be produced, although in some cases (e.g. with *P. megasperma* on some hosts) very dark dry lesions result from infection. *Phytophthora* infection in a seed bed normally occurs in patches.

Environmental Conditions. Pythium develops more readily under conditions of moderate to high levels of soil moisture (i.e. 30 to 90% moisture holding capacity), (12,33). Lack of drainage and resultant poor aeration favour growth of *Pythium*. Lower temperatures, i.e. less than 20°C (68°F) also favour attack by *Pythium* species recorded in New Zealand, although this effect may be indirectly caused by slowing the growth of the host, which exposes it more readily to pathogenic attack. Some *Pythium* spp. are unaffected by soil temperatures of up to 30°C (86°F), (2) *Pythium* is more readily isolated from soil in winter and early spring than in summer and autumn when soil moisture levels are lower and temperatures are higher (21).

Phytophthora spp. also grow more readily under conditions of moderate to high soil moisture (25,29).

Phytophthora spp. have variable optimum temperature requirements for survival and growth (40). Sporangia and oospores of *P. cactorum* survived freezing temperatures, although the hyphae did not. *Phytophthora cinnamomi*, however, has a minimum temperature range for growth of 5 to 16°C (41 to 61°F), an optimum range of 20 to 32.5°C (68 to 90.5°F), and maximum temperature for growth of 30 to 36°C (86 to 97°F) (48). *P. syringae* attack has been observed to occur more readily in the late autumn to early winter period (36).

Both *Pythium* and *Phytophthora* are affected by varying oxygen (O_2) and carbon dioxide (CO_2) levels. *Pythium irregulare* and *Phytophthora megasperma*, when exposed to an atmosphere containing 1% CO_2, produced less than 20% of their normal growth in air (23). Growth and survival of *Pythium irregulare* and *P. vexans* were favoured by higher levels of CO_2 combined with normal concentration of O_2, rather than lower O_2 and normal CO_2 levels (9).

Varying the pH of the potting mix between 4.0 and 9.0 appears to have little effect on infection by *Pythium acanthicum*, *P. debaryanum*, *P. irregulare* and *P. ultimum* (McCully, unpubl.).

In general, any condition which tends to induce poor vigour in seedlings exposes them to a greater risk of *Pythium* or *Phytophthora* infection than where more favourable conditions prevail.

Spread. Pythium and *Phytophthora* are soil-borne organisms and can spread in a similar manner to *Fusarium*. Fruiting structures and zoospores of these pathogens may also be carried in water by either splash dispersal, movement through soil, or in irrigation water (42). Both *Pythium* and *Phytophthora* (25) can survive in host debris in soil, from where infection of susceptible host tissue occurs.

Control. Pythium and *Phytophthora* may be controlled by a number of methods:

1) *Sterilization of Soil.* As for *Fusarium* spp. (see earlier).

2) *Cultural Practices and Hygiene.* Adequate fertilizer balances, provision of drainage, and guarding against sowing seed too deeply are all factors which can assist in preventing *Pythium* and *Phytophthora* infection. Well aerated free-draining soil or potting soil mixes should also be used.

Removal of plant debris, weeds, etc. is also encouraged. The provision of formalin footbaths at the entrance to glasshouses, potting-sheds, etc. to prevent contaminated soil from entering the area sterilized is also important, particularly where crops are grown in the soil. Seedling boxes, particularly those of wooden construction should be thoroughly cleaned and sterilized (e.g. by formalin dip, well prior to sowing seed).

3) *Fungicides.*

(a) *Etridiazole.* This fungicide is sold as 'Terrazole' either as a wettable powder (35% active ingredient (a.i.) or an emulsifiable concentrate (25% a.i.)). Excellent results have been achieved particularly against *Pythium*, although this is not always the case (F.R. Sanderson, pers. comm.). Etridiazole is most commonly used either within a soil mix or as a soil drench. Reports of phytotoxicity have been published, e.g. in *Chamaecyparis lawsoniana* cuttings (44). Etridiazole is not known to have activity against *Rhizoctonia* or *Fusarium*.

(b) *Captan.* This has been the standard fungicide for Pythium control for some years, and is used as a seed dressing, root dip, soil drench or is incorporated in soil. It is relatively inexpensive and has a low toxicity to plants and animals.

(c) *Fenaminosulf.* This fungicides is sold as 'Bayer 5072' (formerly 'Dexon'), a wettable powder which is used as a soil drench. Applications may need to be repeated at 14 day intervals.

Excellent results have been achieved for *Pythium* and *Phytophthora* control with fenaminosulf (6,47). The chemical is toxic to animals and man and extreme care should be taken when using this material. As a lengthy waiting period must be observed, soil application is normally restricted to the early seedling stage of plant growth.

(d) *Thiram*. Thiram can be applied as a soil drench or a seed dressing. It has the advantages of being a relatively safe chemical to handle and has a short waiting period (maximum 7 days in New Zealand). However it may not eradicate the pathogen (24) and may give inadequate control, particularly with *Pythium* (6).

A number of new fungicides are becoming available for use against *Pythium* and *Phytophthora*. These include "Milcol" (drazoxolon), and a systemic material known as "Nurelle". It is most important that the correct fungicides be chosen for control of *Pythium* and *Phytophthora*.

Our own trials and the work of many others (46) have reported an increase in the incidence of *Pythium* and *Phytophthora* where benomyl use has occurred. This is believed to be due to the suppressive effect of the fungicides on antagonists and competitors, thus allowing *Pythium* and *Phytophthora* to grow more freely. Smith *et al*, (39) observed a similar phenomenon when reporting stimulation of growth of a basidiomycete on turf by benomyl application. Neither the water moulds nor most basidiomycetes are controlled by benomyl.

4) *Biological Control*. Researchers are at present evaluating the use of spores of the fungus *Trichoderma viride* as a seed treatment to reduce *Pythium* infection (Robertson, pers. comm.).

Rhizoctonia solani. *R. solani* is an important disease-causing organism capable of infecting plants at most stages of growth from early germination and seedling stage (where pre- and post-emergence damping-off can result) through to mature plants where root and crown rots may develop through *Rhizoctonia* infection. *R. solani* has a wide host range, and is generally air-borne, although cases of seed-borne infection have been reported (17).

As with *Pythium*, *R. solani* has a wide host range. Dingley (7) records the pathogen on grasses, cereals, fodder crops, vegetables (e.g. cabbage, rhubarb, potato) bedding plants (e.g. carnation and anemone) and trees and shrubs (e.g. *Pinus radiata* and *Citrus sinensis*).

Symptoms. R. solani normally infects the host at ground level, eventually girdling the stem at this point causing constriction of the stem — a symptom often referred to as 'wire-stem'. Close examination of the seedling stem at this point (by means of a hand lens) may reveal brown or black mycelium strands running up and down the stem — a characteristic of *Rhizoctonia* infection.

R. solani lesions are normally much drier in nature and darker in colour than those of *Pythium*. The margins of the lesion tend to be more clearly defined, partly because of the darker colouration of the lesion, than is the case with *Pythium* infection.

Where humid conditions prevail, the coarse grey-brown mycelium of *R. solani* may be observed growing over aerial parts of seedlings. Spread from seedling to seedling can occur in this manner, resulting in patches of infected plants covered with mycelium.

Environmental Conditions. Moderate to high soil temperatures (15 to 30°C; 59 to 86°F) (4,19,22), and only slightly moist soil conditions favour growth and pathogenicity of *R. solani*. Pochanina (28) observed that in potato the most vigorous development of *R. solani* on stems and roots was associated with higher temperatures and a simultaneous reduction in rainfall and soil moisture. Papavizas *et al* (26) and Herr (13) observed a similar effect with low inoculum density in spring which increased to a maximum in mid to late summer.

Where extremely dry conditions prevail, *Rhizoctonia* may form resting structures known as sclerotia, which tolerate dry or low nutrient conditions. When favourable conditions subsequently prevail, the sclerotia germinate by means of mycelial growth which can then infect susceptible host plants. Under conditons of high humidity and warm temperatures, coarse grey *Rhizoctonia* mycelium may be seen growing over groups of dead and dying seedlings. In potatoes, the incidence of *R. solani* is reduced in the presence of sulphur, but increased with lime application (8).

Spread. R. solani is soil-borne, both as hyphae and sclerotia, and can be moved with soil. Plant debris may harbour the pathogen, which tends to lie dormant until susceptible live host tissue is placed near it, which it will grow towards and colonize. As with *Pythium*, wooden seed boxes or trays may harbour infection. *R. solani* has also been found to be seed-borne (17) and can be carried on vegetative material used for propagation (e.g. bulbs, corms, tubers, etc.).

Control.

1. *Sterilization of Soil.*

2. *Cultural Practices and Hygiene.* Removal of weeds and plant residues, sowing seed which is debris-free and not discoloured or shrivelled, and provision of hygiene methods as noted for *Pythium* should be observed.

3. *Fungicides.*

(a) *Benzimidazoles.* The benzimidazole group of fungicides was the first fungicide group to successfully control *Rhizoctonia*. Benomyl was found to provide excellent control of the pathogen. Sharma *et al* (37) found that benomyl was most effective against seedling blight of mung bean caused by *R. solani*. Pergola *et al* (27) found benomyl, carbendazim, thiophanate and benodanil all gave good control of *R. solani* compared to quintozene, a previously used non-systemic standard fungicide for this pathogen.

(b) *Other fungicides. R. solani* has traditionally been difficult to control with fungicides. Quintozene and chloroneb have been used, but neither gave entirely satisfactory control (27,37).

Conclusion. Fungal diseases are very important in plant propagation. Those which we have considered:

(a) Are all soil-borne and attack the plant roots.
(b) Are capable of causing seedling and cutting death and decay.
(c) Can be controlled by soil sterilization and plant hygiene procedures.
(d) Can be controlled by fungicides — it is important, however, to ensure that the problem is correctly identified before fungicides are used; e.g. benomyl should *NOT* be used to control *Pythium*. On occasions two or more pathogens may act together on a host to produce a synergistic effect in terms of decay, e.g. *Rhizoctonia* and *Fusarium* on geranium cuttings (16). In cases where a complex of pathogens is thought to be present the use of combinations of fungicides is advocated, e.g. etridiazole and benomyl; chloroneb and benomyl (45).

The universal incorporation of a single fungicide in propagation and potting media may lead to the promotion of growth of fungi resistant to the fungicide. Such a situation should be carefully watched for, should it occur, so that remedial action can be taken.

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LOSS OF PRODUCTIVITY IN CLONAL APPLE ROOTSTOCKS

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Abstract. The paper outlines the apparent loss of rootability and juvenility in the Ottawa series of apple rootstocks in Canada. The lack of a suitable quick chemical test, as well as the uncertainty of using morphological characteristics associated with juvenility for assessing rootability is briefly discussed. Based on published work, as well as anatomical differences between the easy-to-root and difficult-to-root sources of the Ottawa rootstocks, a quick, easy test using the mid-nodal region of the basal internode of one-year old apple wood and staining cross-sections with phloroglucinol-HCl is suggested. Not only the lesser amount of phloem fibre in the easy-to-root type, but also the existence of large gaps in the ring is important. Suggestions are made for retaining rootability in clonal apple rootstocks and for their distribution.

There is a need to safeguard the existing levels of rooting in clonal apple rootstocks but more important, new clonal or vegetative lines must be kept in the juvenile condition especially for their successful propagation by softwood cuttings. According to Beakbane (2), Gardner first reported the loss of rooting ability over the period of change from juvenility to maturity in 1929, but even for tissue culture, Abbott (1) specified juvenile material. This paper is not intended to review the vast amount that has been published on juvenility, but rather it is an

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Abstract. The paper outlines the apparent loss of rootability and juvenility in the Ottawa series of apple rootstocks in Canada. The lack of a suitable quick chemical test, as well as the uncertainty of using morphological characteristics associated with juvenility for assessing rootability is briefly discussed. Based on published work, as well as anatomical differences between the easy-to-root and difficult-to-root sources of the Ottawa rootstocks, a quick, easy test using the mid-nodal region of the basal internode of one-year old apple wood and staining cross-sections with phloroglucinol-HCl is suggested. Not only the lesser amount of phloem fibre in the easy-to-root type, but also the existence of large gaps in the ring is important. Suggestions are made for retaining rootability in clonal apple rootstocks and for their distribution.

There is a need to safeguard the existing levels of rooting in clonal apple rootstocks but more important, new clonal or vegetative lines must be kept in the juvenile condition especially for their successful propagation by softwood cuttings. According to Beakbane (2), Gardner first reported the loss of rooting ability over the period of change from juvenility to maturity in 1929, but even for tissue culture, Abbott (1) specified juvenile material. This paper is not intended to review the vast amount that has been published on juvenility, but rather it is an attempt to bring to the propagator's attention a situation where juvenility and rootability has been inadvertently lost in a series of apple rootstocks and to suggest a rather simple test to ascertain rootability in apple tissue.

In the 1950's the author was involved in an apple rootstock breeding program with Agriculture Canada, but the final selection, as well as the introduction of a series of rootstocks, known as the Ottawa series, was carried out by other researchers when he left that service. Early in the selection program, random samplings of the selection showed high rootability by softwood cuttings under intermittent mist outdoors. Much later nuclei of the rootstock series were received at Saskatoon, Saskatchewan directly from Ottawa and were established in stoolbeds. These stools were cut to ground level annually and no difficulty was experienced in rooting softwood cuttings from them (10). With Ottawa 3, which was of particular interest because of its dwarfing ability, he also cited other researchers, however, who had reported extremely poor rooting or complete failure with this rootstock; at Saskatoon, however, there was 89 to 100 percent rooting with an average root score of 4.8 to 5.0 in a 0 to 5 range (5 best) after seven weeks in an intermittent mist bed outdoors with no bottom heat. The above values were from treatments receiving either 0.1, 0.3 or 0.8 per cent IBA in talc, but there was no rooting trend from hormone concentration. Cuttings not treated with hormone rooted in the same percentage range, but the average root score was less (3.1). Since propagation technique was not in question, it seemed an obvious case of loss of juvenility and rootability.

Hess (6,7,8), reporting to the International Plant Propagators' Society, explained the difference in rooting of easy- and difficult-to-root plants on the basis of rooting cofactors. Applying this theory to apple, Challenger et *al* (5), Quamme and Nelson (12), and Nelson and Pepper (11) all presented evidence of what appeared to be three separate cofactor type responses in apple. The partial transfer of this rooting response to adult softwood cuttings by grafting juvenile tissue into the adult tissue above the rooting medium level was also demonstrated by Nelson (9). On the other hand, Zimmerman (13), working with *Pinus*, was unable to demonstrate a difference in the two growth phases and Nelson and Pepper (11) cited results obtained by a graduate student, Miss Hivang, where the use of toluene to remove fats and pigments from the extracts allowed the extracts from adult tissue to express a root promoting effect similar to the juvenile extracts. Unfortunately, this work was not continued and some of the emphasis on rooting cofactors seems to have been dropped. Regardless, to the author's knowledge, no suitable chemical extraction method that will easily ascertain the degree of rootability in relation to juvenility is available to the plant propagator.

Morphological characteristics have been used to describe the juvenile and adult growth phases and Blair, MacArthur and Nelson (4) cited European literature, mostly German, that became available after World War II to describe the two growth phases in apple. Blair, *et al* (1956) worked with *Malus* × *robusta* 5 apple rootstock which existed in the two growth phases and matched the morphological descriptions. The rooting ability was vastly different, with the juvenile phase being superior. Nelson (10), citing earlier unpublished data, reported that the juvenile crowns showed a marked reduction in rootability of softwood cuttings when the crowns attained a height of only six inches above ground. These crowns had never been allowed to reach the fruiting stage and had not changed in morphological characteristics from that of the juvenile stage. Accordingly, morphological characteristics as described for juvenility could hardly be used as a practical test.

Although not included in the published report (4), MacArthur had observed differences in the fibre content of the phloem in the cross-sections of the two growth phases of *Malus* × *robusta* 5, but a later search of her stored laboratory notes failed to uncover details. Beakbane (2) showed that the formation of fibres and sclereids in the primary phloem acted as a barrier to root formation and that rooting was inversely proportional to the amount of fibre, as well as the continuity of the fibrous ring. She also suggested that this explained the difference in rooting between the juvenile and adult growth phases. This was later confirmed (3) and she elaborated further on the nature of the barrier which was not only mechanical, but also showed that some of the lack of rooting was due to the fact that phloem ray cells abutted fibre tissue and were not connected by living cytoplasmic strands in the shy-rooting types.

A simple test based on these anatomical differences has been suggested by Nelson in a paper entitled, "A Test for Juvenility and Rootability in Clonal Apple Rootstocks", which has been submitted to the Canadian Journal of Plant Science. Essentially, the remainder of this paper is a summary of this recent submission. Using the mid-nodal region of the basal internode of one-year old wood, cross-sections were made with a sharp knife and stained by the phloroglucinol-HCl technique. The colour developed rapidly and very little magnification, if any, was needed to ascertain the difference in phloem fibres illustrated diagrammatically in Figures 1 and 2. Where comparisons could be made, the easy-to-root material at Saskatoon had much less fibre, as well as more numerous and wider gaps in the ring, than the difficult-to-root material gathered at the Agriculture Canada Research Station, Sydney, British Columbia. The varying amounts of fibre in Ottawa 3 and Ottawa 12 are depicted in Figure 1 as examples, but similar differences were recorded for Ottawa 7, 8 and 11, with the amount of phloem fibre being rated very light or light in the material from Saskatoon and medium or heavy in the material from Sydney. The same differences occurred between shoots from the stool beds of juvenile *Malus* × *robusta* 5 (Figure 2A) and adult trees of the same selection (Figure 2B) grown at Saskatoon. Although the adult phase only had a medium amount of fibre, it formed a narrow ring with almost no gaps. The least fibre was found in tissue taken about 7 cm from ground level on transplanted seedlings of the cultivar, Kerr, after their first full season in the field (Figure 2C). All the fruiting trees and selections sampled (BE601, BE6027, Edith Smith, Patterson, Pioneer 60, and U10-11) had at least a medium rating as depicted for Patterson (Figure 2D).

This review of a case of loss of rootability in a series of apple rootstocks points out certain rather important facts about the maintenance of high root capacity and the distribution of rootstocks in a manner which will preserve this rootability. To maintain the high level of rooting, stools of apple rootstocks must be pruned as close to the ground level as possible which will mean periodic pruning back of the crowns themselves. Although crowns for rooting material used solely for commercial rootstock purposes can be allowed to develop slowly in height for several years and still maintain suitable root formation, any propagation of new nuclei for propagation purposes should come from very severely pruned crowns to obtain the highest rooting potential possible. Although, in the case of the Ottawa rootstock series, nuclei have been propagated to send for virus indexing at Sydney, B.C., other sources of the Ottawa or any other rootstock selections should be monitored by the phloroglucinol-HCl test to select and perpetuate those sources with the least fibre present. It is obvious that in the handling of the Ottawa and *Malus* × *robusta* 5 rootstocks currently being held at Saskatoon they have progressed considerably in fibre content, even though they still root satisfactorily, when compared to the fibre content of the Kerr seedlings.

Although the exchange of rooted material over international boundaries does present certain problems, it seems to be the only method of transmitting the high level of rootability. Quarantine and virus-indexing stations must realize that these rootstock nuclei have to be handled differently from nuclei of fruiting cultivars. These rooted plants must be isolated so that the basal tissue can be perpetuated if and when the material is cleared. Also, the practice of distributing budwood or scions, as

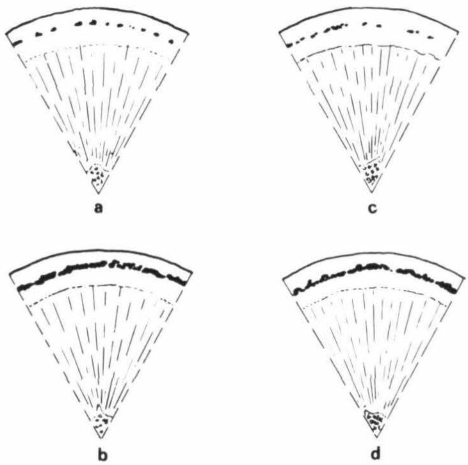

Figure 1. Diagrammatic sketch showing differences in the presence of phloem fibres and continuity of the fibrous ring in cross-sections of the mid-internodal region of the basal internode of one-year old apple wood in the dormant condition. A — 'Ottawa 3' rootstock from Saskatoon, Saskatchewan; B — 'Ottawa 3' rootstock from Sydney, B.C.; C — 'Ottawa 12' rootstock from Saskatoon; and D — 'Ottawa 12' rootstock from Sydney.

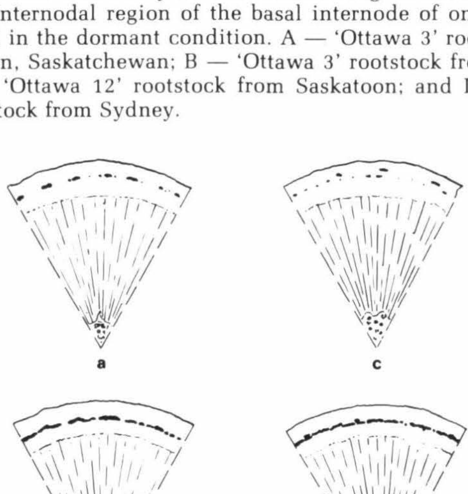

Figure 2. Diagrammatic sketch showing differences in the presence of phloem fibres and continuity of the fibrous ring in cross-sections of the mid-internodal region of the basal internode of one-year old apple wood in the dormant condition. A — '*Malus robusta* 5 rootstock (juvenile); B — '*Malus robusta* 5 rootstock (adult); C — 'Kerr' seedling after one full season in field; and D — 'Patterson' (from fruiting age trees).

practiced with fruiting cultivars, is quite unsatisfactory for transferring the high rooting capacity of the tissue.

Finally, if original clones are maintained in the future and if the amount of liquified phloem tissue is monitored, the loss of rootability as experienced in the Ottawa rootstocks should be avoided. The phloroglucino-HCl test on tissue of the mid-internodal region of the basal internode of one-year old wood in the dormant condition is suggested as a satisfactory, easy, and quick test.

ACKNOWLEDGMENT

The author would like to acknowledge the assistance of Mr. D. Bertoia of the Agriculture Canada Research Station, Sydney, B.C. who supplied the Ottawa rootstock tissue. Through his co-operation the paper and this discussion was made possible.

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TECHNICAL SESSIONS

Monday Morning, December 5, 1977

The twenty-seventh annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:30 a.m. in the Saturn Room of the Sheraton Columbus Hotel, Columbus, Ohio.

PRESIDENT BOSLEY: Welcome to the twenty-seventh annual meeting of the Eastern Region of the International Plant Propagators' Society. I wish to especially welcome those members from the Australian Region, the Great Britain Region, the Western Region and the newly forming Southern Region. At this time I would also like to introduce to you George Oki, President of the International and John McGuire, who is the Program Chairman for this meeting. Also with us this morning is Dean Roy Kottman, Dean of the College of Agriculture and Home Economics here at Ohio State University and he is also head of the Agricultural Extension Service here in Ohio. Dean Kottman will officially welcome us to Ohio.

DEAN KOTTMAN: It is a real pleasure for me to welcome you to the state of Ohio and the city of Columbus, Ohio's third largest city and the capital. I also extend to each of you a special welcome to the Ohio State University, established as the Ohio Agricultural and Mechanical College in 1870. From the looks of your program I am sure you will have a most successful meeting and I extend an open invitation for any of you to come and visit us at the Ohio State University at any time

PRESIDENT BOSLEY: Thank you, Dean Kottman. To get this morning's program underway I will now turn over the podium to Miss Betsy Scarborough who is the moderator for this morning's session.

CHIP BUDDING FRUIT AND ORNAMENTAL TREES

B.H. HOWARD

East Malling Research Station
Kent, England

Abstract. Chip budding achieves rapid union formation in the weeks immediately after budding because the cambium of stock and scion are placed together, in contrast to conventional T budding. Early union formation results in higher bud-take, stronger unions, greater uptake of mineral elements, faster and more uniform growth and the production of more first grade trees from chip than T budded plants. Fungal spores of *Nectria galligena* carried on apple budwood are not introduced under the bark of the rootstocks as readily in chip as in T budding and fewer union cankers develop.

Fruit trees are composite plants consisting of a scion and rootstock because scions are often difficult and slow to propagate on their own roots and rootstocks produce inedible fruit. Good fruit characteristics and ease of rooting are combined by grafting scions onto rootstocks and the most convenient method is to use single bud grafts, i.e. budding. A large part of the production of ornamental trees also involves cultivars selected for their shape, foliage, flower or fruit characteristics being budded onto rootstocks.

There is a continual need to produce both fruit and ornamental trees of improved quality and uniformity for two main reasons. Firstly, fruit growers in the United Kingdom demand large, well-feathered maiden trees which have the framework to carry early crops of apples, and large-scale buyers of ornamental trees require uniform and thick stemmed trees of their selected cultivars. Secondly, it is wasteful of land, labour, planting material, spray chemicals and machinery if buds fail or poor quality trees develop in the nursery row. The objective must be to produce complete stands of high quality trees so that each operation achieves maximum effectiveness.

Budding methods. There are two basic types; those such as shield or T budding which add the scion tissue to a complete rootstock stem by sliding it under the bark through an incision and those, such as chip and patch budding, in which a piece of rootstock tissue is removed and a similar piece of scion tissue carrying the bud is substituted.

Cambial contact. Techniques which substitute scion tissue for a similar piece of rootstock tissue ensure a much better match of the cambia than do techniques involving the insertion of scion material into the rootstock below the bark. Cambial contact in chip budding is good and development of the newly placed scion tissue occurs in step with that of the rootstock during the immediate post-budding period (Figure 1a).

For successful cambial development to occur in a T budded plant callus must completely fill the spaces between the underside of the bark flap and the upper surface of the bud shield so that a new cambium can develop *de novo* in the callus between the existing cambium of the shield, which lies adpressed to the xylem of the rootstock stem, and the cambium of the rootstock, which is exposed at the edge of the raised flap which overlies the shield. The bark may not always lift at the cambium, as has been erroneously assumed in the past, but can separate in the secondary xylem, thus presenting a tortuous line for the developing cambial cells to trace (Figure 1b). Conditions which delay or prevent the filling of voids with callus, such as the onset of cold weather or premature release of the tie, prevent complete cambial development in T budded plants and it is under such conditions that chip budding gives obvious advantages.

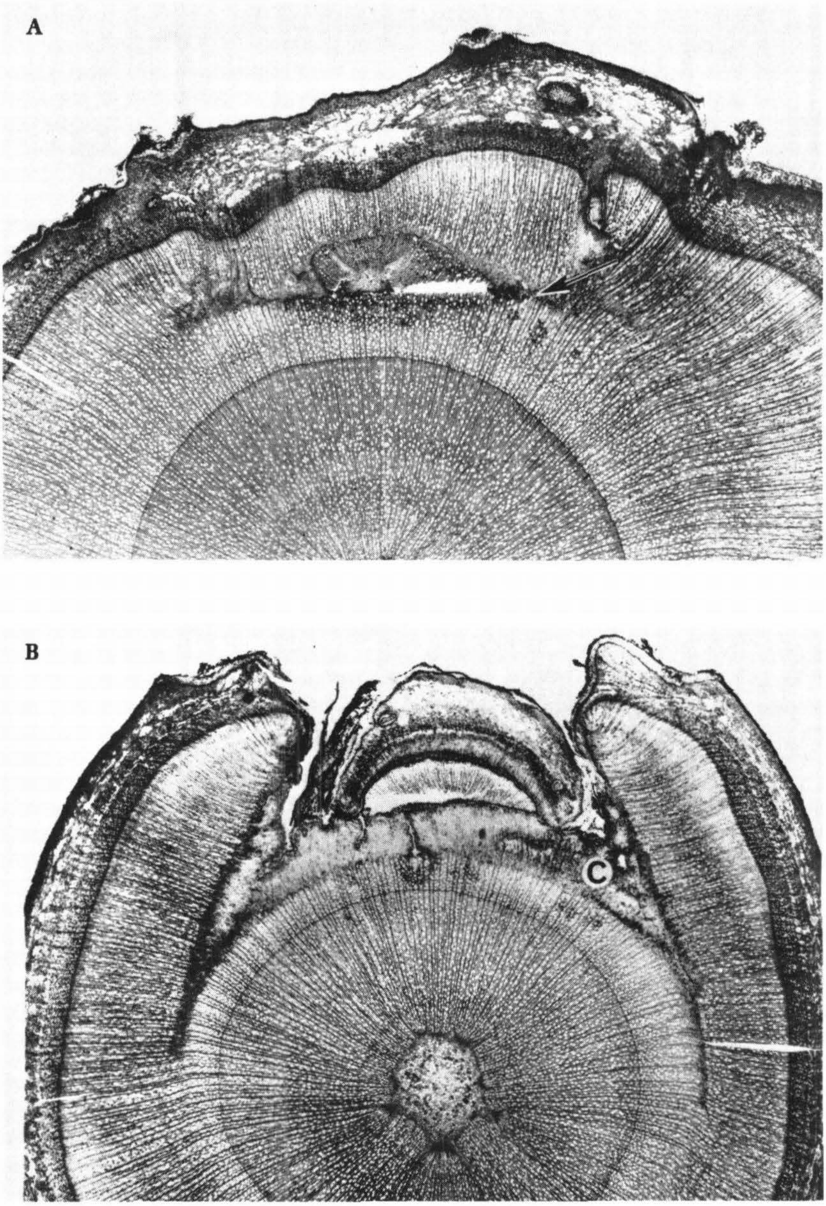

Figure 1. Transverse section through 'Lord Lambourne' apple bud shields and M.26 apple rootstocks approximately 0.5 cm below the buds. (a) Chip, (b) T, sampled November 1971. Junction between chip and rootstock is arrowed, C = callus.

Bud-take. Better matching of the cambia in chip budded plants compared to T budded plants no doubt accounts for the improved bud-take from the former method especially in a range of ornamental trees (Table 1). Among fruit plants there are a few examples of poor bud-take in most species, but reports from commercial nurseries indicate that bud-take of peaches has been greatly improved by changing over from T to chip budding.

Table 1. *Examples of percent bud-take by chip and T methods.*

	Chip	T
Prunus subhirtella 'Autumnalis' mean of 7 different rootstocks	82	25
Acer platanoides 'Crimson King' on *A. platanoides*	70	7
Tilia platyphyllos 'Rubra' on *T. platyphyllos*	89	78
Ulmus × *vegeta* 'Commelin' on *U. glabra*	70	56

Tree growth. The most obvious improvement from chip budding in fruit trees is the uniform and vigorous growth which occurs in spring from unions which were completed the previous autumn, in contrast to those from T buds where some plants invariably grow slowly in the spring as their unions are completed. Young scion growth in early summer contains higher levels of N, P and K in chip budded plants compared with T budded plants and dye passes more readily across chip bud unions as maiden growth begins (2).

By the end of the first growing season chip budded trees have grown either taller, or have produced more and longer lateral branches and are more uniform in size that T-budded plants (Table 2). Larger numbers of high grade trees result therefore from chip budding (Table 3).

Table 2. Effects of chip and T budding on growth of 'Golden Delicious' apple maidens on MM.106 apple rootstock.

	Chip	T
Scion growth from the union (cm)	120.2	111.6
Number of laterals per tree	16.5	11.0
Mean length of laterals (cm)	30.1	22.7
Range of numbers of laterals per tree	12 to 23	0 to 17

Table 3. Percent 1st and 2nd grade 'Cox' apple trees (out of 4 grades).

Apple rootstocks	Chip	T
M.27	84	36
M.9a	80	72
M.26	88	56
MM.106	80	60

Union strength. During summer gales the T budded scion varieties which develop laterals early in the season often break out of the rootstock unless the scion is tied to a rootstock snag or a cane. The 1972 growing season was preceded at East Malling by a severe frost in an otherwise mild winter, during which the temperature fell from 40° to 0°F and returned to the higher temperature during the course of only 5 days. This damaged the cambium of a wide range of plants in the nursery, and it was subsequently very noticeable that chip budded scions succeeded in growing and survived gale damage in greater numbers than T budded plants, presumably because early union formation during the preceding autumn had made them less dependent on early and extensive cambial activity of the rootstock the following spring (1).

Union diseases. In apple orchards stem cankers caused by the fungus *Nectria galligena* may cause severe damage to branches and can only be combatted by expensive treatment involving cutting-out and hand application of fungicide. A primary source of infection is the nursery where sporulating cankers may occur on 1-year-old trees that became infected from the trees used to obtain budwood. When *Nectria* spores carried on budwood are inserted under the bark of the rootstock in the T budding method they are presented with ideal conditions for germination, resulting in a union canker which destroys that tree and serves as a source of splash inoculum to others nearby. Because spores remain on the outside of the chip bud and are not inoculated under the rootstock bark the chance of infection is greatly reduced. Using apple buds treated with a *Nectria* spore suspension, union cankers developed in 64% T budded trees compared to only 15% chip budded ones (Bennett, personal communication).

DESCRIPTION OF THE CHIP BUDDING METHOD AND CONDITIONS FOR SUCCESS

Rootstocks. Rootstocks are trimmed in the normal way to give a clean leg beyond the required budding height. Standing over or to the side of the stock, a piece of smooth stem is selected and the first cut is made to a depth of about 3 mm at an angle of about 20° into the stem to make an acute lip. The knife is then withdrawn and a second cut is made 1½ inch above the first, entering the stem and cutting down to meet the first cut and the piece of tissue removed. The cut should be shaped like an inverted U, not A-shaped; this is facilitated by using a narrow-bladed knife (Figure 2)

Bud chip. The budstick is held with the base towards the operator and the scion chip is obtained by cutting the budstick with cuts similar to those made in the stock. The chip is lifted between thumb and knife blade, transferred to the other hand and placed into the rootstock. If the lip in the rootstock stem has been cut at a sufficient acute angle and the chip placed firmly into it, it should remain in position until tied. The objective is to match the cambium of stock and scion as in all true grafting methods. Therefore, thick-barked stocks should be cut relatively shallower and thin budsticks relatively deeper. When a narrow chip is placed on a thick stock a margin of bark should be visible around the edge of the stock cut except below the lip. This ensures that cambium of stock and scion are opposite to one another (Figure 3).

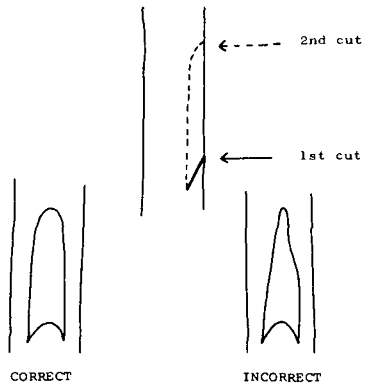

Figure 2. Cutting the rootstock. Top = side view, bottom = front view.

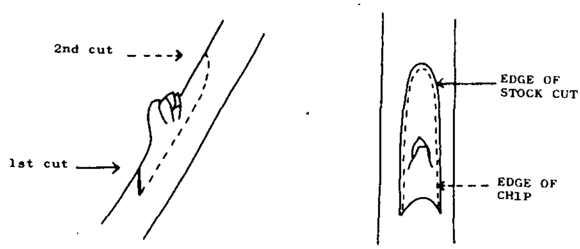

Figure 3. Cutting the budstick. Left = side view, right = front view with chip in place on the rootstock.

The most essential requirement in addition to competent knifemanship is the use of polyethylene film to cover and protect the chip during the healing process, particularly essential because unlike the T budded shield it is not protected by the bark flaps. Rubber strips and patches, thin plastic strips and twine have all proved inferior to polyethylene film. The colour of the film has been shown not to have any effect on callusing through different light transmitting properties, but differences in manufacturing processes may result in relatively brittle or soft textured tapes, the latter being more convenient to work with and giving better results. The tape should entirely cover the bud where entry of the red bud borer midge (*Thomasiniana oculiperda* Rubs.) is to be avoided, as with apples in Southeast England, and should avoid the actual bud while ensuring complete coverage of the cut surfaces where the bud is large and soft, as in *Tilia* spp. Tape widths of 1 or 0.5 inch are available and for some species such as *Acer platanoides* it does not appear to matter which is used. The length of time the tie is left in position will depend on the growing conditions; at East Malling a high proportion of buds are healed-on in 3 weeks, but 4 weeks are necessary to guarantee optimal results in most years with apples and other fruit plants, and ornamental trees such as *Ulmus*, *Tilia* and *Acer* spp.

Budding season. In theory, chip budding can be done at any time of the year because the bark does not have to slip. In practice, successful chip budding is confied to the period April to early September when rootstocks are growing actively (Table 4). The most common time is July and August, similar to conventional T budding, when dormant buds of the current season's growth are used. Spring chip budding is also successful with respect to the effectiveness with which the chip heals onto the rootstock, but under East Malling conditions vigorous scion growth cannot be guaranteed every year and more information is needed on the correct stage at which to remove the rootstock head and how this should be timed in relation to the developing scion shoot.

Table 4. Percent bud-take of 'Cox'/M.26 apple related to date of budding. Ties released after 3 weeks.

Budding dates		Budding dates	
1974		*1975*	
18 July	98	27 February	0
8 August	100	10 April	0*
5 September	88	7 May	96
10 October	0		
21 November	0		

* April budding gave 72% take when ties were removed after 6 weeks.

DISCUSSION

Chip budding appears to have greatest relevance as a replacement for conventional T budding when the period of cambial activity is limited after budding. The faster union formation brought about by the close proximity of the cambium of scion and rootstock makes up for the shorter period during which growth is possible. On this basis chip budding is likely to be more effective in the United Kingdom, where it has been taken up rapidly in fruit and ornamental nurseries, than on the continent of Europe, and in the Eastern United States than along the Pacific Coast, where in Oregon, for example, excellent stands of T-budded *Acer platanoides* 'Crimson King' and *Gletitsia triacanthos* 'Sunburst' can be seen, whereas in England they can only be raised reliably by chip budding.

On the other hand, the use of chip budding in spring in those areas with long summer growing seasons will facilitate the regular production of large trees in one growing season by ensuring rapid union development and early growth. In less favourable areas the chip method is of even greater importance for spring budding, but it may not be sufficient to accomplished the desired tree quality every year. The more cumbersome and time-consuming whip and tongue grafting can be relied upon to produce good quality trees in one season and since the chip budding method provides similar although less extensive cambial contact an investigation is in progress to determine the essential components of the grafting method in comparison with spring chip budding.

The fewer movements involves in chip budding result in slightly faster work compared to T budding in the United Kingdom. In Japan it is reported to be preferred when very large numbers of buds must be placed in a short time, although maximum bud-take is not always achieved under these conditions.

Acknowledgements. Among my colleagues who have played a part in the investigation of the potential of chip budding and helped to rapidly establish it as the main budding method in UK nurseries, Miss M. Bennett was responsible for studies on *Nectria* infection and Dr. D.S. Skene for the anatomonical studies.

Figures 1a and b and part of Table 1 are reprinted with permission of the Journal of Horticultural Science.

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BEN DAVIS: Can you use chip budding on peach and cherry?

BRIAN HOWARD: Cherries are improved by chip budding. Peaches are an uncommon crop in England so I can only give you second hand information from visitors from the U.S. and

France who after visiting us have gone back home, tried it and written us that it works rather well on peaches.

BEN DAVIS: How well does that bud stay in between the budder and the tyer?

BRIAN HOWARD: If it is properly made the wedge at the bottom of the cut holds the bud in very tightly. In fact, we can pull the rootstock back, flick it and the bud still stays in; there is little probability of the bud dropping out between the budder and tyer.

RALPH SHUGERT: In southern Ohio most of our budding will be done in a 30 day period when temperatures frequently go up to 90° to 100°F. What comments would you have about this high temperature under that poly-wrap.

BRIAN HOWARD: Last year we had a very hot dry summer in England and many nurserymen were calling me complaining that they could not get the rind to slip and what about this chip budding they had been hearing about. Those people who tried it under these hot-dry conditions had very good success. However, we have never investigated the direct temperature effect you speak of but I did visit one English nursery where I thought burning might have been a problem. Traditionally, English nurserymen bud on the north side of the stock thinking that when the bud grows out it will grow straighter because it will be growing toward the sun. The fact that we bud on the north side may be one of the reasons we do not have any problem with burning. We also use milky poly tape, but as I tell all my nurserymen, try one row, don't do the whole nursery.

PETER ORUM: Can you use a patch tie on these chip buds?

BRIAN HOWARD: No, you cannot. It does not have pressure applied to the right places, in fact, the only thing we are recommending to date is the polyethylene strips which I have described.

VOICE: Do you recommend setting the bud to one side in order to match the cambia when the stock and scion are different sizes?

BRIAN HOWARD: I am not happy with the idea of placing it to one side, this defeats the concept of knitting and completing the cylinder of cambium. I would recommend that you attempt to match stock and scion as much as possible. With a thick stock you can simply cut shallower if your scion wood is thin or in some cases you can go to the opposite end of the bud stick which may be thicker in order to obtain your bud. By attempting to match the cut sizes we have not experienced a need to set the bud off to one side.

CHIP BUDDING ON A COMMERCIAL SCALE

ALBERT H. BREMER

HIlltop Orchards and Nurseries
Hartford, Michigan 49057

Hilltop nursery specializes in *Malus* and *Prunus* species of fruit trees, raising both nursery and orchard crops on 1500 acres. The majority of our stock is sold on a contract basis, allowing an interval of 2 to 3 years from the time of order to the final delivery of the product.

Chip budding, a recent introduction in our propagation program, may prove to be a dominant factor in increasing future bud stands. We have worked 2 years with this budding technique. It appears to be more costly than conventional T-budding, requiring precise timing and accuracy. Chip budding has possibilities of increasing our winter survival rate in the field.

Understocks for apple are propagated by layering, while peach and cherry rootstocks are started from seed. During the first growing season, apple rootstocks are mound layered with sawdust, undercut in the fall and placed in cold storage through the winter. Early in the spring they are transplanted by machine and grown to suitable grafting caliper. This understock is sprouted to a height of 12 inches at least once prior to budding. Rubbing or removing leaves and branches hardens the green succulent bark and makes it easier for the budder to locate a smooth area to place the bud during the summer. Peach and cherry rootstocks receive the same attention, however they are mostly propagated by seed.

Budding is done by a crew of two, a budder and a tyer. Our budding force consists of 15 to 20 crews. In mid-July, prior to the start of the budding season, each crew is instructed on proper procedure for T-budding or chip budding. The following technique is used with a narrow bladed knife for chip budding:

Step 1. The first cut is a horizontal cut made at about a 30° angle into the stock.

Step 2. To make the second cut the budder is trained to hold his knife at a near vertical position, starting about 1-1/2 inches above the first cut and drawing the knife downward along the side of the rootstock to intersect the first cut.

Step 3. The scion or budwood is held in the palm of the hand and cut in the same manner as the rootstock.

Step 4. The bud is then slipped into the cut on the rootstock, matching the cambium layers.

Step 5. The tyer begins wrapping a plastic band on the upper portion of the bud placing his final tie at the base of the cut nearest the ground.

Step 6. The band is cut with a razor blade and removed after 4 to 6 weeks. The bud and understock then go into dormancy.

In April just as the bud is beginning to break, the understock is cut in a slanting fashion 1/8 inch above the bud. This completes 2 full years of development from initial propagation. Six months later the tree will be harvested and placed in cold storage.

A major problem occurring with chip budding is the need for closer supervision of budding crews. Quite often the tyer will fall behind the budder. Secondly, a chip bud is unlike a T-bud, because the cambium is constantly exposed to the drying summer sun. Therefore the bud is in jeopardy until it is wrapped. Finally chip budding is also more time consuming and more costly than conventional T-budding. Caliper of rootstock and budwood must be matched in size.

Although in its experimental stages, chip budding has proven to be successful, but it has not yet replaced T-budding as Hilltop's major budding method.

HARRY HOPPERTON: Is chip budding really worth it with easy to bud plants like the crabapples? You can T-bud 4000 a day compared to 1000 and you get a 95% stand. In addition, with the chips you have to go back and cut the poly off while with the T-bud the rubber band just falls off.

AL BREMER: I agree with your comments but I still think chip budding has potential for reducing winter bud kill on some plants. I will, however, stay with T-budding for apples and crabapples.

HARRY HOPPERTON: Do you take a thin or thick chip bud?

AL BREMER: Neither, we try to strike a happy medium and much of the supervision for chip budding comes in training the budders to match the size of the stock and scion. We feel it is quite important that they match fairly closely.

DUKE BISCOTTI: I'd like to make a comment on covering the bud. Our growers out in Oregon and Washington have temperatures of 100-110°F and they also felt they were going to experience some damage but as far as I know they have had none. There is apparently some heating and you will see quite a bit of moisture collect under the poly band. The quality of the band you use is quite important; in fact, we use two, one for summer and one for fall budding.

HUGH STEVENSON: Mr. Howard's buds all seem to be completely covered but some of those that you showed were not covered; do you cover your buds?

AL BREMER: We cover the apples but we don't cover the cherries; if you put tension on the cherry buds it destroys them.

MANUAL GRAFTING VERSUS MACHINE GRAFTING

JAMES B. LAW

Stark Brothers Nurseries and Orchards Company
Louisiana, Missouri 63353

Machine grafting has been with us for a long time. From a historical standpoint, M.G. Kains in his book, "Plant Propagation", refers to machine grafting techniques; this book was written in 1916. Robert Garner refers to grafting machines in his classic text, "The Grafter's Handbook". He probably puts his finger on the situation today when he states "grafting machines are more commonly used for vines than for other subjects". He then goes on to state why. Hartmann and Kester also treat the subject in their book, "Plant Propagation: Principles and Practices."

Over a period of time our company has tried a number of grafting machines. The latest one we have tried is the Wahler Graft-Star unit, making what is popularly referred to as the Omega graft. With this unit we were able to produce 5500 grafts in an 8 hour day with a skilled operator. Using an unskilled operator a production level of 3300 grafts per day was reached. This would compare with a 1600-1800 average that we would expect to have made per 8 hour day by a skilled grafter. These grafts were wrapped in the usual manner and placed in grafting boxes for callusing.

We noticed that a browning or oxidation of the machine-cut cambium tissue takes place rather rapidly using this system. My personal feeling is this later reflects on the type of graft stands we secured using this method. It also appears that due to the bruising of the tissue during grafting, an additional several days have to be added to the callusing time.

Our results are as follows:

Apple Cultivar	Grafts Made	Graft Stand	Percent Stand
'Starkrimson'	7,500 Machine Grafts	3,745	49.99%
'Spur Golden'	7,500 Machine Grafts	3,802	50.66%
'Starkrimson'	14,000 Hand Bench Grafts	9,592	68.5 %
'Spur Golden'	14,500 Hand Bench Grafts	9,849	67.9 %

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These counts were taken in June and are total counts so losses due to low spots, poor soil drainage, poor planting technique, mechanical damage, etc. are all included in the totals.

A completed apple graft costs approximately 16¢ ready for planting. Of this less than 2¢ is labor for making the graft, thus labor used for grafting represents only 12% of the cost of the finished graft. With such differences between stands, the need for more total grafts to be made, extra planting costs, extra land costs and all the subsequent following costs, we don't feel the machine grafting approach holds promise at this time. We will try again and continue our tests but it will continue to be a very modest test program for us.

BEN DAVIS: Jim we ran a test much as you did. We made about 25,000 grafts and the trees are being harvested this fall. We got about a 25% take with the Omega grafter and 90-95% take with hand grafting. As you indicate, the grafts cost about 16¢ but with those losses we don't feel we can afford the machine grafting.

POLY TENT VERSUS OPEN BENCH GRAFTING

LEONARD SAVELLA

Bald Hill Nurseries, Inc.
Exeter, R.I. 02822

Grafting of various types of ornamentals has been a practice of propagators for hundreds of years. The types of graft and how they are handled has differed according to the personal preference of the propagator for whatever his reasons.

Considering that we all know the basics of grafting I would like to talk about how, with the use of plastic, we can improve our percentage of success and at the same time lower the time and effort it takes to care for the grafts once they are placed in the grafting bench.

The practice most commonly used by propagators is the open bench and sweat box type of grafting. Whether or not you cover your bench, getting the peat moss at the right moisture content, covering the union on the graft, syringing, draining the glass, rolling back the paper, all these can be eliminated by using the poly tent method.

The poly tent method involves building a frame of wood or wire over the grafting bench. The height and the length of the tent depends on what you graft and how many. A desirable

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The poly tent method involves building a frame of wood or wire over the grafting bench. The height and the length of the tent depends on what you graft and how many. A desirable height is 30 inches above the bench. This will give ample room to reach in and stand the grafts up.

You can also put grafts in a flat and then completely cover the flat with poly. This is a good method to use when space is limited because the flats can be put anywhere in the house where there is room.

When top grafting larger plants another method is to put an inflated poly bag over each graft with a ball of wet sphagnum moss below the union. Seal the poly bag below the moss and put the plants anywhere on the floor where there is room.

One big advantage of grafting in poly tents is that you can double and triple stack the pots in the bench, in the flat or on the floor. This way you can get 2 to 3 times as many grafts in the same amount of bench space as when using the open bench or sweat box method. If you double or tripple stack the pots remember you must have space in some greenhouse to space out the grafts once they are removed from the tent. No wax is used on the unions at any time.

Once the frame is constructed, about 3 inches of wet peat moss is put in the bench, plastic is put over the frame and sealed air tight on three sides leaving the fourth side open until all the grafts are in the tent. The grafts are just stood upright on the peat moss. No covering of the union is used.

When the tent is full it is sealed air tight and no additional care is needed for the next 3 to 4 weeks. Clear plastic (4 or 6 mil) is used so that you can see into the tent and observe what is going on at all times without opening it.

Two points of caution: One — the frame should be constructed in an oval or if you use a rectangular frame the top should be of "A" frame construction. This will allow the moisture-droplets that form to run off the sides into the peat and not on the grafts. Second — grafted woody deciduous plants should be kept separate from the evergreen and conifer grafts because the makeup time may differ. Evergreen conifers and broadleaf grafts are removed from the tent once the callus at the base of the scion is full (usually 4 weeks). Woody deciduous plants are removed from the tent when the leaf bud has broken and the leaf is showing about 1/4 inch long. This is very important. If the deciduous grafts are not aired at this time the leaves will "cook" and your scions will die. They must be aired at this time regardless of size of the scion callus. I have never experienced a situation where the scion was not callused enough to sustain the life of the plant when the leaf was this far advanced and the graft aired.

When the grafts have callused the poly at the base of the tent is loosened to allow air to enter the tent. It is kept loose for

3 days after which time you can remove the grafts from the tent or you can remove the plastic covering the grafts; either way the grafts must now be spaced out slightly. The grafts are now given the normal care that you would give any other plant growing in your greenhouse.

CHARLES McCLOUD: What are your temperature ranges during the various grafting operations?

LENNY SAVELLA: The understocks are brought in from a holding house which usually ranges from 45 to 50°F and when they are grafted they go into the grafting house at a temperature of 76°F and we try to hold this temperature.

CHARLES McCLOUD: What about the temperatures in your tent, on a bright sunny day does the temperature go way up?

LENNY SAVELLA: Yes it may. I forgot to mention this in my talk, but on a bright sunny day it is very important that you put some kind of shading over the top of your tent.

JOE CESARINI: Can you graft lower and cover the union with the peatmoss in the poly tent?

LENNY SAVELLA: No, you can't do that Joe. What I'm trying to do is design a system which requires the least amount of labor, care and attention possible. This method is 100% foolproof. I make the union, stand it up in the tent, the union doesn't have to be covered or waxed and this considerably reduces labor.

DWARF ROOTSTOCKS — PROPAGATION AND USAGE

ROBERT F. CARLSON

Department of Horticulture
Michigan State University
East Lansing, Michigan 48824

Rootstocks, especially for fruit crops, is an old subject with renewed interest. For example, 25 years ago there was very little interest in dwarf apple trees compared to current use of up to 90 percent in commercial orchards. There are practical reasons for this, such as: smaller trees are easier to manage, production per unit of land is higher than the old system, fruit quality is improved and management costs are less. This report is an update on rootstocks and their application for controlling tree size and for increased yields.

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ROOTSTOCKS FOR *MALUS* SPECIES

For the sake of clarity, only the apple rootstocks which are currently used in the U.S.A. will be discussed in order from the most dwarfing to the most vigorous.

Malling 27. Being the most recent introduction, M.27 has not been extensively tested for growth and yield characteristics with American apple cultivars. It is very dwarfing and produces a bush-like tree. The propagation rights of M.27 have been granted to the Oregon Rootstock Company, and rooted cuttings of it should be available in 1979.

M.27 may in the future be useful in dwarfing ornamental *Malus* species of which there are hundreds of cultivars. For example, there is a need for a range of sizes of crab apples from small bush-like to larger trees. This rootstock could also fit into greenhouse pot culture for testing compatibility characteristics of both fruit and ornamental *Malus* species and cultivars. Thus, only a small test area would be needed compared to field testing.

Malling 9. This rootstock is well known because it has been in use for about a century. It will dwarf apple cultivars to 30% of the standard size trees. M.9 used to dwarf apple trees will give small trees which fit into the home landscape. Another ideal place for such trees is for the small orchardist (5 to 10 acres) for "pick your own" fruit. These trees can be held to a maximum height of 8 ft or less. M.9 is very precocious, starting to bear fruit the first and second year with some cultivars.

M.9 also is good for dwarfing of ornamental crab apple trees; however, bud take is usually poor. The cause of this may be due to latent viruses in both this stock and the *Malus* species. The new EMLA 9 no doubt will take the bud better. Trees on M.9 are not free standing and require support.

Malling 26. This rootstock gained rapidly in popularity among commercial fruit growers because it has excellent dwarfing and early fruiting qualities. When budded correctly, M.26 will give a well anchored, free standing tree.

The following rootstocks should be budded about 30 cm high in the nursery: M.27, M.9, M.26 and M.7. In so doing, such trees can be planted 25 cm deeper than they were in the nursery. This will provide more stable trees and eliminate crown suckering.

Malling 7. Without doubt M.7 is the most tested and most reliable semi-dwarf apple rootstock. It is compatible with all cultivars tested, precocious and productive, and it is well anchored. M.7 is prone to some crown suckering, but this is kept to a minimum when trees are budded high and planted deeper in the orchard. This method also improves tree anchorage.

Malling Merton 106 and 111. These rootstocks are semi-vigorous to be used where wider tree spacings are needed. MM.106 is a precocious stock with all cultivars. However, due to its susceptibility to *Phytophthora cactorum*, "collar rot", it should only be used on well-drained, sandy loam soils. MM.111 is not as precocious, but well anchored and dependable on a range of soils. Apple cultivars budded on MM.106 and MM.111 should be spaced about 14 ft apart in the row and the rows 20 ft apart.

New *Malus* Rootstocks. Since most of the apple clone rootstocks to date have been imported, programs are now in progress to develop new rootstocks in the U.S.A. and Canada. Since these will not be available for commercial use for 2 or more years, they are only briefly mentioned here. The Michigan Apple Clone (1) series was initiated in 1948 with the purpose of developing dwarfing precocious, hardy and well-rooted clones. The most promising are now indexed and propagated in Oregon. Other clones are being developed at Geneva, New York and Ottawa, Canada.

CLONAL ROOTSTOCKS FOR STONE FRUITS

Most of the stone fruits (peaches, cherries, apricots, and plums) are propagated on seedling rootstocks. However, few are propagated on clones. For example, peach, plum and apricot can be propagated on St. Julien A or St. Julien X on MC-20-3 plum clones. Recently, the East Malling Station has introduced a dwarfing cherry clone 'Colt'. Both sweet and tart cherries can be propagated on this clone. 'Colt' cherry can be increased by the stoolbed method or by soft and hardwood cuttings.

There exists a great need for the breeding, testing and developing reliable clonal, hardy and scion-compatible, rootstock material for all the stone fruit crops and perhaps also for the ornamental stone fruit cultivars.

DWARFING CHARACTERISTICS

Of the dwarfing clones used, each imparts a degree of dwarfing different from the rest. Hence, the dwarfing clone serves only as a part of the tree size reduction process. Other factors such as the soil condition and tree management play important roles in obtaining and maintaining compact smaller trees.

In the case of fruit trees, each scion/cultivar combination requires a certain tree spacing depending on vigor of the cultivar and the rootstock, the type of soil and system or orchard management (Table 1).

Table 1. Guidelines for tree spacing, as influenced by the rootstock, tree training system and tree numbers.

Apple Rootstocks Small to Large	Training System[1]	Spacing (feet)[2]	Trees/Acre
M.9	St. or Trel.	6 × 14	518
M.26	St. or Trel.	8 × 16	339
M.7	St. or Free	8 × 18	302
MM.106	Free Standing	12 × 20	181
MM.111	Free Standing	12 × 22	165

[1] St. or Trel. = Staked or trellised tree training system. Free standing training system.
[2] Vigorous cultivars will need 2 ft more each direction.

In the future, both fruit and ornamental trees will be propagated on clonal rootstocks for controlled tree size to fit orchard production systems and planned landscape designs. To accomplish this, much plant breeding and testing is yet required.

LITERATURE CITED

1. Carlson, Robert F. (1977) New Apple Rootstock Series. *Compact Fruit Tree.* International Dwarf Fruit Tree Association. Vol. 10:7-8.

Monday Afternoon, December 5, 1977

The afternoon sessions convened at 1:15 p.m. with Dr. Steven Still serving as moderator.

ACCELERATED GROWTH OF CONIFERS

MARION VAN SLOOTEN

Van Pines, Inc.
West Olive, Michigan 49460

The normal growth pattern of a conifer, after the seed germinates, is a series of active growth cycles followed by periods of dormancy. When a seed is planted in the nursery, it germinates and begins its growth by developing a root. Shortly afterwards, the epicotyl needles develop and in a period of 4 to 6 weeks there will be a continuing growth of both the root system and the stem and needles.

Some time later, the stem growth will stop and the tree will develop a bud. The root growth will continue for a period of time and then the tree will become dormant and remain so during the winter until the soil warms the following spring.

After the new growth begins, the same cycle will follow wherein the tree will develop both root and top growth during

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After the new growth begins, the same cycle will follow wherein the tree will develop both root and top growth during the summer followed by a period of dormancy during the winter and new growth the following year.

The priciple of accelerated growth is that the tree is subjected to conditions which break this dormancy period. Instead of going into a dormancy period, the tree continues its height and root structure growth and reaches a size in 5 or 6 months that ordinarily takes 3 or 4 years under field conditions. Apparently in breaking this cycle, we make a physiological change in the tree itself. The accelerated growth tree will continue to grow at a rate which is faster than normal after it has been planted in the field to grow under normal conditions.

This is the theory of accelerated growth. Apparently this physiological change which we have developed in the tree in the juvenile stage induces it to grow at a rate that it ordinarily wouldn't attain until it was 10 or 15 years old and a large tree. Some trees planted out by Michigan State University have flowered and produced viable cones at the age of 5 years. These were White Spruce and ordinarily they would take 10 or 15 years before they flower and produce cones. On this basis we have surmised that the trees have had a physiological change when subjected to the acceleration process. Now for the system we use to accelerate our conifers. First, we are growing the trees in styrofoam blocks with each tree having its own cell which contains a plug of dirt 1 × 1 × 5-3/4 inches deep. We are using a growing mix consisting of half peat and half vermiculite.

The cells in the block are filled with the growing medium and tamped thoroughly to assure that there's ample medium packed into each cell. The blocks are vibrated and tamped and additional soil is added so that there is adequate soil in each cell and it is firmly packed in.

The block then goes to the seeder and we put at least two seeds in each cell, depending on our germination tests. We want to make sure that each cell will have at least one live plant. Then we cover the seeds firmly by putting a thin application of chicken grit over the top of all the seeds. The blocks are then set into steel racks which hold 9 blocks and are set onto benches in the greenhouse. As soon as the blocks are located on the benches, we water them thoroughly.

Our watering system is a walking sprinkler which moves down each bay. It has arms reaching out into each side over each of the benches on the sides of the bay. The amount of water can be controlled by controlling the speed that the sprinkler travels.

The seeds germinate in 1 to 2 weeks in greenhouses held at 70°F and quickly push up and put on their first needles. At this time we turn on the lights so that the plants get 24 hours of natural and artificial light. Our HVO flourescent lights give out about 250 ft-c of light at bench level.

Shortly after the plants attain their epicotyl growth, the thinning operation is performed with a little set of manicure scissors. The thinners try to leave the strongest plant that is growing the closest to the center of the cell. The plants that are cut out are shaken from the block.

The fertilizer program is begun as soon as the plants have germinated. Liquid fertilizer is included with each watering. The fertilizer program varies because we find that the different plants have different fertilizer needs.

The growing routine is followed for the next 4 months. The plants grow very rapidly and we are looking for a plant with a 6 inch stem and a completely developed root system which we feel will produce the optimum growth when it is outplanted. When the plants reach this size we begin reducing the fertilizer and water and lowering the temperature. These changes induce the plant to go dormant and develop a bud system.

The root systems develop very rapidly and will appear at the bottom of the growing block in a matter of a few weeks. The roots will extend a short distance out of the bottom of the block and then will burn off as they are exposed to the air. This system of root pruning induces the plant to develop new and more roots which follow the same pattern of going down through the growing medium, extending and being pruned off. We think this particular feature has a definite advantage in developing the root system we want.

The temperature is lowered further to thoroughly chill the plant so that it will break bud and continue growing in the field. If the plant is not subjected to this chilling, we find that when it is outplanted it will go dormant and wait until it has gone through a cold period before producing new growth.

In the process of making the plant go dormant we also induce a considerable amount of root growth. This is necessary because we do not consider the plant finished until it will do what we call "plug". This means that the plants have developed a root system so firm and solid that the roots and dirt come out of the cell in a solid plug. When the plants have reached this condition, we remove them from the cells and either ship them or put them into cold storage. Shipping the plug plant is almost like shipping a container grown plant because we have a solid root system in the plug and the roots are not disturbed during the harvesting and shipping. We feel that one of the keys to the accelerated growth program is this massive root system which arrives at the customer's site completely intact with no damage done to any of the fiber roots.

We are only growing a few varieties and continue experimenting with new varieties each year. Some of these varieties will respond immediately to the accelerated growth program and others have been complete failures. An example is the Eastern White Pine which we have not been able to accelerate. This tree follows the normal time cycle for growth and dormancy that you would find when it is growing under natural field conditions. It will grow for a short period of time and then becomes dormant and will stay dormant in the greenhouse even though the growth conditions are right for acclerating other pines and spruces.

One of the phenomenon we have noticed in our greenhouse operation is the situation where a pine will set a bud on the stem but will continue growing beneath it. It continues its growth with the bud setting on top and the needles and stem developing beneath the bud and growing as steadily as if it had not set a bud. Apparently we have triggered a condition where the trees both want to go dormant and still respond to the greenhouse atmosphere and continue to grow.

NITROGEN NUTRITION OF JUNIPERS[1]

JAMES E. KLETT

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With the trend to faster production of saleable nursery plants in containers, the nursery industry utilizes large amounts of fertilizers in their growing procedures, especially nitrogen. The effects of NH_4^+ and NO_3^- sources of nitrogen, on growth of woody ornamentals in containers have not been studied to any great extent. Differential response of certain horticultural plants to NH_4^+ and NO_3^- has been reported (1,2,3,8) and in most cases better growth was reported when NO_3^- was the N source. However, species specificity has contributed to diversity in results obtained from two nitrogen sources (4,6,7). Experiments were conducted in the greenhouse and outdoors to evaluate the effect of N form on growth, appearance, cold hardiness and N composition of five cultivars of juniper.

Greenhouse Study

MATERIALS AND METHODS

Rooted cuttings of *Juniperus procumbens* 'Nana', *J. chinensis* 'Pfitzeriana', *J. communis* 'Repanda', *J. sabina* 'Broadmoor' and *J. horizontalis* 'Wiltonii' (blue rug juniper) were potted in a

[1] Contribution No. 1547, Department of Horticulture-Forestry, South Dakota Agricultural Experiment Station, Brookings, SD 57007.

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soil:peat:sand medium (1:1:1 v/v), pH 6.8. Two hundred ml of 200 or 400 ppm N solution as $(NH_4)_2SO_4$, KNO_3 or NH_4NO_3 was applied twice a week to each pot. Other macro and micro nutrients were applied as Hoagland's #1 solution. Plants were grown in a greenhouse at 25± 3°C from April 1976 to March 1977. A factorial design was used with 3 nitrogen sources, 3 fertilizer rates, 5 cultivars and 6 replicates. Leaf and stem tissue were harvested in March 1977 and dry weights recorded. The plant tissue was ground in a Wiley Mill to pass a 20 mesh screen for tissue analysis. Tissue NO_3^- and NH_4^+ were determined electrometrically (5) using a distilled water extract of the dried plant tissue.

RESULTS AND DISCUSSION

The least amount of dry weight growth occurred in *Juniperus communis* 'Repanda' and *J. sabina* 'Broadmoor' which were the first cultivars to show toxic symptoms to nitrogen fertilization. There was no significant difference among the other three cultivars. The interaction of fertilizer rate and cultivar on dry weight was significant. An increase in dry weight occurred with an increase in rate from 0 to 200 ppm in *J. chinensis* 'Pfitzeriana' and *J. procumbens* 'Nana'. These two cultivars showed no nutrient toxicity until late in the experiment. Both cultivars showed loss of weight at the 400 ppm rate, however. The other three cultivars decreased in dry weight with an increase in fertilizer rate. The greatest decrease was determined with *J. sabina* 'Broadmoor' and *J. communis* 'Repanda' where toxicity symptoms were observed 4 months after potting. Toxicity was first observed on plants treated with KNO_3; therefore, NO_3^- concentrations were determined in the plant tissue. Other researchers (4,6,7) have reported better growth on several different woody plant species with NH_4^+ rather than NO_3^- nitrogen. KNO_3 resulted in a significantly greater effect on NO_3^- concentrations in different juniper cultivars than the other sources. *J. communis* 'Repanda' had the greatest concentration of NO_3^- and it was also the first cultivar to show signs of nutrient toxicity. *J. horizontalis* 'Wiltonii' had the lowest concentration of NO_3^- which showed very little toxicity. The interaction of fertilizer rate and plant cultivar was significant at the higher NO_3^- concentrations in all five cultivars. At both rates *J. communis* 'Repanda' had significantly higher concentrations of NO_3^- than the other cultivars. At the termination of the experiment all cultivars treated with KNO_3 were dead except *J. procumbens* 'Nana'. This cultivar showed less toxicity with either the NH_4^+ or $NH_4^+ + NO_3^-$ forms of nitrogen. *J. communis* 'Repanda' was also the first cultivar to show visual toxicity signs when treated with either NH_4^+ or $NH_4^+ + NO_3^-$ forms of nitrogen.

Plants fertilized with NO_3^- had more severe toxic symptoms than those fertilized with NH_4^+ or $NH_4^+ + NO_3^-$ nitrogen. Also more toxicity was observed at the higher rate. Different species responded differently to N source fertilization.

A similar experiment was conducted outdoors under lath during the 1976 growing season to examine if there is a correlation between nitrogen nutrition and cold hardiness of junipers grown in containers.

Outdoor Study

MATERIALS AND METHODS

Rooted 2 year old cuttings of *Juniperus chinensis* 'Hetzii', *Juniperus sabina* 'Broadmoor', *Juniperus procumbens* 'Nana', *Juniperus horizontalis* 'Wiltonii' and *Juniperus communis* 'Repanda' were potted in a soil, peat, sand medium (1:1:1 v/v) on June 1, 1976. The plants were placed outdoors and fertilized twice a week starting June 22 with 200 ppm N solution as either NH_4NO_3, KNO_3 or $(NH_4)_2SO_4$. Additional K was added to the $(NH_4)_2SO_4$ and NH_4NO_3 sources to equal the amount of K being added from KNO_3; therefore, all treatments were equal except for different N forms. The plants were grown outdoors in a protected area and fertilized until Sept. 28, 1976. The experimental design was a replicated split plot having 4 nitrogen sources, 5 cultivars, 3 sampling dates and 4 replications. The plants were moved to a lath house in an exposed area in December 1976 and remained there throughout the 1976-77 winter season. Temperatures of selected pots were recorded by means of thermocouples placed 2" deep in the pots.

Temperatures were recorded at 4 hour intervals starting at midnight. Two replications of each treatment were brought into the greenhouse on January 14, February 11, and March 11, 1977. The plants broke dormancy in a greenhouse maintained at 16°C night and 21°C day under 2000 ft-c of light.

RESULTS AND DISCUSSION

The greatest media temperature fluctuations occurred during January. The coldest temperatures were recorded during the first part of January when the ambient air temperature 3 ft above the pots reached −30°C and the container media reached −19°C in one treatment. Media temperatures fluctuated with air temperatures, warming considerably in mid-February during a warm spell and again in mid and late March.

Two replications of each treatment were brought into the greenhouse on January 14 and given 2000 ft-c of light to help break dormancy. After 1 week under these conditions some cultivars showed more winter burning on the foliage but none of the junipers had started new growth. After 2 weeks some cultivars started to break dormancy. The cultivars treated with $(NH_4)_2SO_4$ showed the least amount of burn. *J. communis* 'Repanda' showed some tip burn, and *J. procumbens* 'Nana' had burn over most of the plant. The NO_3^- treated plants showed fairly severe winter burn on all cutlivars except *J. horizontalis* 'Wiltonii'. Cultivars treated with NO_3^- were slowest to break dormancy. All treated with NH_4NO_3 showed dieback except *J. horizontalis* 'Wiltonii'. After 3 weeks in the greenhouse most cultivars had started new growth, all had some dieback, but 'Nana' was dead. The check plants all had browning but none were dead; and all had new growth 1 mon after bringing them into the greenhouse. This was a little slower than N-treated plants.

The second sampling date was Feb. 11. Plant media had two temperature fluctuations prior to this date varying from 0°C to −19°C. One fluctuation occurred in mid-Jan. and the other just before the Feb. 11 sampling date. The $(NH_4)_2SO_4$ treated junipers all suffered some winter burn but none were severely damaged except *J. communis* 'Repanda', which died. *J. horizontalis* 'Wiltonii' showed no winter burn. Junipers treated with KNO_3 were all dead after 1 mon in the greenhouses except *J. horizontalis* 'Wiltonii' which showed only minor dieback. The NH_4NO_3 treated junipers suffered varying degrees of winter burn. After 1 mon of greenhouse conditions *J. communis* 'Repanda' and *J. procumbens* 'Nana' were dead and browning was present on both *J. chinensis* 'Hetzii' and *J. sabina* 'Broadmoor'. No winter damaged occured on *J. horizontalis* 'Wiltonii'. The check plants showed varying degrees of winter burn though *J. horizontalis* 'Wiltonii' showed very little.

Another two replicates of plants were brought into the greenhouse on March 11 after having been exposed to numerous severe fluctuations in temperatures. The snow cover on these plants had melted by mid-Feb. leaving them exposed.

Severe damage was again observed on the KNO_3 treated plants and after 3 weeks in the greenhouse all cultivars were dead except *J. horizontalis* 'Wiltonii'. The NH_4^+ treated plants also suffered winter damage but only *J. communis* 'Repanda' and *J. chinensis* 'Hetzii' were dead. Browning was observed on the other 3 cultivars but all had started new growth. All cultivars treated with the NH_4NO_3 suffered winter burn; *J. procumbens* 'Nana', *J. chinensis* 'Hetzii', and *J. communis* 'Repanda' were dead after 3 weeks. By April check plants were all growing in the greenhouse but all had suffered some burn and lacked vigor from lack of essential nutrients.

Some trends were evident from these three sampling dates. Plants which were left in more exposed conditions and underwent extreme temperature fluctuations showed the most winter damage. Junipers treated with KNO_3 or NH_4NO_3 suffered more winter damage than those treated with $(NH_4)_2SO_4$. The check plants suffered the least winter burn but all lacked good vigor.

J. horizontalis 'Wiltonii' was the most tolerant cultivar showing only minor burn with NO_3^- fertilization. This could be due to its prostrate growth habit which protected it from exposure. *J. communis* 'Repanda' had the highest mortality. Varying amounts of damage was observed on *J. chinensis* 'Hetzii', *J. sabina* 'Broadmoor', and *J. procumbens* 'Nana'.

The two replications which were left outside over winter showed much damage. The greatest number of plants suffering damage were those treated with KNO_3 and NH_4NO_3. *J. horizontalis* 'Wiltonii' was the most tolerant cultivar.

These studies have shown differential responses of juniper cultivars to different nitrogen sources. In both experiments $NO_3^+ + NO_3^-$ resulted in more juniper toxicity than either NH_4^+ or $NH_4^+ + NO_3^-$ fertilization.

Further studies are being conducted to determine if the last date of fertilization in the fall and method of winter protection play major roles in juniper nutrition and hardiness. Additional greenhouse studies are also being conducted using lower fertilizer rates than previously used.

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CHARLIE PARKERSON: If you were applying 200 and 400 ppm of N twice a week did you take soluble salt readings, and what were they?

JIM KLETT: I measured soluble salts at the end of the experiment; using the soil-paste method. They were all 15+ which is very high.

MYCORRHIZAE AND PLANT GROWTH

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It has long been assumed that soil borne fungi adversely affect nursery crops. Stem and root rots, dampening off, etc., are common fungal problems to the nurseryman. However, there are groups of soil-borne fungal organisms which are beneficial to plants. Mycorrhizal fungi are capable of forming a symbiotic relationship with plant roots. This plant-fungal association is called mycorrhiza and literally means "fungus root"; *myco* meaning fungus and *rhiza* meaning root. The coexistence established between the root and fungus is generally beneficial to both organisms. However, there are exceptions or variations to this general definition ranging from fungal parasitism to total dependence of the plant on the mycorrhizal fungus. Mycorrhizal fungi can also exhibit specificity ranging from many plant-host associations to a single plant-host. They are naturally occuring fungi and 80 to 90% of all plants are reported to have a mycorrhizal association(s).

There is overwhelming evidence that many plants, including some of our most important nursery crops, could not survive without mycorrhizae. Most mycorrhizal associations occur naturally, and with a few exceptions, the nurseryman is quite often unaware of existing mycorrhizal benefits. Slow growth or poor field survival of a particular plant is often assumed to be characteristic or attributed to poor cultural practices rather than to the absence of mycorrhizal fungi.

Benefits of a mycorrhizal fungus can be species specific. A classic example is *Rhizoctonia* spp. which are beneficial fungi to orchids, but are serious pathogens on other hosts. In addition, there is evidence that mycorrhizal fungi are ecologically

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Benefits of a mycorrhizal fungus can be species specific. A classic example is *Rhizoctonia* spp. which are beneficial fungi to orchids, but are serious pathogens on other hosts. In addition, there is evidence that mycorrhizal fungi are ecologically adapted to specific soil environments. The ectomycorrhizal fungus *Thelephora terrestris* Ehrh. ex. Fr. occurs naturally in conifer forests of the Southeast. Consequently, conifer seedlings produced in the Southeast are generally infected with *T. terrestris* from spores blown into seedbeds. However, when *T. terrestris* mycorrhizal conifer seedlings were outplanted onto a drastically disturbed site in Kentucky, only 2% survived compared to nearly 50% survival for conifer seedlings infected by the ectomycorrhizal fungus *Pisolithus tinctorius* (Pers.) Coker and Couch (4).

Mycorrhizal types. Mycorrhizae can be divided into three classes; ecto-, endo- and ectendo- mycorrhizae. Ectomycorrhizae occur on feeder roots of both gymnosperms (especially *Pinaceae*) and certain angiosperms (willows, oaks, birches, hickories, walnuts). Ectomycorrhizae are characterized by swollen short roots and specific branching characteristics ranging from monopodical (nonforked) to forked or even multiforked (ramiform) configurations. Ectomycorrhizae may exhibit more than one type of branching pattern on the same plant. I have found monopodial, "Y" shaped, and ramiform branching patterns on *Pisolithus tinctorius* mycorrhizae of yellow birch (*Betula alleghaniensis*) seedlings. Ectomycorrhizal roots can vary in length from 1 to 2 mm, as on many species of pine, up to 10 mm or more.

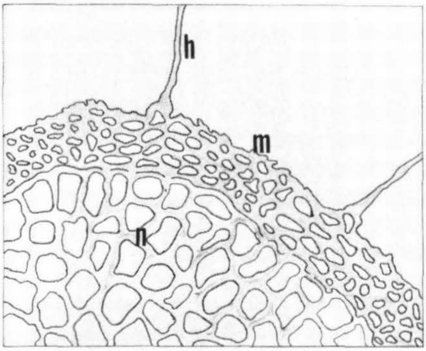

Figure 1. Diagram of root cross section with ectomycorrhizal infection. m, fungal mantle; n, Hartig net in cortex; h, hyphal strand.

Root hairs are lacking in ectomycorrhizae and have been replaced with profuse development of fungal hyphae which may or may not completely surround the entire feeder root forming a sheath or mantle (Figure 1). This fungal mantle prevents feeder roots from coming into immediate contact with the surrounding soil and imparts the mycorrhizal root a characteristic color ranging from white, brown, yellow, black, blue or combinations thereof. These fungal or hyphal strands radiate outward from the root surfaces, distances of 15 to 20 ft or more. The hyphal strands appear to substitute for root hairs increasing the root surface area and function in water and nutrient uptake. Fungal strands also penetrate internally into the root cortical region forming a network of intercellular hyphal strands. These interconnecting fungal strands are collectively referred to as a Hartig-net and appear to replace the middle lamella, a pectin-like material which cements the root cells together. Hartig-net development in all mycorrhizal infections is restricted to the cortical region.

Ectomycorrhizal fungi can produce aerial fruiting bodies which release billions of wind blown spores. The fruiting structures are often called "puffballs" since large clouds of spores are released when mature fruiting bodies are opened. Aerial spore disemination greatly enhances the spread of ectomycorrhizal fungi in nursery soils.

Endomycorrhizae are found on many agronomic and nursery crops. Their presence may go undetected since only a loose network of hyphal strands may appear on the surface of feeder roots. Hyphal strands of endomycorrhizae generally penetrate through the epidermis into cortical cells, hence the prefix endo- is used (Figure 2). These penetrating hyphal strands can coil around forming shrub-like structures called arbuscules and/or produce thin-wall, spherical to oval structures called vesicles. Thick-walled spores are also produced on or near the root surface or inside cortical cells. Generally, endomycorrhizal fungi do not drastically modify the morphological features of a root as do ectomycorrhizal fungi. Endomycorrhizal fungi generally do not produce aerial fruiting bodies, consequently, their disemination in nursery soils is more restricted than ectomycorrhizal fungi.

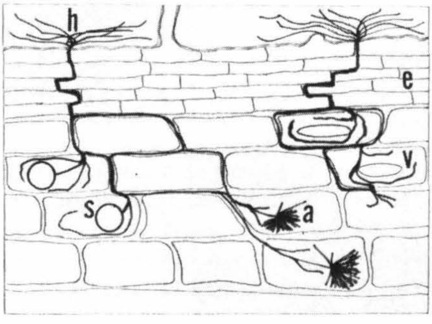

Figure 2. Diagram of root longitudinal section with ectomycorrhizal infection. h, hyphal strands; s, spores; a, arbuscules; v, vesicles; e, epidermal region.

A third class of mycorrhizae found on pine species has been classified as an ectendo-type. The taxonomic classification of ectendo-mycorrhizae is still in doubt, however, they appear to exhibit characteristics of both ecto- and endomycorrhizae (8). Ectendomycorrhizae may or may not develop a fungal mantle, but both inter- and intracellular hyphal strands occur in the cortical region of the root (Figure 3). Very little is known about the species of fungi involved. They have been found in nursery soils and appear to be associated with species which are normally ectomycorrhizal plants (7).

Mycorrhizal fungi have been associated with increased plant growth, rooting of cuttings, nutrient and water uptake, and disease resistance (1,3,5,6). The remainder of this paper is a preliminary report on the effects of the ectomycorrhizal fungus *Pisolithus tinctorius* on swamp chestnut oak (*Quercus prinus*).

Many oaks species are characteristically slow growing. Although growth of oak seedlings has been accelerated by repeated fertilizer applications, the added production costs can often outweigh the benefits. Cultural techniques which increase height growth of oak seedlings while reducing production costs would be a substantial benefit to the nursery industry. Tailoring oak seedlings grown in fumigated seedbeds with a specific mycorrhizal fungus may be a possible mechanism of increasing plant height growth. The objective of this study was to determine the interaction of the mycorrhizal fungus *P. tinctorius* with swamp chestnut oak seedlings.

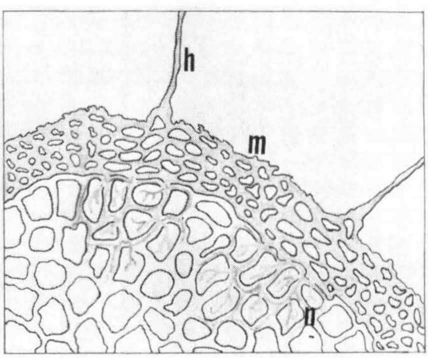

Figure 3. Diagram of root cross section showing ectendomycorrhizal infection and penetration of hyphal strands into cortical cells. m, fungal mantle; n, Hartig net; h, hyphal strand.

MATERIALS AND METHODS

In the fall of 1976, swamp chestnut oak seed was collected and immediately planted in 10 cm pots containing sterilized

Weblite.[1] Seedlings were grown for 4 months at prevailing greenhouse temperatures (20 to 25°C day/20° night), and an extended photoperiod of 18 hours. Seedlings were fertilized daily with a 15-15-15 water soluble fertilizer at a rate of 200 ppm N and once a week with a Hoaglands micronutrient solution (2).

An isolate of *P. tinctorius* was obtained from sporocarp tissue following procedures of Miller.[2] The isolate was subcultured in 9 cm Petri plates on a modified Melin-Norkrans agar medium (6). After 3 to 4 weeks of dark incubation at 21°C ± 2°C, 8 mm discs were removed from the periphery of fungal colonies and used for mass innoculation of 3.75 liter jars. Mass production of mycorrhizal inoculum using a peat-vermiculite substrate was accomplished following the procedures of Marx (5).

After 3 months the *P. tinctorius* inoculum was removed from the jars, passed through a 5 mm mesh screen, collected in cheesecloth, and leached with 8 liters of cool tap water. Excessive water was squeezed from the inoculum. The inoculum was placed in plastic bags, and stored at 3°C for 24 hours before use.

Twenty uniform swamp chestnut oak seedlings were repotted into 15 cm pots containing a 1:10 (V/V) mixture of *P. tinctorius* inoculum and sterilized Weblite. No additional fertilizer was added after repotting. All seedlings were grown in the greenhouse as previously described. Initial and final height growth measurements were recorded and seedlings were inspected monthly for mycorrhizal formation.

RESULTS

Visible mycorrhizal formation occurred between the third and fourth month after seedling inoculation. I believe that this is the first report of *P. tinctorius* mycorrhizal formation on swamp chestnut oak. However, only 9 of the original 20 inoculated seedlings exhibited mycorrhizal development at the last inspection date, November 30, 1977. By the fifth month, hyphal strands penetrated the entire container medium of infected seedlings. Sporocarp production also occurred within 5 months in 6 of the 9 containers with mycorrhizal plants.

The mycorrhizal fungus was responsible in nearly doubling plant height growth. The total average increase in plant height growth of mycorrhizal plants was 306% compared to 164% for nonmycorrhizal plants (Table 1).

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[1] Weblite is a soil-less commercial nursery mix manufactured by Weblite Corporation, P.O. Box 12887, Roanoke, VA 24029.

[2] Personal communication from O.K. Miller, Dept. of Botany, Va. Poly. Inst., Blacksburg, VA.

Table 1. Effect of *Pisolithus tinctorius* on height growth of swamp chestnut oak 5 months after inoculation.[y]

	Average % increase in plant height[z]	Range of % increase in plant height
Infected	306	203 - 397
Noninfected	164	131 - 185

[y] Seedlings inoculated when 4 months old.
[z] Significant at 1% level within column.

Mycorrhizae on swamp chestnut oak completely changed root morphology and was characterized by both profuse monopodial and short ramiform and branching patterns (Figure 4, 5). The fungal mantle on ramiform mycorrhizal roots completely covered the entire root, whereas the fungal mantle on monopodial mycorrhizal roots was restricted to the apical, non-suberized portion of long roots. Ramiform short roots were between 0.3 and 0.8 mm in length. Root hairs were absent on mycorrhizal roots. In addition, all mycorrhizal roots were 2 to 3 times larger in diameter than nonmycorrhizal roots.

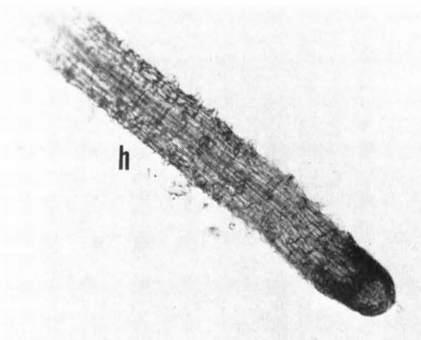

Figure 4. Nonmycorrhizal root tip of swamp chestnut oak. h, root hairs. 100X.

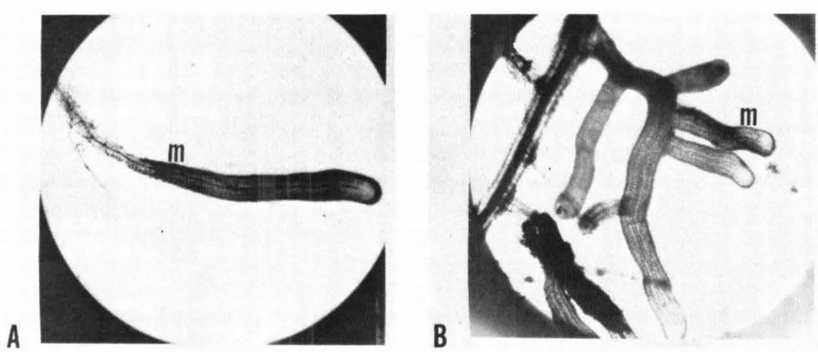

Figure 5. Mycorrhizal branching patterns of swamp chestnut oak. A, monopodial; B, ramiform. Note the presence of the fungal mantle (m) completely covering the root tip in A and the entire ramiform branched root in B. 60X.

DISCUSSION AND CONCLUSION

Plant production is becoming an exacting science with constant changes occurring in supplies, governmental regulations, financing, marketing strategies, as well as cultural practices. In recent years, new cultural practices have sought to change the "natural biological system" in order to increase plant production. Advancements in nursery production practices such as, large scale field fumigation and use of soil-less propagation and container media have eliminated many soil-borne pathogens as well as beneficial mycorrhizal fungi. Reintroduction of specific mycorrhizal fungi into sterile nursery soils or container media may be a functional method of increasing plant growth. In order to maximize mycorrhizal infections and potential benefits, the interaction of mycorrhizal fungi with individual nursery crops and production practices such as fertilization, irrigation, pest control, container media, etc. must be thoroughly investigated.

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MARTIN MEYER: How do you inoculate your plants with mycorrhizae?

DALE MARONEK: We have been trying several different methods. The ectomycorrhizae produce spores in puff balls. Using spores we get a very low percent of infection. We are now growing our inoculum in culture jars in the lab following the procedures worked out by the Southeastern Forest Experiment Station. This provides vegetative mycelia with which we can inoculate the container media at a ratio of 1 part inoculum to 1 part container mix. For endo-mycorrhizae, the mycelium is grown on roots of an alternate host such as sorghum, we grind up the sorghum plant, take a spore count and use that as the inoculum.

JIM CROSS: Have you run any experiments where the container mix has an optimum or high level of nutrients in it before inoculation with the mycorrhizae?

DALE MARONEK: We feel that one advantage of mycorrhizae is that you don't have to use as high a level of fertilizer. In some cases, high fertilization rates seem to suppress the development of mycorrhizae, in other cases too little fertilizer will also restrict development of the fungi.

BRUCE BRIGGS: Do you have any idea of how the mycorrhizae influence root initiation?

DALE MARONEK: Fungi in general are known to produce plant hormones. Many produce auxins and we are currently looking at the production of cytokinins that are produces from some of the mycorrhizae that we are working with. Not all produce the cytokinins but some do.

BILL ALMY: Are they affected by fungicides normally used in nurseries?

DALE MARONEK: Some are and some are not. We have been trying to provide small amounts of fungicides to some of the mycorrhizae to condition them to this situation and prevent their complete destruction if this fungicide is applied to the plants growing in the soil.

VOICE: How fast does the mycorrhizae move through the soil?

DALE MARONEK: After 2 years on a plot that is 25 feet square we can find mycorrhizae totally permeating the corner areas of the plot. We feel it could easily move 5 to 10 feet per year.

CHARLIE PARKERSON: Isn't that only in the presence of a root?

DALE MARONEK: Yes, the roots of a host plant must be present in the soil but the hyphae may extend 20-30 ft from the host root.

FLOOR HOT WATER HEAT FOR INDOOR PLANT PROPAGATION

MARY ANN DiCENZI

Plant Systems
Mentor, Ohio 44060

Our method of propagation at Plant Systems involves the use of ground heat. It is not a miraculous process, the plants do not spring up overnight. However, it is a natural process that speeds up the rooting of cuttings. This is a system I am sure other growers may wish to investigate. It is likely to become one of the most popular methods of plant propagation in the future.

Many references can be found in the history of plant propagation concerning the utilization of bottom heat to aid in stimulating rooting. Each firm might have different facilities available to them and in our case we had a conventional plastic covered quonset house which is 14 feet wide and 135 feet long. Since there is not a lot of head room for using conventional benches and since the greatest width is at the base it was decided that if the propagation trays could be set on the floor that the greatest return per square foot would result. It was decided that warm water circulated through plastic pipes in the floor could do a job of providing enough heat for propagation while allowing a cool temperature at the leaf surface and above so as to reduce respiration.

It was decided to use an A.O. Smith-Hydronic Boiler, model HW-100P, which has a maximum BTU input of 100,000, and a maximum BTU output of 80,000. The unit has the ability to throttle the flame so that on low demand there is a low flame, and with high demand a high flame. This provides for a much more uniform water temperature in the pipes than a full "on or off" type boiler. There is a circulating pump that runs whenever the flame is on. The energy to keep the crop roots at 72°F is 42% less than if under bench hot air unit heaters were used. The boiler is only 26-1/2 inches high, and occupies 4.5 square feet of floor space. The house will hold 50,000 cuttings in growing trays, and we turn the house over every 2 to 3 weeks.

We decided to use Celenese high temperature black polyethylene pipe. However, we have since found that probably any black plastic poly pipe will do since the top water temperature is only 110°F which is the lowest setting on the boiler. The pipes are spaced 1 ft apart on top of 5 inches of crushed stone. This type of situation ensures perfect drainage. You can make one large loop by starting at the boiler's hot outlet and looping back and forth the length of the house until you have covered the floor and then returning the end to the inlet side of the boiler. We are going to do just that the next time. We did, in fact, make a header for both outgoing and return water. However, we now feel that it was a lot of work that was not needed. The pipes were then covered with 4 inches of coarse sand and then the crop set on that.

It is easy to hold good root temperatures, and we found during the winter that we could have 72°F root temperature with frost forming on the inside layer of the double plastic layer house, and a 48°F temperature at 4 feet above the crop. One problem was drip caused by the plastic being much colder than the air or the crop. We are not sure how to deal with this easily, however, it is clear that this moist air must be removed or heated.

The final results are excellent. The heat saving is significant, and the crop response is very good. It might, furthermore, be a very good and efficient house for cold storage where you might like to keep the roots at say 40 degrees, and yet let the tops of the plant freeze. It has been suggested to us that we insulate under and around the house but we did not find a great loss out the sides which would have melted the snow, and we could not have lost too much out the bottom and still heated the crop during the coldest winter on record and done it with 42% less heat than we would have expected to use by other means.

The items we have produced in this house is a list of 55 different types of indoor plants. Some of the faster would be well-rooted in 7 days after sticking with the slowest taking 30 to 40 days. This autumn is our first opportunity to try rhododendron under these conditions. We invite you to visit us in Mentor and look at the unit anytime.

ANDY KNAUER: Was there any other form of supplemental heat in these houses?

DICK BOSLEY: No there was not.

CHARLIE PARKERSON: Putting this hot water through lines 135 ft long, is it stone cold when it gets to the other end?

DICK BOSLEY: No there is very little difference from one side to the other.

TOM McCLOUD: What was the cost of this installation?

DICK BOSLEY: I don't recall, but the boiler is the most expensive part and I think it was around $400. The black plastic pipe is relatively inexpensive and I would anticipate quite a number of years of use out of it. You can't leave it freeze, that would ruin the boiler.

PETE VERMEULEN: We have been using a house very similar to this for 8 years with very good results. We did, however, experience 8-10° difference in the temperature of the flats. This was a contact problem since at that time our pipes were set in gravel. We applied pebbles over this and it corrected the problem. You could get rid of the condensation by using double poly, this would also save heat.

DICK BOSLEY: Ours is double plastic.

DAVE BAKKER: In Canada we spray the insides of the house with a material called "Clear"; it reduces the surface tension and the condensate simply runs down the sides of the walls and does not drip on the foliage of your plants. The material is relatively inexpensive, I guess it would cost $4 to $5 to do a house such as yours.

LEAF MOLD FOR CONTAINER CULTURE

WILLIAM FLEMER III

Princeton Nurseries, Inc.
Princeton, New Jersey 05840

Using leaf mold for growing container plants on a commercial scale? It sounds like a return to the era of monastery gardening, or at least a capitulation to the organic gardening extremists — mumbling incantations about compost! However, the use of composted leaf mold is none of the above, but a very practical and inexpensive source of humus in certain parts of this country. In carrying out "clean air" programs, a number of the densely populated eastern states have enacted rigid no open burning regulations, which include among other things a total prohibition of leaf burning. This has posed a real problem for suburban municipalities with abundant shade trees. As the fallen leaves are collected each autumn they have perforce been dumped in large piles in vacant lots as they cannot be incinerated as was the practice in earlier times. These huges piles of decayed leaves can be a valuable source for nuseries and at the same time their removal can be of great benefit to the municipalities which have often faced inundation under an ever growing surplus of them.

Our firm has worked out a mutually satisfactory arrangement with several nearby towns which satisfies both our needs. The municipalities collect and pile the leaves on vacant prop-number of years of use out of it. You can't leave it freeze, that would ruin the boiler.

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Our firm has worked out a mutually satisfactory arrangement with several nearby towns which satisfies both our needs. The municipalities collect and pile the leaves on vacant property owned by the towns. The leaves lie in piles for the following summer season. Soaked by winter rains, they decay and compact, reducing their volume to 1/4 that of the fall when they were collected. The following winter we send over a large loading tractor and dump trucks and load and haul all the previous year's leaves to our own composting yard. This can be done in even the coldest weather. The leaf piles decompose even in winter and the heat given off by the process is enough to prevent the piles from freezing. Fertilizer is added and the leaves are piled again for further decay.

After a second year of decomposition, the resulting composted humus is ready for use. Cost is far below any other humus source in our area and comparable to the cost of composted bark for those container nurseries located within trucking distance of big lumber or paper mills. Loading and hauling the leaves to our yard costs approximately $1.00 per yard, and fertilizing and repiling costs approximately an additional $1.25 per yard. The resulting humus has an analysis of Mg - 400 ppm, P - 200 ppm, K - 250 ppm and a pH of 6.0. The compost is minerally far richer than bark or sawdust. The leaves contain much of the fertilizer which the homeowners spread upon their lawns and gardens, and plants grown in the humus made from them seem to require less fertilizing than the same species grown in bark or sawdust mixes.

The compost is used in several different ways. Our standard mix is made up with a front end loader in the following proportions — two bucket loads of humus, one of soil, and one of coarse sand. The ingredients are piled together in a large heap, as a sort of pre-mixing device. The tractor bucket loads of the mix are run through a large Lindig shredder and discharged on a long rectangular concrete sterilizing pad. The shredder is moved back away from the accumulating pile repeatedly to produce a long narrow pile of shredded mix. This pile is then leveled off to about 18 inches in depth, covered with a heavy sheet of polyethylene, and sterilized with methyl bromide gas. The manufacturer's directions suggest aerating the pile after 24 hours, but we find we get far better weed kill by leaving the pile under the plastic cover for 3 days. The hotter the weather, the more effective is the gas sterilant. In August weather tremendous heat builds up beneath the plastic and this not only enhances the effect of the gas, but it also causes the hard seed coats of usually resistant species like annual morning glory to soften and become permeable. A much better weed kill results. Gas treatment for weed control is virtually worthless in the spring when the soil and humus are cold and soggy, and the efficacy gradually increases throughout the summer until September, when the nights begin to cool and soil temperatures also start to decline. Our other basic mix is 2 parts of humus to one part of coarse sand. This is made up in two forms, one which we call "low-lime" mix which is used for ericaceous plants (10 lb of ground limestone per cubic yard of mix), and one which we call "high lime" mix for other plants which grow well in a high organic mix but prefer a higher pH (20 lbs/cu yd). In both of these mixes, we would prefer larger particles of humus; the Lindig shredder grinds the humus too fine. A P.T.O. manure spreader does not mix the humus and sand thoroughly enough, and we frankly have not yet found the ideal machine for mixing to our specifications.

In late summer we treat all the mix which will be needed for the following spring's canning. Sterilized mix is stored under cover in a fibreglass-covered building and is ready to use whenever needed throughout the winter and following spring. Having mix, containers, and liners ready for instant use enables us to get much of our canning done at times when the field crews are forced inside by inclement weather. At such periods, what used to be costly "down time" is now converted to useful accomplishment.

Obviously, composted leaves are not available in the quantities required by really large-scale container firms such as those found in California and the southern states. However, there are quantities available and going to waste which are more than adequate for the smaller grower. They are a supply of humus with greater than normal nutrient content. And, in this era of rapidly escalating costs for every kind of supply and material, it is a pleasant surprise to encounter one which is far cheaper today than the conventional organic materials like peat were even a decade ago.

A SOLAR GREENHOUSE FOR PROPAGATION[1]

CARL E. WHITCOMB

Oklahoma State University
Stillwater, Oklahoma 74074

In the last few years much interest and emphasis has been placed on the development of solar heated greenhouses. Nearly all that have been reported to date use a separate solar collector system, then transfer the heat to the greenhouse by some type of heat exchanger. Thus the heat and heat distribution is similar to a conventional greenhouse. By contrast, the self contained, solar heated greenhouse at Oklahoma State University was constructed using the heat collection capacity of the greenhouse as

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the collector system, storing the heat in water and sand in the floor to stabilize the greenhouse temperature. Our greenhouse, therefore, is entirely bottom heat and well adapated to propagation.

Operation of the Structure. The greenhouse is a Quonset type structure 26 × 72 ft (dimensions can be varied), constructed from 3/4 inch galvanized pipe bows placed on 6 ft centers with one center purlin (Figure 1). Covering is by 3 layers of air inflated polyethylene. The triple layer system gives even greater heat conservation and is essential for heat accumulation between the inner 2 layers. Thus the inner 2 layers of covering constitute the solar collector system as a mist is injected between the two layers using garden type "soaker hoses" on 6 ft centers (Figure 2). Interior shading by the mist is only about 10%. As the mist between the layers of poly is warmed and additional mist is released the moisture flows down the sides of the greenhouse. On each side and one end of the house, double rows of concrete blocks create a gravity return for water back to the floor for storage (Figure 3). Water is pumped from the floor reservoir through the mist lines, between the inner layers of poly and is allowed to return back down the sides to the floor where it is stored. The greenhouse floor is graded so gravity controls the flow of water from the sides to the end where it is picked up by the pump. The sand layer varies from approximately 8 to 12 inches thick depending on the slope of the floor and the relative position in the house. This sand layer, once heated, provides convective heating of the entire floor. Convective heating from the floor is much more efficient in heating containers sitting on the floor than forced air type heaters which primarily heat the air rather than the growing medium in the container.

The sand heat reservoir lays on a sheet of 1-inch styrofoam to stop downward heat loss. A layer of 6 mil black polyethylene provides the waterproof lining. The styrofoam also prevents stones or clods from puncturing the polyethylene and causing leaks. Likewise, there is a layer of 6 mil black polyethylene over the top of the crowned sand layer and below the layer of gravel which is the finished floor of the greenhouse. Thus the double layer of poly on the roof of the house where the mist is injected plus the water return and the sand reservoir in the floor is a closed system. That is, water can be circulated through this system, heat absorbed and heat released, without loss of water. With this system a greater heating efficiency can be realized as opposed to adding cold water or where evaporation could occur. In addition, water and nutrients used in the rooting and growth of cuttings does not mix with the heating system, thus reducing the potential algal and disease problem. However,

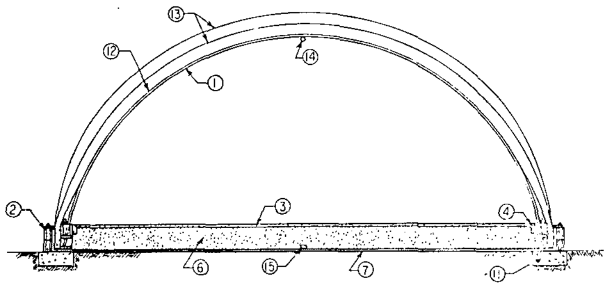


Figure 1. Cross sectional view of quonset type solar greenhouse.

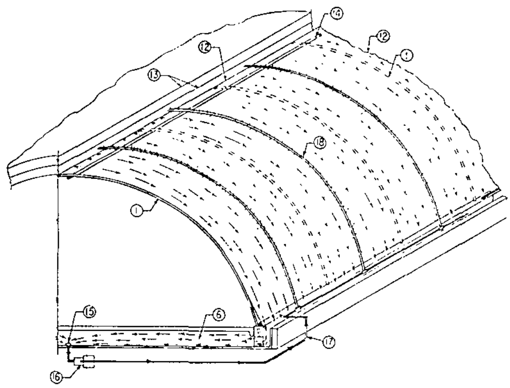
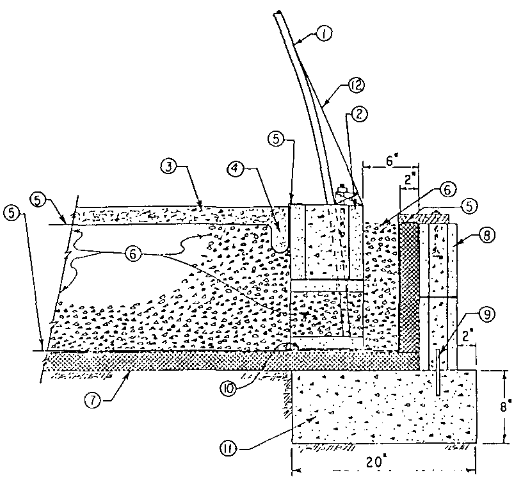


Figure 2. Water flow system between the inner two layers of poly which acts as the solar collector.



Key to Greenhouse Components Shown in Figures 1, 2 and 3.

1. Pipe bows, 3/4" galvanized pipe on 6' centers
2. Concrete blocks, 8 × 8 × 16"
3. Limestone screenings work floor
4. Excess water drain
5. Waterproof poly liners
6. Sand for water storage
7. Styrofoam insulation
8. Concrete blocks, 4 × 8 × 16"
9. Reinforcing dowel
10. Felt paper, 40 lb.
11. Concrete footing
12. Interior poly film
13. Center and exterior poly films
14. Center purlin connecting bows
15. Free water collection tube
16. Centrifugal pump
17. Water distribution lines
18. Soaker hose sprinkler lines

Figure 3. Detail of water return system to the floor.

copper or other chemicals may be required to prevent algae development.

The north end of the greenhouse has been framed, insulated and covered with a permanent building exterior siding to reduce heat loss. In addition, since we have a north primary entrance, the addition of an air chamber type door and small work-room assembly minimizes entrance of outside air into the greenhouse. This type of air chamber door assembly helps a great deal in conserving heat within the greenhouse.

A solar greenhouse of this type will require close management to achieve maximum heating. This management will include the early fall operation of the heat collector system to build up the heat reserve in the sand-water floor. In Oklahoma this means the collection system should be operational by late September or early October in order to raise the floor temperature to 22 to 25°C (70 to 78°F). Subsequent operation of the heat collection system would be whenever the temperature between the inner two layers of plastic exceeded the water temperature of the floor by approximately 3°C (6°F).

The following suggestions and explanations may make this type solar greenhouse more widely adaptable:

1) If additional heat storage is required for more northern areas, the sand layer depth can be increased with, perhaps, an earlier startup time in the fall.

2) Early operation showed that with a floor temperature of 18°C (65°F) and −9°C (11°F) outside temperature, an inside air temperature of 8°C (46°F) could be maintained with no supplemental heat.

3) The water injected between the two layers of polyethylene is not heated directly by the sun's rays, but rather by the warm air. For example, with 4000 ft-c and 10°C (50°F) outside temperature and 21°C (70°F) in the collection chamber the water could be heated to about 18°C (65°F). On a colder day with 4000 ft-c, and −7°C (20°F) outside temperature and 50°F in the collection chamber the water could be heated only to about 4.5°C (45°F).

4) The third layer of plastic over the structure provides the same insulation capacity to the collection chamber as would be provided to the inside air of a standard double poly greenhouse. This third poly layer increased the heat collection capacity by about 10-12°C (20-25°F).

5) The one inch layer of styrofoam beneath the entire greenhouse greatly reduces the downward loss of heat. This would be of even greater importance in more northern climates.

6) The sand used in the storage system must be packed in

order to prevent shifting of the work floor. However, sand size must be sufficiently uniform to allow water to circulate at a reasonable rate. Precise specifications are not currently available.

Temperature of the growing medium in containers sitting on the floor remained the same as floor temperature. The heat is transferred from the floor to the containers (Figure 3). This provides an ideal bottom heat system which has been shown effective in propagating many cuttings. In addition, the lower air temperatures experienced in this greenhouse assist in keeping the cuttings dormant throughout the rooting period. However, a good ventilation system must be provided to prevent excessive heat in late winter and early spring. Because this greenhouse is quite efficient in retaining heat during winter it also accumulates heat readily in the early spring which may stimulate unwanted soft succulent growth. Our experience to date has shown that we can maintain a low air temperature in early spring by simply drawing in cool outside air with thermostatically controlled fans.

This greenhouse is very economical to construct (materials are about $2.00/sq ft) and provides bottom heat and temperature controls more suitable for propagation than other greenhouses. Even in more northern areas, only a small amount of supplemental heat should be needed on very cold nights, reducing or eliminating the expensive fuel bills encountered in recent years.

FACTORS CONTROLLING REGENERATION FROM ROOT CUTTINGS

CHARLES W. HEUSER

Department of Horticulture
The Pennsylvania State University
University Park, Pennsylvania 16802

Root cuttings as a method of reproducing plants are little used in today's modern nursery and probably will be used even less in the future. Modern methods, such as tissue culture appear to represent the future trend. Root cuttings, however, are applicable to a wider number of woody plants than is realized. The ability of root cuttings of many plant species to regenerate whole plants has been recognized and described in the horticultural literature over a long period of time and extensive lists of species have been compiled (7,18). Propagation through root cuttings assumed a more important role before the introduction of propagation aids such as, auxins and mist. Flemer (7) cites two principal reasons for the rarity of this method. 1. Many plants for which it is the best technique are infrequently grown order to prevent shifting of the work floor. However, sand size must be sufficiently uniform to allow water to circulate at a reasonable rate. Precise specifications are not currently available.

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Despite the difficulties involved propagation by root cuttings may be the best procedure to increase selected plants that are difficult to root or do not come true from seed. Flemer (7) has summarized the more important woody plants which can be propagated by root cuttings. The subject of propagation by root cuttings has received attention in both the *I.P.P.S Proceedings* and *The Plant Propagator.* Both publications contain information on root cutting propagation methods but research results on the factors involved in the control of adventitious root and bud formation are lacking. The position regarding the physiology of regeneration forms the basis of this presentation.

SEASONAL VARIATION OF REGENERATION

It has been documented for a number of woody plant species that regeneration from root cuttings varies strikingly with the season of the year (9,13). Seasonal differences in apple and raspberry root cuttings, for example, have demonstrated distinct "on" and "off" periods, autumn-winter and spring-summer respectively. The seasonal differences in survival of apple root cuttings resembles seasonal responses demonstrated with raspberry by Hudson (8) who correlated winter survival with starch accumulation. Robinson and Schwabe (15,16) also showed with apple that maximum accumulation of storage polysaccharides occured in autumn (November) coinciding with the highest regeneration potential and survival rate of cuttings. Cuttings of many herbaceous perennials, in contrast, regenerate readily at any time of the year.

Alteration of the seasonal variation may be possible. Marston and Village (11) demonstrated that regeneration of red raspberry from root cuttings could be achieved with plants growing in summer conditions which normally lead to poor regeneration by applying certain treatments to the shoots, 3 to 5 weeks before taking root cuttings. The best regeneration occurred from plants that had the tip half of the shoot and all axillary buds removed. Experimental results with *Populus* (5,6) indicate that polarity of auxin might account for the seasonal variation in shoot formation from roots in these plants. The results with red raspberry and *Populus* species suggests the possibility that changes in auxin levels as affected by the stage of shoot development may interact with carbohydrates and account for the seasonal variation in regeneration potential. Since both auxin and polysaccharides exert demonstrable influences on root regeneration a suitable balance between each is probably required before the optimum potential for regeneration can be achieved.

AUXINS

The presence of auxin has been demonstrated conclusively in roots. Auxin is also transported within roots from root base to root apex, that is, in an acropetal direction and the transport is polarized. A strong polarity of bud and root initiation occurs with more shoots formed towards the basal end, i.e. nearest the crown, and more roots formed towards the apical end of the root segment (1, 2,10,14,19). The polar transport of auxin within root pieces may, therefore, be an important mechanism controlling the distribution of adventitious roots and buds (5,6,16).

In general exogenous applications of auxins suppress bud development and stimulate root initiation on root cuttings, further supporting the important role of auxin in root regeneration (1,2,4,10,19).

CYTOKININS

Cytokinin treatments increase bud numbers, increase the bud producing region and counteract auxin inhibition (2,3,12). Exogenous cytokinin applications also inhibit root formation when applied to the distal end. The kinin induced buds in many instances exhibit a different developmental origin. Often the cytokinin stimulates callus formation on the proximal end of the root cutting with resulting development of shoot primordia in the callus (2,12,19).

In conclusion, the diverging behavior of the ends of root cuttings with regard to organ production has been interpreted as the result of different hormonal regimes at organ forming sites in the root segment. Exogenously applied auxin and cytokinin can profoundly influence the regeneration of root cuttings. Auxins in general stimulate roots and inhibit bud initiation (16) while cytokinins stimulate bud and inhibit root formation. Both groups of hormonal substances need further critical study on woody plants in order to explore their possible use in commercial propagation through root cuttings.

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CHARLIE PARKERSON: You mentioned increasing bud production on root pieces by treatment with cytokinin, are these segments predisposed to bud formation?

CHARLIE HEUSER: No, in those cases a callus is first formed and the bud arises from the callus. In root segments where cytokinins are not needed for bud development, the buds often arise from the pericycle or other tissue, so the origin of the buds is quite different.

JOHN WILDE: In the 1930's and 1940's, while working at Cornell University we did a survey of over 200 species concerning propagation by root cuttings. One of the things that we observed was there there was no development of adventitious buds unless true secondary wood existed in the segments — the buds always develop from the secondary tissue. Another interesting observation was that if hypocotyledonous buds were present on seedlings grown from these species the plant could almost always be propagated by either underground stems (stolons) or root segments.

Most of the legumes can be grown from root cuttings and the easiest way for the small nurseryman to do this is to grow them *in situ* by driving a sharp shovel into the ground in concentric circles around the plant. By this method you can produce 5-6 liners of legumes such as *Gymnocladus* and *Gleditsia*.

CHARLIE HEUSER: You are right, a great many plants can be produced by root cuttings and the article by Stoutemeyer contains a considerable list of these.

PROPAGATION OF WOODY PLANTS BY ROOT CUTTINGS

CARL ORNDORFF

Kalmia Farms Nursery
Clarksville, Maryland 21029

Asides from growing by seed, the next oldest method of propagation of woody plants is by root cuttings or root sprouts. Early settlers of America brought woody plants from Europe by this method and used this method of transporting them as they moved westward in settlement of their new homelands.

Very little can be found in the literature on plant propagation concerning the use of root cuttings for woody plants. L.H. Bailey in *The Nursery Manual*, published in 1920, devotes three paragraphs to the subject. His primary discussion is of the bramble fruits, horseradish and certain tropical foliage plants. He states, with no elaboration, that fruit trees may be grown from root cuttings. Bailey also states that true root cuttings possess no buds whatsoever. This would seem subject to question. (Possibly I should have entitled this presentation "root sprouts" rather than "root cuttings".)

James S. Wells in his *Plant Propagation Practices*, published in 1957, devotes two paragraphs to root cuttings. He outlines briefly a method of making root cuttings, but does not state what materials may be grown by this method.

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Today, aside from the growers of herbaceous perennial plants, very few growers extensively use the root cutting method of propagation. Herbaceous perennials frequently propagated by root cuttings include: oriental poppy, summer phlox, echinops, summer anemone, stokesia, cornflower and other members of the composite or daisy family.

COMMERCIAL PROPAGATION OF WOODY PLANTS BY ROOT CUTTINGS

Commercial propagation of woody plants by root cuttings is seldom found in our nurseries. One major producer of deciduous shrubs and trees in Iowa is using this method to mass produce hybrid lilacs. Aside from this grower, one rarely finds a grower who will admit using the root cutting method. There seems to be a mark of disgrace to use or to suggest using this method.

My business started using this method in 1938 for the production of many hybrids of the old-fashioned lilac, *Syringa vulgaris*. Since 1938 we have tested this method on many deciduous trees and shrubs. Many can be grown easily by root cuttings, but are more economically and/or more quickly grown by other methods. This is especially true of softwood stem cuttings grown under intermittent mist.

Woody plants that can and have been grown easily by root cuttings, but have not proven especially economical or practical are: almond, aralia, aronia, campsis, clethra, cotinus, euonymus, elaeagnus, forsythia, gleditsia, holly, mahonia, prunus, pyracantha, pyrus, rhodotypos, sarcococca, spirea, symphoricarpos and virburnum.

However, there are several important exceptions. Flowering quince, *Chaenomeles*, can gain one full years growth over softwood stem cuttings. A two-year root cutting plant is equivalent to a three-year softwood cutting plant and has more and heavier branching.

Hybrids of the old-fashioned lilac, *Syringa vulgaris*, grown by root cuttings produce own root plants in less than half the time required of those produced by softwood stem cuttings. It is possible to produce heavy 6 to 10 cane lilacs, 3 to 4 ft tall, after 2 years in the field.

Root cuttings may be expected to yield plants with a useful life expectancy of three to four times those grafted on species lilac or privet. In addition to understock suckering, grafted plants have a relatively short useful lifespan due to graft incompatibility, stem borers and non-renewal of wood. Should lilac borers infest own-root lilacs, cut out infested branches and destroy. Renewal is immediate and almost unnoticable. We have own-root lilacs over 40 years old and these are in the best of condition.

Be mindful, lilacs that are weak as grafts will be equally weak on their own root. Strong graft produced plants are strong as own-root plants.

FLOWERING QUINCE AND LILAC BY ROOT CUTTINGS

A simple, low cost, highly productive method of growing quince and lilac by root cuttings has been used by our business. Plants are dug in the fall as soon as dormant, but before freezing. Then, they are either stored or cuttings are made immediately. Heavy fleshy roots are removed and cut into approximately 4 inch lengths. Should these roots have above ground sprouts, remove by pruning at the soil line. Be sure to observe polarity while cutting and potting.

Potting is normally in 3 inch clay pots. Growth rate will be slower and watering will be a labor and maintenance problem if plastic or peat pots are used. Roots are allowed to project about 1 inch above the soil line. A potting mixture of soil, peat and perlite is normally used. The pots are placed and maintained with a perlite mulch in the greenhouse beds, the pots being covered to a depth of about one-half inch.

The potted plants are carried from December until March in a cool greenhouse at a night temperature of 33 to 36°F. About one thorough watering per month will be required. From March through April, the night temperature may be increased to 45 to 50°F with two to three waterings per month.

By late April, light monthly feedings of a soluble fertilizer is advisable. At this time plants should be 6 to 8 inches tall. One thorough weekly watering is all that is normally needed. The mulch of perlite should be allowed to dry slightly so as to make a good feeder root system that will withstand midsummer field planting. Pot-bound, 12 to 24 inch plants should be ready for field planting in July. Little top growth should result for the remainder of the summer, but root growth should be heavy.

However, there is one production problem with lilac. There may be difficulty in securing your initial own-root stock plants for propagating. First, try to secure the desired varieties from a grower who has own-root plants. Be careful, some misrepresentation has occurred in the trade. Second, take grafted plants and set 6 to 8 inches deeper to have own-roots form above the grafts. After about 2 years, remove and cut off privet or species lilac root and replant. Species understock is difficult to identify. All cultivars of lilac will not layer. Third, taking softwood cuttings in May is a possible method. However, rooting is poor and rate of growth is slow; and this should be used as a last resort.

We have converted over 100 cultivars by layering, but have discarded many as not being desirable.

FLOWERING CHERRIES

One unexpected experience with root cuttings occurred in growing flowering cherries. Root cuttings, especially *Prunus* 'Halle Jollivette', resulted in very crooked stems and nearly 50% were unsalable. Softwood stem cuttings gave reasonably straight stems of which over 90% were salable.

FORSYTHIA

We have successfully employed an unusual type of root cutting propagation that we are pleased with although we have been accused of being crude and very non-professional. We have employed this primarily for forsythia, but it can be used for other shrubs.

In autumn, when a field is cleared of a crop, we plow the field at a rather shallow depth. This is followed by harrowing with a spring-tooth harrow, rather than a disk harrow. The young root sprouts or layers are collected by the harrow and dumped in piles, then forked on a truck and hauled to the propagating greenhouses. Here the root clumps are root pruned to about 6" stems. These root masses, with their pruned stems exposed, are packed in flats of wet perlite and stored in outside cold frames for the winter. These cold frames are unheated but are recessed and somewhat protected.

As soon as the ground can be worked in March or April these root masses are planted on normal field spacing with the planting machine. The flats go directly to the planter, giving minimum handling. By autumn, choice salable 2 to 3 ft plants are ready. This may be non-professional, but we have heavy, well-grown plants without normal propagating procedures.

FUTURE POSSIBILITIES

There are other possibilities for using root cutting as a method of practical and economical propagation. We have grown flowering crabapples from root cuttings of the tea crabapple, *Malus hupehensis*, and the redbud crabapple, *Malus × zumi*. Plants on their own root have given more uniform growth, but the best feature is the small percentage of suckering from the base, which is so pronounced on budded or grafted plants on most understocks.

The only production problem is getting the initial crabapples on their own roots. This we are investigating. If successful, production of a superior crabapple is assured.

The methods cited here enable us to conclude that root cuttings are a profitable, practical and usable way of propagating certain woody plants. Additional possibilities for the future should not be disregarded.

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GUS MEHLQUIST: I think it should be mentioned that periclinal chimeras do not come true from root cuttings.

LYNNE LAMSTEIN: Are you making a distinction between root cuttings and root sprouts and were the root cuttings placed horizontally or vertically in the bed?

CARL ORNDORFF: No, I'm not making the distinction between the two since it is often hard to do. The cuttings are set vertically in the pot and about 1 inch projects above the surface of the medium. With root cuttings you must maintain the polarity.

Monday Evening, December 5, 1977

A session concerning the teaching of plant propagation was held Monday evening with Dr. Bruno Moser serving as moderator.

BRUNO MOSER: The tremendous increase in enrollment in horticultural courses during the past few years has caused some problems in the usual methods of teaching. Classes, which up until the last 4 years had 10 to 25 students, could be worked with very conveniently giving individual instruction to each student in the course. There was a considerable amount of "hands-on" teaching and field trips consisted of loading the students into a few cars and going out to a nursery, but with classes today of 100 to 200 students, it is becoming more and more difficult to provide the student with the type of instruction we feel he needs.

This session is designed to show you what some of the people in other universities are doing and to tell you about some of the new things we are doing in plant propagation courses. We would also like to get some feedback from any growers present as to things you think ought to be included in a plant propagation class.

MICROPROPAGATION EXERCISES IN TEACHING PLANT PROPAGATION

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Most students in university-level plant propagation courses are aware of the rapidly developing field of tissue culture as it relates to the propagation of plants. Many are eager to have some first-hand experience with the techniques involved.

In our plant propagation course at the University of California, Davis, which is given in the spring quarter, we are presently accommodating about 150 students with five 3-hour lab sections per week. In the lab we cover the usual aspects of propagation by seeds, cuttings, grafting and budding, layering, etc. Into this we have interjected two exercises using aseptic culture techniques. The first is handled during our two laboratory sessions on seed propagation in which the students sterilize and plant cymbidium orchid seeds, on nutrient agar as is done commercially. After seeding, the flasks are placed in growth chambers for germination and development of the seedlings. In the second exercise the students cut apart cymbidium orchid shoot-tip protocorms, transferring a portion to rotating flasks for further proliferation. The remaining protocorms are planted in nutrient agar in flasks for formation of roots and shoots and development of the plants. The orchid protocorm exercise is included during one of our two laboratories on cutting propagation. The ability of cymbidium orchids to regenerate new plants has been known, of course, for many years starting with the work of Morel in developing virus-free plants (4,5,6).

By using both seeds and protocorms, we are able to relate the aseptic culture techniques to both sexual and asexual propagation.

FACILITIES

Since no room space was available for setting up transfer chambers, a six station unit was constructed from a war surplus metal field telephone exchange. Figure 1 shows outside and inside views of this reconstructed chamber. Students work in the transfer chamber by placing their arms through holes over which plastic is draped (Figure 1).

Dust particles in the chambers are reduced by maintaining filtered air (5 micron filters) under positive air pressure and by the use of ultraviolet lamps operating when the chambers are not in use. A thermostatically controlled electric heater, together with an air conditioning unit, maintain the temperature in the chamber at approximately 70°F.

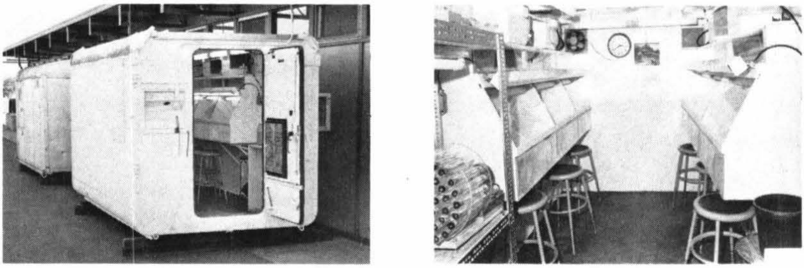

Figure 1. *Above.* Outside view of 6-station aseptic transfer chamber developed from war surplus telephone exchange unit.
Below. Inside of chamber showing transfer stations where work is done under filtered pressurized air.

PLANTING ORCHID SEEDS

The students are furnished the material and equipment shown in Figure 2 for planting the orchid seeds. Each student is supplied with a vial which contains a small amount of orchid seed. He is also furnished a 125 ml flask containing sterilized nutrient agar. The composition of this is basically the Knudson C medium as developed for germinating orchid seed (3).

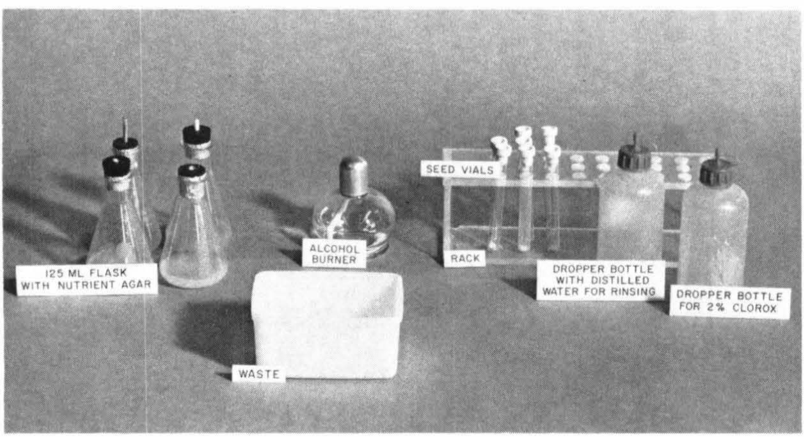

Figure 2. Equipment and material provided each student for sterilizing and planting orchid seeds.

$Ca(NO_2)_2 \cdot 4H_20$	1000 mg/l	$MnSO_4 \cdot 4H_20$	7.5 mg/l
$(NH_4)_2SO_4$	500 mg/l	$FeSO_4 \cdot 7H_20$	25 mg/l
KH_2PO_4	250 mg/l	sucrose	2%
$MgSO_4 \cdot 7H_20$	250 mg/l	agar	1.5%

This medium has been modified (2) by replacing the KH_2PO_4 with 18 ml of potassium phosphate buffer prepared by combining 97.5 ml of 0.1 M KH_2PO_4 solution (13.6 gm in 1 liter water) and 2.5 ml of 0.1 M K_2HPO_4 solution (17.4 gm in 1 liter water). This maintains the pH at 5.3 without further adjustment. To this, 1 ml of a micro-nutrient solution is added as given below.

$MnSO_4 \cdot 4H_2O$	1.81 g	$CuSO_4 \cdot 5H_2O$	0.08 g
H_3BO_3	2.86 g	$(NH_4)_2MoO_4$	0.09 g
$ZnSO_4 \cdot 7H_2O$	0.22 g	Distilled water	995 ml

Iron can be supplied in several ways: iron tartrate (1 ml of a 1% stock solution); inorganic iron ($FeCl_3 \cdot 6H_2O$, 1 mg/l) or $FeSO_4$, 2.5 mg/l; or chelated iron. Chelated iron can be supplied as NaFeEDTA, 25 mg/l, or by mixing Na_2EDTA and $FeSO_4 \cdot 7H_2O$ in equimolar concentrations to give 0.1 mM Fe.

The students then sterilize the seed, using aseptic techniques, with 2% Clorox according to the following directions (1).

1. Fill tube containing seeds 1/2 full with sodium hypochlorite (2% Clorox) solution, add stopper, and shake for 5 minutes. This will sterilize the seeds. Use mild wetting agent (as 7x) to aid in wetting seeds.

2. Invert test tube, loosen stopper slightly, and slowly drain out disinfectant solution, rotating tube so that seeds adhere to sides.

3. After draining, add sterile water to fill tube less than half full and shake several times. Slowly drain out rinse solution, rotating tube so that seeds adhere to sides. Then add 20 drops sterile water.

4. Remove stopper from sterilized flask, flame opening, then pour water and seeds onto nutrient agar. Replace stopper in flask and give it a few gentle swirls to distribute seeds.

5. Write name on flask with wax pencil.

The flasks containing the seeds are then placed in a growth chamber held at about 70°F with about 200 ft-c light intensity. This chamber is shown in Figure 3. The appearance of the germinated seeds after 8 weeks is shown in Figure 4. Growth of the orchid seedlings is very slow, but by the end of the quarter the students can determine fairly well the results of their work.

Infection in the nutrient medium was a problem until we rigorously enforced the directions that before they began work the students must wash their hands and arms thoroughly above the elbow, rinsing them well with an alcohol-iodine solution. To prepare 1 liter of this solution mix 737 ml of alcohol and 263 ml of distilled water. About 6 crystals of iodine are dis-

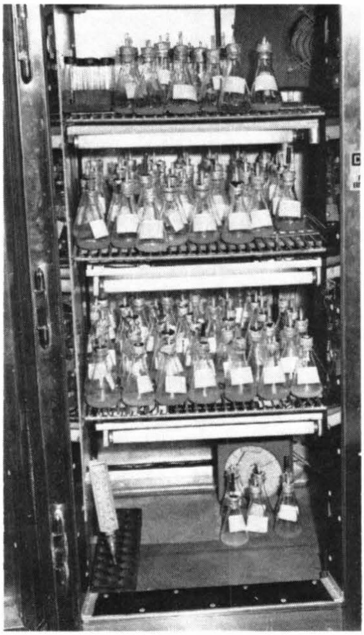

Figure 3. Growth chamber containing flasks of orchid seeds planted by students on nutrient agar.

Figure 4. Appearance of germinated orchid seeds after about 10 weeks.

solved in alcohol before water is added. Arms and hands should be washed immediately before working in transfer chambers. Some flasks still become infected, but this is rare.

A teaching assistant stays with each group of students in the transfer chamber from the beginning to the end of the exercise explaining the procedures to be followed.

DIVIDING AND PLANTING CYMBIDIUM ORCHID PROTOCORMS

Several hundred protocorms are prepared in advance of this exercise from orchid shoot tips so that each student will have about six well-developed protocorms for his use. Using the same transfer chambers as described above, the students are provided with the equipment illustrated in Figure 5; i.e. flasks of protocorms to be divided; Petri dishes; tweezers and scalpel for cutting up the protocorms; small nutrient agar bottles for placing the developing protocorms for further growth; and a liquid medium for placing the divided protocorms for further proliferation. The same aseptic techniques as used in planting the orchid seeds are required for the protocorms.

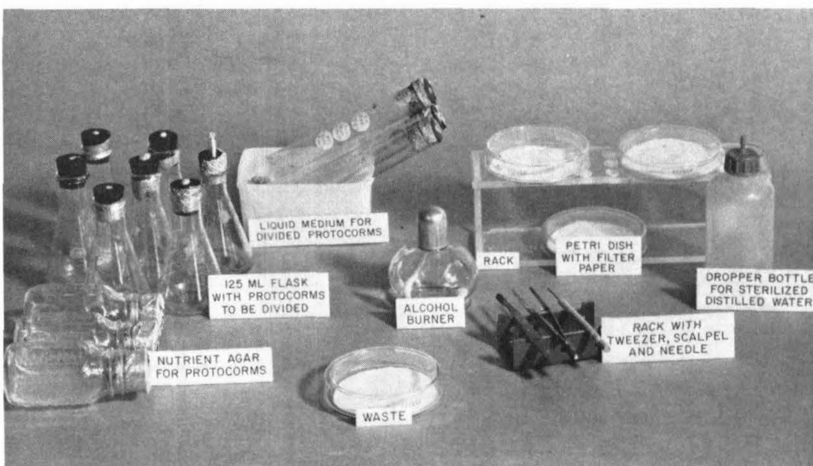

Figure 5. Equipment and material provided each student for dividing and planting orchid protocorms under aseptic conditions.

The protocorms planted in the nutrient agar bottles for growing on are placed in a growth chamber at 70°F and 200 ft-c as shown in Figure 6. The appearance of these plants after about 7 weeks is shown in Figure 7. The protocorms make much more rapid growth than do the orchid seedlings.

Figure 6. Growth chamber containing flasks of nutrient agar on which the orchid protocorms have been planted by the students.

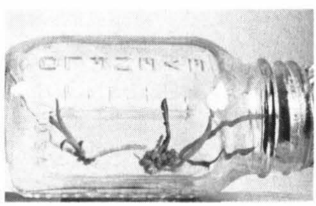

Figure 7. Growth of protocorms on nutrient agar after about 8 weeks.

Two rotating devices are used for maintaining the cut-up protocorms for further proliferation, as shown in Figure 8. One holds 125 ml flasks; the other holds 2.5 × 20 cm test tubes.

The solid medium used for growing the established protocorms is basically that of Wimber (6), as follows:

	Grams		Grams
KNO_3	0.525	ferric tartrate	0.03
$CaHPO_4$	0.20	tryptone	2.00
KH_2PO_4	0.25	sucrose	20.00
$(NH_4)_2SO_4$	0.50	agar	12.0
$MgSO_4$	0.25	water	1000 ml

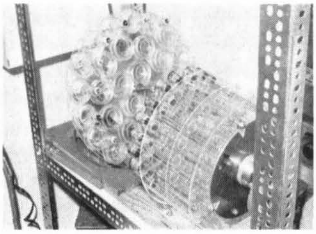

Figure 8. Two rotating devices for holding flasks (*left*) and test tubes (*right*) in which divided protocorms are placed for further proliferation.

The liquid medium used in the rotating vessels for further protocorm proliferation is the same as given for the solid medium except the agar is omitted.

These two exercises in orchid propagation, using aseptic culture techniques, one involving sexual propagation and one asexual propagation, provide an excellent means for developing many concepts during the classroom discussions preceding and following the actual laboratory work. The results have been highly successful and give the students considerable satisfaction in using aseptic culture methods.

It would be desirable, of course, to have the students gain more experience in media preparation, sterilization techniques, and other procedures such as callus cultures and shoot tip excision but time is not available to do this when these exercises are inserted into an already busy laboratory schedule. The exercises described would be a good introduction to an advanced course in tissue culture techniques in plant propagation.

Acknowledgements. The cymbidium orchid seeds and protocorms used in these classroom exercises were supplied by the Rod McLellan Co., South San Francisco, California, through the courtesy of Richard Smith.

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MULTI-MEDIA TEACHING METHODS

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Projected visuals have become one of the most effective tools in communicating ideas to people. In education, the need to make more use of visual aids increase as the need to improve communication methods increases. Visual presentations can easily be improved and at the same time made more interesting and informative.

Several methods of visual presentation are open to the instructor — audio-tutorial, wide-screen, multiple-screen and/or multiple-images. All of these methods have proven to be effective in developing concepts and in maintaining student interest (1,2,3,4,5,6).

The audio-tutorial system places the emphasis on the individual student's learning ability (4,6). It is designed for independent study with the aid of several to many learning events integrated into a meaningful sequence. Consequently, the slow learner has the opportunity to repeat the process as many times as necessary while the fast learner can move along more rapidly and without delay. Traditionally, the learning experience takes place in a booth (carrel) equipped with a projector, tape deck and many other aids needed for that lesson or exercise.

A modification of the audio-tutorial booth system is a portable system that a student can take to any room that has facilities for projection. The portable system offers a more economical approach to the booth audio-tutorial method. It is also advantageous where space for booths is limited or nonexistent.

Wide screen presentations generally refer to a projection screen wider than tall. The Eastman Kodak Company (1) recommendations are for a 1:2 or 1:3 screen height to screen width ratio for best results. It should be emphasized that wide screen projection employs the standard one-projector, one-image system. Since the image is on the screen for a relatively short period of time, in most instances, a discontinuous train of concentration develops in the viewer. This can be overcome by dividing the projected image in half or thirds and then showing each progressively. Image divisions of this type also offer a greater flexibility through the progressive addition of material. Of course, all of these progressive additions can be effectively handled by using projectors with automatic short slide-changing time cycles or with dissolve controls.

Multi-screen and multi-image presentation denotes the use of two or more screens or images at one time using normally proportioned screens or images. The number of screens and/or images being shown will depend upon presentation requirements and physical limitations of the room. In any event, image size should be in proportion to the size of the audience. Tape recorded music or sound effects may be cued in at appropriate times while "live" commentary is delivered if desired. Such sound effects usually require a second person stationed near the projectors to start or stop the sound effects. Of course, sophisticated techniques are available to dovetail live and recorded sound effects into a synchronized presentation.

The simplest form of the multi-screen or multi-image system is the use of two projectors for either front or rear projection. The basic multi-screen system utilizes two projectors which may be advanced or reversed independently or together and two screens. Control is obtained by using two remote controls taped back-to-back and held in one hand or through a control panel mounted on the podium. In the basic multi-image system two projectors, a dissolve control unit, and one screen is used. However, the two-simultaneous-image advantage is lost and each image is seen for a relatively short period of time.

From the basic two projector multi-screen system, one can add as many projectors, dissolve units and screens as desirable. The number of units added are limited only by space limitations imposed by the room and/or audience. In addition, movie projectors and overhead projectors can be added as desired or needed. Generally speaking the number of projectors and screens are equal. However, one can develop a multi-screen presentation by using three screens, six projectors and three dissolve units. It should be emphasized that a programmer is necessary once the system is synchronized with sound, or a movie projector is added, or more than two slide projectors are used.

Multi-media projection systems have the advantage of greater flexibility in presentation techniques and images that are in front of the viewer for a longer period of time (1,2,3). It is also much easier to make comparisons between events or situations (2,3,5). Such comparison presentation permits strong associations to be forged between practical and theoretical concepts. Details concerning a technique or concept are often more easily seen and noted by students than by conventional demonstrations.

Obviously multi-media systems are not without problems or pitfalls. The foremost problem is that students may find it difficult to take notes in a darkened room. However, a series of prepared handouts covering the lecture and/or laboratory can help alleviate the problem. The detail of the handouts should be adequate to cover the subject, yet allow the student to concentrate on the subject matter being presented (2,3,5). A second disadvantages is the time needed to plan, prepare, and set up each presentation (1,2,3,5). Artwork, slides, and diagrams need to be planned for each individual presentation. Once the artwork is made and arranged into a sequence, the program can be used over again and the time involved is only that which is required to maintain or add to the presentation.

Generally speaking multi-media methods have been well received by viewers. They are systems that organize and present material more effectively. They provide a means by which the instructor can concentrate on the presentation of material rather than take precious time to draw or illustrate on the blackboard. While it is exhausting; it is fun to do. It is certainly an exciting and challenging method of instruction.

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TEACHING PLANT PROPAGATION BY VIDEO TAPE

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For 1 year now we have had portable color video-tape capability in our teaching program at Purdue. Television has been used in horticulture, food science and landscape architecture courses and has been very well received by the students.

A major problem in the laboratory and field with large groups is that many often cannot satisfactorily observe demonstrations. We have found that with close-up television everyone can see equally well and, in addition, individuals have the opprepared handouts covering the lecture and/or laboratory can help alleviate the problem. The detail of the handouts should be adequate to cover the subject, yet allow the student to concentrate on the subject matter being presented (2,3,5). A second disadvantages is the time needed to plan, prepare, and set up each presentation (1,2,3,5). Artwork, slides, and diagrams need to be planned for each individual presentation. Once the artwork is made and arranged into a sequence, the program can be used over again and the time involved is only that which is required to maintain or add to the presentation.

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A major problem in the laboratory and field with large groups is that many often cannot satisfactorily observe demonstrations. We have found that with close-up television everyone can see equally well and, in addition, individuals have the opportunity to go back and review the technique at the audio visual center. Those who may have missed a laboratory can see the demonstration by simply replaying the tape. With today's classes of upwards of 200 students, field trips are virtually impossible. The best we can do is bring commercial operations to the students on tape. The disadvantage is that students cannot see as much as they would on an actual field trip. They also do not have the opportunity to ask questions. It is up to the instructor, therefore, to ask questions that will bring out information of interest to the students. Closely related to field trips are interviews and discussions with people of interest thereby presenting the student with additional opinions and viewpoints. It is easier and more interesting to interview people in their own environment, and a permanent record is maintained for future use. Perhaps the most important use of television is to present vitally important techniques that cannot be introduced during the course. For example, plant propagation at Purdue is offered in the spring semester which is actually completed before the start of the growing season. We introduce softwood cuttings of deciduous trees and shrubs via television.

The cost is relatively high (Table 1). However, there are often monies available for improvement of teaching programs. A share of the cost of our equipment came from a competitive grant program within Purdue designed specifically for the purpose of teaching improvement. In addition there are often private monies available within States to improve teaching, especially if it will result in greater student exposure to commercial operations and the private horticulture sector. As an alternative, most university telecommunications or audio visual departments have, or will shortly have, portable color taping equipment for use by other departments, often at no cost and with accompanying technical assistance.

Table 1. Representative costs of required equipment and accessories for color video taping capabilities.

Unit	Cost ($)
Camera (Sony)	$ 4,600
Recorder (Sony)	2,300
Monitor (RCA 24 inch)	450
Lights	580
Tripod	225
Microphone/Headphones	150
Travel Cases	125
Porta-Cart	270
Total	$ 8,700

MODERATOR MOSER: We have just heard from three members of the academic area and before we open this up to general discussion, I want to call on Pete Vermeulen for a few comments and observations that he has made from a grower's standpoint. When I was in New Jersey I often took my courses to Vermeulen's nursery because they always have so many interesting things going on there.

PETE VERMEULEN: We always appreciate having the field trips come in, but it does take time out of a busy schedule. Because it does take time we try to get the maximum out of field trips. We try to make all of our facilities and expertise available to the students. When you plan on taking students to a nursery I think it is helpful to apprise the students ahead of time as to the type of nursery they will be visiting. I'm sure this is done in a general way, but I think it ought to be more specific. I think it is also helpful if the instructor will pre-phase some questions and get some interest areas of the students which can then be passed on to the owner or person at the nursery who will be showing the students around. I also think it would be interesting and helpful to have comments made by the students in a follow-up discussion. We are being observed by a "new set of eyes" and such criticisms and comments can be used to help us improve our operation. From this we can also tell how much influence our input has had on the students learning ability and hopefully where we can improve this.

Now I would like to ask a question concerning the video equipment. I was fortunate in being able to stear some grant money to Cook College but it will be available over a 3 year period, can the purchase of this equipment be phased in over a 3 year period? We won't have the nearly $9000 to spend all in 1 year which you have indicated is the cost of the setup at Purdue.

MODERATOR MOSER: The equipment we have will probably be nearly obsolete in about a year. I think the price will come down drastically in the near future and it will not cost nearly as much to get into the video field. I would also comment that if any of the industry groups are interested in having this type of equipment for use at their university and they would appropriate a sum of money and then approach the Dean of Resident Instruction for the Ag College and ask him if he would match their sum of money I would guess that in almost all instances he would do so. By doing this the industry groups can get much more for the money they appropriate.

PAUL BOSLEY: I'd like to tell you about a system that we have tried in Ohio that doesn't cost a lot of money. A nurseryman who specializes in some particular field is asked if he will give a 15 or 30 minute talk at a specific time on a specific date indicating that he does not have to leave home to give the talk. Any slides or other visual materials needed for the talk are sent on ahead to the instructor at Ohio State University. At the specified time he places a long distance call and the classroom is set up with microphones to handle this. The visual materials can then be displayed in the classroom as the nurseryman talks on the phone. If it is considered desirable some time can be left at the end of the talk for questions and answers. I think the system works quite well because they come back each year for other talks.

TOM FRETZ: This system has been used in the plant materials courses at Ohio State University but as yet it has not been used in the plant propagation courses. The system has worked quite effectively and the only cost is that of the long distance phone call.

RON GIROUARD: I'm not sold on the idea of audio-visual material in the classroom. In the past 2 years I have not used a single 35mm slide in my lectures. I believe that an intelligent statement made by a knowledgeable person is preferred by my students. I think it is more important for the professor to learn to communicate effectively. I do use xerox and the students pay for the cost of the xeroxing. This can be taken home by the student for further study; he doesn't have to copy it into his notes while the lecture is being given. The audio systems we've been discussing become obsolete at a rapid rate, often not permitting interchange of pieces of equipment. This requires constantly buying new pieces of equipment. In addition, the professor finds himself spending considerable amounts of time taking pictures, editing audio-visual tapes, etc. Prepared tapes will also become obsolete both because of their content and because of bleaching of their colors. Although these remarks may seem somewhat pessimistic I am still convinced that the professor who can communicate effectively and takes time to talk to his students will never be replaced by a television set.

MODERATOR MOSER: Ron, I thank you for sticking up for the professor, but I think the other speakers would agree with me that these are unique innovations to bring a little something extra to the class. I think these speakers would also agree 100% with you that you don't replace the professor with a television set but rather that they are supplements to bring a new dimension to the course.

BRUCE BRIGGS: I would like to relate some concerns that I have, and have seen, concerning tissue culture labs on the west coast. One nurseryman set up a tissue culture lab and hired college students who had training in this area to do the work. Although this is an exciting area, after a period of time the work becomes monotonous and the students became disenchanted with the work and eventually they left. This nurseryman went out and picked up some of his field hands who were not particularly qualified at tissue culture but he gave them a nice white gown, a nice clean place to work and several other things which they had not previously had and they were quite happy.

Another nurseryman who had no knowledge of tissue culture himself set up a lab and hired a student to run it. When the technician gets up and leaves the nurseryman has a real white elephant on his hands.

I throw these two observations out to you to make you aware of some of the problems which can develop in this new area. How would you as teachers forsee handling this situation without causing some of the problems I have mentioned?

HUDSON HARTMANN: There are a lot of tissue culture labs being set up in California. I think the problems are much like those of any other job and that is you have to fit the right person into the right job. It is necessary to teach tissue culture techniques in plant propagation or else the student would feel short-changed. Whether such students will fit into a tissue culture lab situation I am not prepared to say, but as Bruce has pointed out these problems will materialize.

GUS MEHLQUIST: I think it should be pointed out that although a student in a modern plant propagation course should know tissue culture techniques it does not mean that he will be the one to do the work every day. He should have enough knowledge to be able to train technicians and oversee their work. It is a complicated problem. We should not look to the universities to supply mere technicians but rather supervisors because if they do not get a salary commensurate with other fields they will go to the other fields. Most of the students who graduate from the University of Connecticut are in some form of agricultural sales because that is where the money is.

JIM ETHRIDGE: We have also found that it is the boredom of the job of tissue culture which causes most of the problems. We have found that the situation can be handled by alternating the students skills in other areas to break up the monotony.

VOICE: I think the students need courses in business. Most of the students I've encountered know nothing about business and that is the name of the game. I'd like to see them have some courses in business in place of courses such as poetry writing, etc.

PAT CARPENTER: In talking with some of my colleagues around the country I find there are more and more business courses being put into the nursery curricula. At the University of Connecticut I have developed a horticultural commerce option in which we recommend about 2 dozen courses from the school of business administration. The business training is coming but perhaps it is a little slow in some areas.

MODERATOR MOSER: Is there any area of plant propagation that you commercial growers would say if you are going to emphasize an area it ought to be this one?

VOICE: They just can't do the work because they haven't used a knife enough. Every student I've ever seen that came out of a university doesn't know how to use a knife which is the basic tool of the plant propagator. They don't know how to sharpen it and they don't know what a good knife is.

VOICE: My students all buy knives but there just isn't enough time in one course for a student to make say 1,000 practices to become adept at making a particular graft.

CHIKO HARRMAKI: There seems to be considerable confusion as to the role of the university as opposed to that of a technical school or vocational school. At the university we are attempting to develop an educated man who is knowledgeable in many areas. The vocational type of school trains the individual in a narrow area and teaches him many of the mechanical skills which the university student can only get by going out on the job and doing them or by serving at least one summer internship at a nursery.

MODERATOR MOSER: One of the real take-home lessons of this session is that instructors in plant propagation and the nurserymen within each state need a better exchange of information. Both groups are working towards the same end, but I'm not sure how we can best get there. I think it is important that we continue to work together to try to reduce some of the problems which have been discussed here this evening.

Tuesday Morning Session, December 6, 1977

The Tuesday morning session convened at 8:30 a.m. with Dr. Everett Emino serving as moderator.

EVERGREEN HERBACEOUS PERENNIALS

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The majority of cultivated herbaceous perennials are characterized by foliage and stems which die to the ground at the end of the growing season. However there are some species of herbaceous perennials with evergreen foliage. Such plants, representing many different plant families, are found in many of the world's temperate floras. Generally they have creeping underground rhizomes, stolons or somewhat enlarged rootstocks which provide a source of water and food storage during the winter. Many of the small, low-growing genera such as *Coptis*, *Mitchella*, and *Pyrola* are found in northern latitudes where the snow cover affords winter protection for the evergreen leaves.

Evergreen herbaceous perennials lack secondary stem tissue and thus can be distinguished from suffruiticose evergreen perennials such as *Epigaea repens* and *Daphne cneorum* which have persistent woody stems. Several other well-known evergreen perennials are classed as subshrubs, or suffrutescent perennials, whose stems are woody at the base. This group includes *Iberis sempervirens*, *Pachysandra terminalis*, *Potentilla tridentata*, and *Vinca minor*.

Since with only a few exceptions, all of the evergreen herbaceous perennials are propagated by division it seemed appropriate to discuss them in groups according to landscape use or growth habit. All of the plants discussed are cold-hardy outdoors through Plant Hardiness Zone 7.

PLANTS OF MAJOR LANDSCAPE VALUE

Asarum (Aristolochiaceae) — the evergreen species of wild ginger are excellent platns for use in shady areas. Some species such as *A. europaeum* are satisfactory groundcovers spreading rather rapidly, while others such as *A. shuttleworthii* remain in discrete clumps. *A. arifolium*, *A. shuttleworthii*, and *A. virginicum* — all native to the southwest U.S. — have variable often strikingly mottled leaves. There are also many ornamental

Japanese species, varieties and cultivars which are not cultivated in this country and deserve to be better known. All are readily propagated by division of the rhizome. Selfsown seedlings are sometimes found around established plantings. Seed usually takes 2 years to germinate.

Bergenia (Saxifragaceae) — Bergenias have long been valued for their handsome large leathery leaves and their ability to grow in dry shaded areas. Although *B. ciliata* has densely hairy leaves, the other species commonly cultivated such as *B. cordifolia*, *B. crassifolia*, and *B.* × *schmidtii* have glabrous foliage. Cultivars developed in Europe with very showy red, pink or white flowers included 'Ballawley', 'Evening Glow', and 'Silver Light'. All are propagated by division of the thick rhizome or by seed, although some Bergenias do not flower freely and seldom produce seed.

Festuca ovina var. *glauca* (Gramineae) — the Blue fescue is a distinctive landscape plant because of its fine-textured blue-gray leaves produced in neat mounds. It is easily propagated by division of the crown or by separation of the basal offsets.

Helebores (Ranunculaceae) — the hellebores are noted for their large compound leaves and for their flowers in late winter to early spring. The commonly grown species are *H. niger*, the Christmas rose, and *H. orientalis*, the lenten rose. The former has white to pinkish flowers while the latter has greenish to purple or creamy flowers. Other evergreen species worthy of cultivation include *H. foetidus* and *H. lividus* subsp. *corsicus*, both of which grow to 2 feet. All have a thick rootstock which may be divided in the autumn with care in handling the very brittle roots. The most effective method of increase is from seed sown after 6 weeks of stratification. Established plantings of *H. orientalis* will freely selfsow in shaded moist sites, producing an interesting array of flower colors.

Liriope (Liliaceae) — *Liriope* and *Ophiopogon* are often difficult to distinguish unless flowers are present. *Ophiopogon* has drooping flowers in short arching racemes while *Liriope* has sessile erect flowers on upright spikes. *L. muscari* has showy purple flowers in September and deep somewhat tuberous roots. As the plants remain in distinct clumps they are often used as edging material. 'Variegata' and 'Monroe White' are excellent cultivars. *L. spicata* which spreads rapidly by stolons is widely used in the southern US. as a groundcover. Some of its roots are swollen and the flowers are often hidden by the foliage. Since all Lilyturfs are easily propagated by division, seed is rarely used.

Ophiopogon (Liliaceae) — Often known as mondo-grass, *Ophiopogon* is also widely grown in the southern U.S. as a groundcover. *O. jaburan* has long grass-like leaves and non-tuberous roots. *O. japonicus*, dwarf mondo, has short leaves, tuberous roots, and spreads by stolons forming a dense mat. *O. planiscapus* includes the distinctive cultivar 'Nigrescens' which has nearly black leaves and also spreads by slender stolons. About 25% of the seedlings of this cultivar will also have the dark leaves. Propagation of all *Ophiopogon* species is easily accomplished by division.

PLANTS OF LESSER LANDSCAPE VALUE

Aspidistra elatior (Liliaceae) — Although best known as an indoor plant this Japanese native will grow outdoors in sheltered sites in Zone 7. It is often used in Japanese gardens as a specimen or in mass plantings in dense shade. Propagation is by division in early spring.

Equisetum hyemale (Equisetaceae) — Common scouring rush has dense clusters of evergreen tubular stems growing 4 or 5 feet which arise from a widely branching rootstock. It has long been valued as an accent plant in Japanese gardens. Because of its unique architectural character, it deserves to be considered for wider use as a specimen plant in moist areas. It is easily propagated by division.

Galax urceolata (Diapensiaceae) — Galax is noted for its glossy foliage which turns bronze-red in the winter. The leaves were formerly collected in large numbers for use in the florist trade. Plants are collected in the mountains of Virginia and North Carolina to Georgia. Here it grows as a woodland groundcover in dense masses from scaly rhizomes. Propagation is ordinarily by division of the matted rootstocks. Seed sown outdoors in the fall will germinate the following spring.

Lamiastrum galeobdolon 'Variegatum' (Labiatae) — Variegated golden archangel is a fast growing groundcover spreading by long prostrate stems which root readily at the nodes. It thrives in shady dry areas. The yellow flowers and silver-mottled leaves which are essentially evergreen through Zone 7 are highly ornamental. It is easily propagated by division, by layers, and by stem cuttings taken during the growing season.

Pachysandra (Buxaceae) — Although the widely cultivated *P. terminalis* is a suffrutescent perennial, two of the four other species are evergreen herbaceous plants. *P. procumbens*, Alleghany pachysandra, has dully mottled leaves and spreads slowly by rhizomes as a groundcover. *P. axillaris*, an Asiatic species seldom cultivated, has somewhat rugose leaves. Both species may be propagated by division or by stem cuttings taken during the growing season.

Rohdea japonica (Liliaceae) — The many cultivars of this plant are highly valued by Japanese collectors for their great diversity of foliage patterns and shapes. The leathery elongated leaves arise from a compressed basal stem. Clusters of red berries add further ornamental interest. Plants have successfully overwintered outdoors in the Washington, D.C. area. Propagation is by division of offsets from established plants or by seed.

Shortia (Diapensiaceae) — Shortias, with their glossy leaves and attractive flowers, are valued as small specimen plants in the woodland garden where they may slowly spread to form colonies. Both our native *S. galacifolia* and the Japanese *S. uniflora* have white flowers, while the Japanese alpine *S. soldanelloides* has pink flowers with fringed corolla lobes. The slender creeping rhizome with clusters of leaves may be divided for propagation. Seed is seldom produced.

Miscellaneous — In addition, a few herbaceous perennials may be considered evergreen, at least during mild winters. Plants such as *Armeria*, some *Sedum* species, and some *Dianthus* species and cultivars would fall into this category.

SMALL NATIVE PLANTS OCCASIONALLY CULTIVATED

Chimaphila (Pyrolaceae) — The common species of pippsissewa in eastern U.S. are *C. maculata* with gray-mottled leaves and *C. umbellata* with lustrous bright green leaves. Short stems arise from slender creeping underground rhizomes. The rhizome may be divided into sections, each with a stem and leaves. Plants are difficult to cultivate however, perhaps because of a mycorhizal requirement.

Coptis (Ranunculaceae) — The goldthreads have small dark glossy leaves arising from a slender yellow rhizome. *C. groenlandica* is hardy in Zone 2. It may be propagated by seed sown in the fall, or by division of the rhizome into sections with a stem and leaves. *C. trifolia* seed will germinate readily in a moist medium.

Goodyera (Orchidaceae) — Rattlesnake-plantains are sometimes used in terrariums or cultivated in the wildflower garden for their rosettes of attractive white-veined evergreen leaves. They grow from creeping rhizomes or stolons forming small colonies. The most ornamental species are *G. pubescens*, *G. repens* var. *ophiodes*, and *G. tesselata*. They do not lend themselves readily to asexual propagation, although offsets may be separated or the rhizomes divided. Plants for commerce have usually been collected in the wild.

Lycopodium (Lycopodiaceae) — Clubmosses are spore-bearing evergreen herbs representing about 450 species. Those native to North America are often found in the wild in immense clonal colonies spreading by rhizomes. Although all are highly ornamental they are rarely cultivated because of the difficulty of successful transplanting due to their mycorhizal requirements. *L. lucidulum*, shining clubmoss; *L. selago*, fir clubmoss; and *L. selago* var. *patens*, Lloyd's clubmoss, are sometimes cultivated. *L. lucidulum* has been successfully propagated by cuttings in a Nearing frame. These two species also produce gemmae, or plantlets, in the axils of the upper leaves which fall to the ground when fully developed.

Mitchella repens (Rubiaceae) — Partridge-berry is often grown in woodland gardens or in terrariums. Its red berries and small rounded leaves on trailing stems are of great winter interest. It is easily propagated by division of the stems which root at the nodes, or by stem cuttings taken during the summer. Seed take 2 years to germinate.

Pyrola (Pyrolaceae) — Most of the 12 or so species occur both in North America and Asia. They have lustrous rounded leaves arising from a scaly slender and rather brittle rhizome. White to pink flowers are borne on slender spikes well above the foliage. *P. elliptica* (shinleaf), *P. asarifolia*, and *P. rotundifolia* are sometimes transplanted or propagated by division of the rhizomes, but a probable mycorhizal association precludes widespread success.

HARDY EVERGREEN FERNS (Polypodiaceae)

Although all may be grown from spores, traditionally the common American evergreen species have been collected from the wild to meet commercial demands. *Asplenium platyneuron*, ebony spleenwort, and *A. trichomanes*, maidenhair spleenwort, may be propagated by division of offsets. Spores often germinate readily in moist areas near established plants. Woodferns, *Dryopteris marginalis*, *D. austriaca* var. *intermedia*, and *D. austriaca* var. *spinulosa* may slowly increase to produce up to six crowns at the apex of the thickened rootstocks. These are difficult to divide, however. *Phyllitis scolopendrium*, hart's-tongue fern, eventually forms several crowns or offsets from short upright rootstocks which may be divided. Spores germinate readily in the greenhouse. *Polypodium vulgare*, common polypody, spreads by surface rhizomes which may be easily divided. Christmas fern, *Polystichum acrostichoides*, is probably the best of the evergreen ferns for landscape use. Although it may be found in extensive colonies in the wild, the rootstocks spread very slowly. Established clumps may be lifted and carefuly divided in early spring. Other evergreen species include *P. aculeatum*, *P. lonchitis*, and *P. munitum*.

EDITOR'S NOTE: Dr. H.S. Bhella of the Regional Plant Introduction Station at Iowa State University, Ames, Iowa presented a talk on the propagation of eastern white pine, *Pinus strobus* and riber birch, *Betula nigra*. Papers have already been presented in *The Plant Propagator*, 22(4):8-10 and 23(2):5-7, respectively, and are, therefore, not repeated here.

PROPAGATION OF SELECTED MALUS TAXA FROM SOFTWOOD CUTTINGS

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Abstract. Cuttings of *Malus* × *atrosanguinea*, *M. floribunda*, *M.* 'Hopa', *M. hupehensis*, *M.* 'Selkirk' and *M. siebodii zumi* var. *calocarpa* were collected at two week intervals from May 14 to August 6, 1976. IBA, NAA or a combination were applied at concentrations of 2500, 10000, 20000 or 30000 ppm as a 5 sec dip. Control was a 50% alcohol solution. Parameters used to evaluate rooting included root number, root length, degree of callus formation and rooting percentage. May and early June cuttings rooted in the highest percentages. The 2500 and 10000 ppm IBA treatments proved most effective. The two highest hormonal concentrations resulted in phytotoxicity. *M.* × *atrosanguinea*, *M. floribunda*, and *M.* × *z.* var. *calocarpa* exhibited the best rooting followed by *M.* 'Selkirk', *M.* 'Hopa' and *M. hupehensis*.

Crabapples are commonly propagated by four methods: root grafting; top working; spring budding with dormant buds; and summer budding (16). Commercially crabapples are usually field-budded in August or benchgrafted during the winter months (6,8,12,13,14,16). However, many problems arise from these two propagation methods. Budding crabapples poses a number of problems. With many cultivars the wood is hard, the bark very thin or the scions very slender. Some crabapples have a hard hump beneath the bud making it difficult to complete a proper cut. Others have a depression beneath the bud so it is difficult to get enough tissue beneath the bud without cutting too much wood above and below the bud. Buds and leaf petioles vary greatly in size, making some very tedious to handle. Also, if budded early in the season some crabapple cultivars start growth before winter, usually in a horizontal direction. This may produce crooked shanks the following year. Most budded crabapples must be staked from the time they are 12 to 14 inches high, because the stem stiffens rapidly behind the growing tip, long before a union is established at the base. Finally, production costs are very high with budded material (16,17).

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EDITOR'S NOTE: Dr. H.S. Bhella of the Regional Plant Introduction Station at Iowa State University, Ames, Iowa presented a talk on the propagation of eastern white pine, *Pinus strobus* and riber birch, *Betula nigra*. Papers have already been presented in *The Plant Propagator*, 22(4):8-10 and 23(2):5-7, respectively, and are, therefore, not repeated here.

PROPAGATION OF SELECTED MALUS TAXA FROM SOFTWOOD CUTTINGS

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Abstract. Cuttings of *Malus* × *atrosanguinea*, *M. floribunda*, *M.* 'Hopa', *M. hupehensis*, *M.* 'Selkirk' and *M. siebodii zumi* var. *calocarpa* were collected at two week intervals from May 14 to August 6, 1976. IBA, NAA or a combination were applied at concentrations of 2500, 10000, 20000 or 30000 ppm as a 5 sec dip. Control was a 50% alcohol solution. Parameters used to evaluate rooting included root number, root length, degree of callus formation and rooting percentage. May and early June cuttings rooted in the highest percentages. The 2500 and 10000 ppm IBA treatments proved most effective. The two highest hormonal concentrations resulted in phytotoxicity. *M.* × *atrosanguinea*, *M. floribunda*, and *M.* × *z.* var. *calocarpa* exhibited the best rooting followed by *M.* 'Selkirk', *M.* 'Hopa' and *M. hupehensis*.

Crabapples are commonly propagated by four methods: root grafting; top working; spring budding with dormant buds; and summer budding (16). Commercially crabapples are usually field-budded in August or benchgrafted during the winter months (6,8,12,13,14,16). However, many problems arise from these two propagation methods. Budding crabapples poses a number of problems. With many cultivars the wood is hard, the bark very thin or the scions very slender. Some crabapples have a hard hump beneath the bud making it difficult to complete a proper cut. Others have a depression beneath the bud so it is difficult to get enough tissue beneath the bud without cutting too much wood above and below the bud. Buds and leaf petioles vary greatly in size, making some very tedious to handle. Also, if budded early in the season some crabapple cultivars start growth before winter, usually in a horizontal direction. This may produce crooked shanks the following year. Most budded crabapples must be staked from the time they are 12 to 14 inches high, because the stem stiffens rapidly behind the growing tip, long before a union is established at the base. Finally, production costs are very high with budded material (16,17).

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Grafting has the following disadvantages; the wood of some cultivars is very slender; others produce many spurs and only short terminal shoots; so ample scion wood may not be available; and some sucker prolifically from the rootstock. Viruses have become a very serious problem in clonal rootstocks, and the propagation method itself is conducive to a rapid spread of the disease. Incompatibility between scion and rootstock is another problem with the added possibilities of knot or gall infection at the graft union (1,2,3,8,11,15,16,17).

Budding is the preferred method (8,16,17), but grafting is also practiced (12,13,16,17). The principal advantages of budding are: much larger 1 or 2 year trees are possible; production of a better formed top and heavier rooted tree; and if scion wood is limited a tree may be produced from each good bud, whereas the normal graft requires a scion piece of at least three buds (17).

The advantages of growing crabapples on their own roots preclude suckering and incompatibility problems; plants do not need to be staked; the work is not as tedious as budding and grafting; and costs of propagation would be lowered by the practical nurseryman (18). Disadvantages include the increased time to produce a tree suitable for field or landscape planting (17). Also, specific recommendations must be developed for each crabapple taxon since individuals would respond differently.

Several individuals (4,9,13,16,17) have discussed putting crabapples on their own roots, but the commercial practice (4,10,13) is uncommon. *Malus* × *atrosanguinea*, *M.* × *arnoldiana*, *M. baccata* var. *mandschurica*, *M.* × *purpurea* 'Eleyi' *M.* × *purpurea* and *M. sylvestris* have been rooted from softwood cuttings (4,5,7,9) but the percentages were not high. Most of these studies employed low levels of rooting compounds applied as a soak over a 4 to 24 hour period (5) or used low concentrations of Hormodin #1, 2 or 3 (4,7,9). Brown and Dirr (2) showed that softwood cuttings of *Malus floribunda*, *M.* 'Hopa', *M.* 'Selkirk' and *M.* × *zumi* var. *calocarpa* could be effectively rooted if cuttings were collected early in the growing season and treated with high hormonal concentrations. In general, propagation of crabapples from hardwood cuttings has not proven successful (2,5,10,12,17).

This study was designed to determine if six commonly cultivated flowering crabapples (*Malus* × *atrosanguinea*, *M. floribunda*, *M.* 'Hopa', *M. hupehensis*, *M.* 'Selkirk', *M.* × *zumi calocarpa*) could be successfully rooted from softwood cuttings collected from mature trees using various hormonal concentrations on cuttings at selected periods throughout the growing season, so that specific recommendations could be made for each taxon. This study was also undertaken to determine whether the effects of maturity could be overcome by high hormonal concentrations.

Softwood cuttings of the six previously mentioned crabapples were collected at approximately two week intervals from May 14 to August 6, 1976. The hormone treatments consisted of a 50% alcohol solution as control and 2500, 10000, 20000 and 30000 ppm IBA, NAA or a combination of the two, dissolved in a 50% ethanol solution. The cuttings were 4-6 inches long and consisted of the current season's growth. The basal portion of each cutting was stripped of foliage, given a 1 inch basal wound, and the remaining leaves cut in half to reduce the surface area. The cuttings were given a 5 sec dip in the hormonal solutions. Ten cuttings per treatment were used. Immediately after treatment the cuttings were placed in a 1 peat:1 perlite (v:v) medium to a depth of 3 to 4 cm with a spacing of 3 cm between cuttings and 6 cm between rows, and placed under intermittent systems which provided 6 sec of mist every 6 min during daylight hours. The temperature of the rooting medium was 25°C. The greenhouse temperature was maintained at 24°C day/20°C night. The photoperiod was natural and the greenhouse was given a medium shade.

Seven weeks from the date the cuttings were taken they were evaluated. The parameters used for evaluation were root number, length of the five longest roots, degree of callus and the rooting percentage. After evaluation the cuttings were transplanted to 4 inch pots and placed under intermittent mist for another 7 to 10 days. They were then moved to the greenhouse and kept under long days.

Malus × atrosanguinea. The optimum date for taking carmine crabapple cuttings was approximately May 14 (Table 1). Cuttings treated with 2500 ppm IBA rooted 100% had an average of 8.9 roots per cutting and the five longest roots average 45.2 cm. Cuttings taken June 24 and treated with 10000 and 20000 ppm IBA also rooted 100%. The average root numbers were 11.0 and 11.5, respectively, and the length of the five longest roots was 37.7 and 29.1 cm, respectively. Cuttings taken June 10 and treated with 2500 and 10000 ppm IBA rooted 100%, however, root numbers and lengths were not as great (5.9 and 7.5 roots per cutting, respectively, and 24.1 and 39.3 cm long, respectively).

Malus floribunda. Cuttings taken on May 27 and treated with 10000 and 30000 ppm IBA and those taken June 10 and treated with 30000 ppm IBA rooted 100% (Table 1). The root numbers were 19.6, 17.8 and 13.0, respectively, and the root lengths 38.6, 18.6 and 47.0 cm, respectively. Ninety percent rooting occurred on cuttings taken June 24. These cuttings were treated with 20000 and 30000 ppm IBA. Root numbers and lengths were high (16.2 and 22.5 roots per cutting, respectively, and 35.2 and 47.3 cm, respectively).

Table 1. The most efficient hormonal concentrations for a given date and cultivar representing the best rooting percentage, number and length.

	Sampling Date	Hormonal Concentration (ppm)	Rooting Percentage	Root Number	Root Length (cm)
Malus × *atrosanguinea*	May 14	2500 IBA	100	8.9	45.2
	June 10	2500 IBA	100	5.9	24.1
	June 10	10000 IBA	100	7.5	39.3
	June 10	30000 IBA	100	7.4	18.7
	June 24	10000 IBA	100	11.0	37.7
	June 24	20000 IBA	100	11.5	29.1
M. *floribunda*	May 27	10000 IBA	100	19.6	38.6
	May 27	30000 IBA	100	17.8	18.6
	June 10	30000 IBA	100	13.0	47.0
	June 24	20000 IBA	90	16.2	35.2
	June 24	30000 IBA	90	22.5	47.3
M. 'Hopa'	May 14	2500 IBA	90	7.3	32.8
	May 14	10000 IBA	80	15.4	13.4
	May 14	20000 IBA	80	28.1	17.3
	June 10	10000 IBA	90	4.5	7.9
M. *hupehensis*	May 14	2500 IBA + NAA	90	2.3	6.4
	Aug. 6	2500 IBA	70	1.6	6.2
	Aug. 6	10000 IBA	60	2.5	6.0
M. '*Selkirk*'	May 14	2500 NAA	100	9.3	32.0
	May 14	2500 IBA	90	6.7	32.1
M. × z. var. *calocarpa*	May 14	2500 IBA	90	9.7	43.4
	May 14	10000 IBA	80	17.7	34.3
	May 14	2500 NAA	80	6.9	31.5
	May 27	2500 NAA	100	8.3	39.9
	May 27	2500 IBA + NAA	80	3.5	15.2

Malus 'Hopa'. Hopa crabapple cuttings collected on May 14 and treated with 2500, 10000, and 20000 ppm IBA had the best rooting percentages (90, 80, and 80%, respectively) (Table 1). Root numbers were sufficient to allow transplanting (7.3, 15.4 and 28.1 roots per cutting, respectively). Root lengths were adequate (32.8, 13.4 and 17.3 cm in length, respectively). Although cuttings taken on June 10 rooted 90%, the root numbers (4.5) and length (7.9 cm) were not as well developed as the above mentioned.

Malus hupehensis. The best rooting percentage for the tea crabapple occurred on May 14 (Table 1). Cuttings treated with 2500 ppm combination rooted 90%. However, root numbers and lengths were sparse (2.3 and 6.4 cm, respectively). On August 6, cuttings treated with 2500 and 10000 ppm IBA rooted, but the percentages were not as high as commercial propagators would like (70 and 60%, respectively). Root numbers (1.6 and 2.5, respectively) and lengths (6.2 and 6.0 cm, respectively) were also minimal.

Malus 'Selkirk'. Maximal rooting (100%) was achieved on cuttings taken May 14 and treated with 2500 ppm NAA (Table 1). Root number and length were well developed (9.3 roots per cutting and 32.0 cm long, respectively). IBA at 2500 ppm was also effective on this date (90%). Root number was less than the NAA treatment, but length was comparable (6.7 roots per cutting and 32.1 cm long, respectively).

Malus × *zumi* var. *calocarpa*. Twenty-five hundred and 10000 ppm IBA-treated cuttings collected on May 14 had the greatest root numbers (9.7 and 17.7, respectively) and lengths (43.4 and 34.3 cm long, respectively) (Table 1). However, their rooting percentages were 90 and 80%, respectively. Twenty-five hundred ppm NAA treated cuttings collected May 14 and May 27 rooted 80 and 100%, respectively. But root numbers (6.9 and 8.3 roots per cutting) and lengths (31.5 and 39.9 cm long) were inferior to the previously mentioned treatments. Twenty-five hundred ppm combination cuttings collected on May 27 also rooted 80%. Root number was 3.5 per cutting and length was 15.2 cm.

Wide variances in rooting were observed among the selected crabapple taxa. Evaluation of rooting should be based on more than percentages. In many instances rooting percentages ranged from 80 to 100 yet the cuttings could not be effectively transplanted because only one or two short roots had formed. Cuttings which did not receive a hormonal treatment (control) showed limited rooting. The two highest concentrations often resulted in defoliation or death of the cuttings. Increasing the hormone concentrations did not result in increased rooting on cuttings collected later in the season. One nurseryman (4) noted that for cuttings made from the same shoots he adjusted the level of hormone according to the degree of maturation of the wood. The May and early June-collected cuttings continued to grow after transplanting while the late June, July and August cuttings either went dormant or died.

This study showed that crabapple cuttings collected in May or early June and treated with 2500 and 10000 ppm IBA could be effectively rooted in acceptable commercial quantities. The earliest-sampled cuttings were transplanted immediately after rooting and continued to grow thus facilitating field planting the spring following rooting.

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PROPAGATION OF HYBRID LILACS

DON WEDGE

Wedge Nursery
Albert Lea, Minn. 56007

PROPAGATION BY GRAFTING

The production of lilac has been our major specialty since 1935. We graft 120,000 to 150,000 each year. In brief, our method of propagating hybrid lilac is to bench graft the lilac scion on green ash root pieces. We use a whip graft and secure the graft with grafting thread. The completed grafts are packed in poly bags, then placed in refrigerated storage, kept at a temperature of 31 to 35°F until we are ready to plant them directly to rows in the field.

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Over the years we have made many experiments, 500 to 1000 grafts per trial, to test out a method and repeated it 2 years or more to double check the results. Like a good gambler we play the percentages learned from these experiments. Late years the stands of our lilac grafts have been quite consistant ranging from 70 to 90% per variety.

To raise this percentage closer to the 100% goal, we must look to the men handling the grafting knife. The sign of a good craftsman is a graft with a perfect contact the entire length of the cut, the cambium layers matching and in contact along at least one side.

It is ironic that this fall we dug the only poor crop we have had in the past 30 years. A number of things conspired to cause the poor results. We were not able to complete our field plantings until June 20th that year because of continuous rains. Because of wet ground the field planting crew did not or could not plant the grafts to the usual depth. Because of the late planting the grafts did not make their usual growth. The shallow planting depth plus an open winter with extremely cold weather resulted in winter-kill of many of the weaker plants.

Grafting lilac scions on green ash (*Fraxinus pennsylvanica*) root stocks might be called a form of layering. We are taking a stem section from above ground, attaching a nurse root, and placing the union deep into the soil. The nurse root will, if a good graft is made, feed the stem until it starts to put out its own roots. When this happens the lilac scion rejects the nurse root. On a few white varieties a small percentage of the nurse roots persist.

One year old green ash seedlings are cheaper to produce than privet; in three trials, ash gave the best stands. Two and 3 year old ash seedlings do as well but the fibrous roots make it more difficult to wind the graft.

Grafts packed in poly bags, gave an average increase of 17% over those packed in boxes with moist shavings, sawdust, or peat and eliminated the time of separating grafts from the packing material. The buds should remain dormant; we consider this important. Storing completed grafts in refrigerated storage until planting makes this possible. We feel the graft can be more firmly bound with thread and that tape prohibits roots from emerging at the base of the scion where they are most apt to develop first. Our test runs have proven this true.

Planting is done with a 2-row mechanical transplanter. From past experience we found lilac grafts should not be planted until the ground is warm enough for corn planting. After the grafts are set in the trench, they are cultivated — almost covering the graft.

An irrigation system is good insurance. One good soaking after planting forces the grafts into an early quick start. The grafts are cut back in the fall to force more canes. At 2 years the plants are mostly 18 to 24 inch and after 3 years mostly 2-3 and 3-4 ft. A shaker digger on a D2 caterpillar with 3 ft clearance takes most of the hard work out of harvesting. Our 3 yr lilacs are 100% own root.

The grafting of lilac is essential to filling out our yearly work schedule, keeping our key employees profitably employed with inside work from January 15 to March 15 — a time of year there is not much else we can do in Minnesota.

We feel that proper tilth of the soil is very important in producing well rooted quality lilacs. In preparing a field we plow under two green manure crops; a crop of corn and a crop of sorghum-sudan grass both when about 4 to 5 ft high.

PROPAGATING BY ROOT SUCKERS

Carl Orndorff reported to this Society in 1974 excellent results propagating *Syringa vulgaris* by piece-root cuttings. Prompted by his presentation, this past year we saved all the roots from plants discarded and roots broken in the grading process. These were cut into 3 to 4 inch pieces, some 15,000, and lined out this past May in a coarse sand bed which was kept moist and fertilized periodically.

From this first years trial nine varieties resulted in a good percentage of plants to line out, seventeen varieties produced none or too few plants to make it worthwhile. My conclusion is that this method has its limitations as to quantities and varieties, but is worthwhile to supplement other methods. From our experience this first year it would seem that a piece-root must have a growth bud visable in order to develop into a new plant.

Root suckers had been our method of propagating the common purple lilac because they always put out so many root suckers. This characteristic has given lilac in general a bad name as many people remember a single old common purple lilac taking over an area 20 ft across, and presume all lilacs are alike.

I have been wondering, if continuing to use root suckers would result in succeeding generations producing plants with more and more tendancy to put out root suckers? My son says no, that all characteristics of that particular clone will remain the same.

PROPAGATING BY SOFTWOOD CUTTINGS

This past spring, for the first time, we tried propagating lilac by softwood cuttings, in coarse sand, under a white poly covered tunnel and intermittent mist. We were quite pleased with the results. Some 7700 cuttings of 22 varieties were stuck. Most varieties rooted 66 to 86%. The first batch was taken May 5 to 7 just as the bloom was starting to open; the second was taken May 18 to 20 at the tail end of the blooming season. With four varieties we made numerous trial tests with the following results:

Syringa vulgaris cultivars	No hormone: Short tips 3-4 inch	No hormone: Long cuttings tips	No hormone: Long cuttings base	IBA 1666 ppm
'Monge'	72%	83%	66%	84%
'Madame Antoine Buchner'	45%	51%	62%	

	No hormone	IBA Quick Dip (ppm) 1660	IBA Quick Dip (ppm) 2500	IBA Quick Dip (ppm) 5000
'Paul Thirion'	78%	77%	86%	
'Ellen Willmott'	20%	22%	26%	37%

Many others had large callus but no roots. If I understand correctly this means a stronger IBA solution should have been used. These tests indicate the stronger treatments produced better rooting, and that all three types of cuttings will root reasonably well.

I have gone through the IPPS *Proceedings* and *The Plant Propagator* and asked for advice in regard to the best time to take cuttngs of hybrid lilac. Four sources related the timing to condition and size of the cuttings, i.e. when new growth has reached a length of 4 to 6 inches and before stems become hard and woody. Four associated the timing to time of bloom — three recommended taking cuttings when blooms first begin to open and the other one shortly after blooming. Four used the condition of the buds, i.e. taken before terminal bud is visable, when terminal bud is unfolding, as soon as terminal buds are formed.

Robert Nuss, Penn State, stated "the narrow period of time cuttings will root appears to be related to flowering and subsequent bud set." Roy Nordine reported fair to good results taking cuttings in the Chicago area from June 12 to July 11. In a letter to me in 1956 he wrote that Dr. Chadwick had learned on a trip to Europe that greenwood cuttings taken late in summer when the flower buds were being formed for the next season, gave much better results than those taken at an earlier date. Last year, Ray Halward at Hamilton, Ontario reported his best rooting, a commendable 80%, from the last week in June until second week in July. Henry Chase of Chase, Alabama, in a phone call said that they have stuck greenwood cuttings in August with good rooting in 4 to 5 weeks and even had 75 to 80% rooting on hardwood cuttings stuck in coldframes in the winter.

Conclusions — Although most consider the short period in the spring the only time to take cuttings, you may, if you are a good propagator and have the knowhow, have success at later dates.

PROPAGATION OF *CLEMATIS*

RAYMOND J. EVISON

Treasures of Tenbury Limited
Tenbury Wells, Worcestershire, England

Clematis propagation in the United Kingdom is generally carried out by the use of cuttings, grafting, seed, or division of roots. My company only uses three methods, that of propagation from cuttings, seed and division; species are generally the only ones produced from seed. Seed is acquired from plants growing in our garden. Quite a number of species do not come true from seed and produce variations, these variations are acceptable in general commerce. The species which are produced from seed are as follows; *Clematis afoliata*, *C. campaniflora*, *C. hirsutissima* var. *scottii* (syn. *C. douglassi* var. *scottii*), *C. fargesii* var. soulei, *C. flammula*, C. *integrifolia* 'Rosea' C. *integrifolia* 'Olgae', *C. viorna*. *C. vitalba* and *C. viticella*. The herbaceous types are produced from divisions. Selected clones of the above species are increased from cuttings, however, in most cases they prove to be difficult. Afoliata can also be propagated by layering on a commercial scale. All other species and cultivars are reproduced from cuttings.

Stock Plants. Stock plants are only used for new species or cultivars and other clones which are very difficult to root from cuttings. In general stock plants produce cutting material which is too large for the type of commercial production methods that I use.

Cutting Material. Cutting material is harvested from young plants 6 weeks after the plant has been potted in a 7 cm pot, this material is strong and healthy and is the ideal juvenile material, producing the right size of cutting for production requirements.

Method of Taking Cutting Material. Cutting material is removed from young plants using a new, one-sided razor blade per variety. A new blade is used to prevent unapparent disease infection being passed from one variety to another. Cuttings are placed inside a container which is lined with a Captan soaked cloth. The position where the young plants are cut to give the cutting material varies from cultivar to cultivar. Generally, two fully matured nodes with correctly formed leaves remain, dis-

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Treasures of Tenbury Limited
Tenbury Wells, Worcestershire, England

Clematis propagation in the United Kingdom is generally carried out by the use of cuttings, grafting, seed, or division of roots. My company only uses three methods, that of propagation from cuttings, seed and division; species are generally the only ones produced from seed. Seed is acquired from plants growing in our garden. Quite a number of species do not come true from seed and produce variations, these variations are acceptable in general commerce. The species which are produced from seed are as follows; *Clematis afoliata*, *C. campaniflora*, *C. hirsutissima* var. *scottii* (syn. *C. douglassi* var. *scottii*), *C. fargesii* var. soulei, *C. flammula*, *C. integrifolia* 'Rosea' *C. integrifolia* 'Olgae', *C. viorna*. *C. vitalba* and *C. viticella*. The herbaceous types are produced from divisions. Selected clones of the above species are increased from cuttings, however, in most cases they prove to be difficult. Afoliata can also be propagated by layering on a commercial scale. All other species and cultivars are reproduced from cuttings.

Stock Plants. Stock plants are only used for new species or cultivars and other clones which are very difficult to root from cuttings. In general stock plants produce cutting material which is too large for the type of commercial production methods that I use.

Cutting Material. Cutting material is harvested from young plants 6 weeks after the plant has been potted in a 7 cm pot, this material is strong and healthy and is the ideal juvenile material, producing the right size of cutting for production requirements.

Method of Taking Cutting Material. Cutting material is removed from young plants using a new, one-sided razor blade per variety. A new blade is used to prevent unapparent disease infection being passed from one variety to another. Cuttings are placed inside a container which is lined with a Captan soaked cloth. The position where the young plants are cut to give the cutting material varies from cultivar to cultivar. Generally, two fully matured nodes with correctly formed leaves remain, dis-counting any juvenile leaves. In some cases only one fully matured node need remain. The cutting material is then transferred from the growing house to the preparation room and placed in a cool location, all material being completely covered and not exposed to sunlight.

Method of Making Cuttings. It is very important to handle all cutting material with great care, avoiding contact with the leaves if at all possible. At no time should material be exposed to sunlight, except when the cuttings are actually being made. As clematis grow very rapidly and cutting material in most cases becomes entangled, it is important when the cutting is being selected from the vine that the bottom-most node on each stem is used first. It is also important not to handle the leaves, only the stem, node or leaf petiole. The cutting shape and size is important for my particular method of growing on. The internodal cutting consists of one leaf petiole and leaf, the other being removed, on some occasions the remaining leaf is reduced in size. The stem is cut 0.5 cm above the node and 3.5 cm below the node. The prepared cutting is placed immediately in a holding tray, which is lined with a Captan soaked cloth. When about 150 cuttings have been prepared they are transferred to a dipping container; this container is immersed for 5-10 sec in a Captan solution and afterwards the cuttings are completely covered, keeping the sunlight away from the foliage. It is very important to keep all work benches clear of unwanted material and that a clean surface is used for preparing cuttings.

Insertion of Cuttings. The cuttings are inserted in a compost which consists of one part loam, one part peat, two parts grit and two parts of fine screening sand. The peat and loam are passed through a 0.5 cm mesh sieve and all materials are thoroughly mixed. Pea gravel (1 cm) is placed in the bottom of 6 cm deep seed trays which will give adequate drainage during rooting. The seed tray is filled with the compost and lightly firmed; a thin layer of screening sand is placed on top of the firmed compost. All the prepared boxes are covered with damp hessian [burlap] to keep the compost in a moist condition. Although there is no specific pattern for insertion of the cuttings, the spacing of each cutting should be no closer than 1 cm from the next node. All cuttings which are pushed into the compost should be arranged to give even foliage distribution throughout the cutting tray. The cutting should be inserted until the node is just below the surface of the compost. A conglomeration of foliage will lead to micro-climates and botrytis. The number of cuttings per tray varies depending upon the cultivar, generally only 110-125 cuttings are placed in each tray. The rooting hormone which is used is May and Baker Seradex No. 2. As soon as the tray is full of cuttings it is placed on the propagation bed, making sure that the bottom of the tray makes firm and even contact with the sand bed. Again great care must be taken when maneuvering the tray into position taking extreme care not to damage any leaves from surrounding trays. When the tray is placed on the propagation bed the tray is given a light watering at the end of a cutting period, either morning or afternoon. The cuttings are then watered in, using a watering can with a coarse rose. The solution used is a mixture of Captan and water. When cutting propagation is underway, I use a team of approximately six people. They will average 1,000 cuttings per person per 6 hr day; this includes the person collecting the cutting material and the insertion of the cuttings.

Propagation House Conditions. The propagation beds consist of ground level beds with adequate drainage which is underneath a layer of closed cell polystyrene sheeting of 2.5 cm thickness. Five cm depth of fine sand is placed beneath electric heating cables and 5 cm of sand above the cables. The bed temperature is kept at 75°F (24°C) approximately. No weaning is carried out unless the cuttings have been rooted during the late autumn months, weaning is then carried out on a gradual basis. The air temperature of the propagation house is kept at a minimum of 60°F (15°C) and a maximum of 90°F (31°C). It is important to keep a good circulation of air throughout the propagation house.

Shading. Direct sunlight must be avoided on all cuttings until they are fully rooted. Various types of shading 40-75% shade is used depending upon sunlight conditions throughout the various months of the year.

Misting. I use a manually controlled mist system. The frequency and amount of mist depends upon weather conditions. Generally in good sunny conditions the cuttings are misted each hour with a fine mist of 15-20 sec duration. All cutting material must be allowed to dry off before nightfall. All concrete pathways and areas where plants are not in position are kept moist, giving a high humidity level in the propagation house.

Watering. The mist system used is not sufficient to compensate for evaporation and water taken up by rooted cuttings. Slight irregularities in misting will give different conditions to each tray even with the good misting pattern, therefore, at the beginning of each day all cutting trays are checked for watering. This may seem costly, but with the amount of cuttings per tray and the total value that they will realize, the time spent in labour is well compensated.

Disease in Propagation. The only problem usually experienced is the buildup of fungicidal spores when leaves touch each other, or from damage during preparation. A drench of Captan is used at 2 week intervals as a preventative. A dusting of a material called Botrilex is used alternate weeks with the Captan drench. However, it is still necessary for the propagator to remove dead or damaged foliage at weekly intervals to prevent any large buildup of botrytis or other disease.

Growing On. In general, cuttings root within about 21 days. They are then allowed to grow on for a further 5 weeks, allowing the leaf axil buds to start into growth before potting. It is very important that selection and grading is adhered to before potting. Only strong healthy cuttings which are producing top growth should be used. These are removed from the cutting tray by tipping the contents of the tray out onto a clean bench surface in one block if at all possible. The rooted cuttings should be removed from the tray by selection using thumb and finger lightly pulling at the node and easing the root system out of the compost. All roots are trimmed to a length of 7.5 cm from the tip of the node to the bottom of the root system. The cuttings are then potted by a Dutch Javo Potting Machine into a 7 cm square pot using a compost which consists of approximately 65% peat, 15% loam and 20% grit and sand.

The fertilizer used is Vitax Q4 at the rate of 4 oz/bu. The pH of the compost after mixing is approximately 5.7. The compost is mixed in an adapted agricultural meal mixer. The rooted cutting when potted is placed in a carrying tray which in turn is placed in a polythene tunnel-house (5 × 16M) with 10,000 plants per house. When potting some species which have a very fine fibrous root system, it is important to take great care when handling them because they are generally very fragile and will fall away. It is important with these fibrous rooted species that the soil conditions are not allowed to become too dry or too wet for excessive periods during the winter months.

After Care. The polythene tunnel-house is kept closed for about 3 weeks after potting the cuttings in order to keep a high humidity level and is only vented during very hot conditions, when the temperature inside the polythene tunnel-house exceeds 90°F (31°C). During hot weather the potted cuttings are misted 20-30 sec each hour. Six weeks after potting the rooted cuttings will have produced approximate 30 cm of growth. This new growth produces the next batch of cutting material. After this, the plants are allowed to grow on for a further 6 weeks, during which time each plant is caned and tied into position. A liquid feed program is carried out through this growing period. In most cases two or even three new stems are produced giving a compact bushy plant.

Other Pest Control. Other pests usually experienced are aphids, slugs and mice — the latter two during winter conditions can be very damaging to newly formed leaf axil buds and young growth. Their control is very important. Mildew occurs very occasionally.

To Conclude. A propagation schedule will read in this manner: A cutting is prepared, allowed to root and grow for 8 weeks after preparation of the cutting, it is then potted and allowed to grow for 6 weeks when it is pruned giving the next batch of cutting material. The plant then grows for a further 6 weeks producing a strong healthy clematis, it is harvested and dispatched. Rooted cuttings are potted from late January onwards. The January potted cuttings are kept at a minimum of 50°F (10°C) by warm air heaters. When new growth appears, approximately 2-3 weeks after potting, supplementary lighting is used to give a 14 hr day. The light used is of a very simple nature, three fluorescent milk white tubes 2.5 metres in length per tunnel-house, this gives sufficient daylight extension and is a great advantage. It is very important to ensure that late flowering cultivars are potted before the middle of August, otherwise they do not become fully established, or what is termed "integrated cutting", before the winter. Early flowering cultivars and species may be potted as late as mid September with the understanding that the air temperature is kept at 50-55°F (10-12°C) using supplementary heating, and lighting with the daylength again kept at approximately 14 hr minimum. I produce some 250,000 young clematis plants annually by these methods.

The morning session adjourned at 11:30 a.m. and at a luncheon meeting in the Jupiter Room, Dr. Alvan Donnan of Oakdell Inc. Apopka, Florida gave a slide presentation concerning commercial propagation of foliage plants by tissue culture.

Tuesday Afternoon Session, December 6, 1977

Dr. Emino, moderator of the morning session also served as moderator for the first portion of the afternoon session. Mr. Duke Biscotti then served as moderator for the second portion of the afternoon program.

PROPAGATION OF *POTENTILLA*

KATHLEEN S. FREELAND

Weston Nurseries
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Potentilla, also known as cinquefoil, is a member of the rose family. It is used as a rock garden plant or in borders or group plantings. *Potentilla fruticosa* is one of the most commonly grown species of its genus. The name potentilla was originally given to this group because of its potency as a medicine. Since fevers were often blamed on evil spirits, a medicine that reduced fever was looked upon as a potent against evil spirits. The name potentilla, a diminutive for powerful, arose from this belief. Most *Potentilla fruticosa* is hardy to Zone 2. Fruticosa is the latin word for shrubby, which describes the growth habit of this deciduous, densely leafy shrub, much branched and with bright yellow flowers (some have white or red flowers).

Potentilla is propagated by division, seeds and cuttings. Cuttings are by far the most economical commercial method; it is this method of propagation which will be discussed exclusively in this article.

Cuttings may be taken any time from early summer through fall. A cutting is taken from the current year's growth, 4 to 6 inches long (longer cuttings have also proven to be successful). Cuttings are gathered in the early morning and stored in sealed plastic bags in a refrigerator until time to be processed. The lower leaves are removed from the cuttings (to prevent rotting). A new 45° angle cut is made and the cutting is dipped in hormone powder (the most commonly used powder at Weston Nurseries is Hormo Root B with Thiram). The treated cuttings are then stuck in a 50% peat and perlite mixture, either in flats or in a greenhouse bench. Bottom heat at about 75°F hastens rooting. Mist is used sparingly, — about 6 sec/10 min, depending on the weather. No mist is used at all on overcast or rainy days, to prevent mildew problems. Cuttings root in about 6 weeks. The rooted cuttings are removed from the bench when the rootball is about the size of a quarter, and are flatted in a soil mixture of equal parts peat, perlite and bark.

Cuttings taken in early summer can be planted directly out in beds. Care must be taken to provide the young plants with daily watering and shading from direct sunlight. The beds should be covered with hay or some other form of protection for the winter. Poison bait of some type should be placed at intervals under the hay. Rooted cuttings that have been flatted may be overwintered in cold frames covered with hay, or covered with poly or sash, using some form of rodent poison. Cuttings may be kept in a poly tent where the temperature doesn't go below freezing. An alpine house has also been used successfully for overwintering these cuttings. The hay or other winter protection should be removed early in the spring. Cold frames and alpine houses must be ventilated on sunny days, to obtain good air circulation.

Potentilla fruticosa cultivars grown successfully by Weston Nurseries using this method include: 'Arbuscula'; 'Gold Cup', 'Jackmannii'; 'Katherine Dykes', 'Klondyke', 'Longacre', 'Mandshurica', 'Maanelys' (syn. 'Moonlight'), 'Primrose Beauty', 'Tangerine'. A new cultivar from England, soon to be distributed in this country is *Potentilla fruticosa* 'Red Ace'.

PROPAGATING FRENCH HYBRID LILACS BY SOFTWOOD CUTTINGS

ROGER G. COGGESHALL

Cherry Hill Nurseries, Inc.
West Newbury, Massachusetts 01985

Lilacs have been reproduced asexually for centuries. The methods used have varied greatly from continent to continent and from nursery to nursery. Many nurseries prefer to propagate their lilacs by root-grafting onto understocks of *Ligustrum*, or *Fraxinus*, while others prefer to propagate them from suckers, or divisions. At Cherry Hill Nurseries, Inc., located in the northeastern corner of Massachusetts, about 4 to 5 miles from the ocean, we have found that a softwood cutting procedure works well.

TIMING

The single most important factor in the success or failure in the rooting of softwood cuttings of French hybrid lilacs, is the time the cutting material is collected. In our latitude this operation begins around May 25 and continues until the end of June.

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TIMING

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Although development of new growth varies from year to year, best results have been obtained between these dates.

CUTTING SELECTION

Only current season's growth is used. As growth rates vary among cultivars, the length of the cutting wood selected will vary. The collected cutting material is placed in 2 mil poly bags and is placed in a cool cellar to prevent the soft growth from heating in the bags. No additional moisture is added to the bags. An attempt is made to collect just enough cutting material for each day's propagation. We try to work with the freshest material possible.

CUTTING PREPARATION

Following collection, the new softwood cuttings are trimmed to 3 to 4 inches, depending upon the length of the internodes. The cuttings are stripped of all but two pairs of leaves and the very soft terminal growth is pinched out. Often the cutting material selected is so soft a terminal bud has not formed. In other cases, mainly where the growth is more firm and mature, the terminal bud is left. However, the two small underdeveloped leaves on either side of this terminal bud are removed. The cuttings are now ready for a hormone treatment.

HORMONE TREATMENT

Two hormone concentrations are used; Hormodin #2 and Hormo-Root B. Both are used in powder form, which is sprinkled out onto pieces of paper. Care is taken to see that the basal ends of the cuttings do not get too wet. If they are allowed to get too wet, too much hormone powder will stick to the basal ends and the cuttings will be killed. The hormone powders on the papers must be kept dry from day to day. Great damage can be done to these softwood cuttings by too strong a hormone powder. The growth is so soft it is easily killed by "overdosing." In general, we have found that the white cultivars require the longest time to root (2 to 3 months), while the darker colors are the quickest to root (1 to 2 months).

ROOTING MEDIUM

We have found that the best rooting medium for softwood cuttings of French hybrid lilacs is a 1:1 mixture of sand and perlite. The sand is a clean, washed sand, while the perlite is a coarse horticultural grade. The two ingredients are combined thoroughly on a volume basis. Mixing is a messy job due to the dryness of the perlite (a respirator helps); the medium is watered thoroughly for several days prior to sticking. Once the medium is satisfactorily moist the cuttings are stuck approximately 2 inches apart in rows which are approximately 4 inches apart. Great care is taken to see that the cuttings are firmly watered in, which is difficult with this medium, as the perlite tends to "float" to the surface.

PROPAGATING STRUCTURES

One of the reasons for our success in rooting softwood cuttings of lilacs is the structure we root them in. After the cuttings have been stuck, we mist them to prevent wilting. The time clocks are set so that the cuttings receive 6 seconds of mist each 30 seconds.

In addition to misting, the cuttings receive additional humidity by covering the propagating structure with 4 mil, clear polyethylene plastic. This creates a very high humidity situation for the cuttings to root in. The plastic covering also causes a buildup of heat on a clear day. When this occurs we ventilate the house to reduce the heat buildup. We try to maintain an air temperature of approximately 100°F.

Root initiation begins with a 10-14 day period under these hot, humid conditions. After rooting, the cuttings are gradually hardened off by reducing the amount of misting until they are watered only as needed by hand (late August).

The cuttings remain in the rooting bench for the entire winter. They freeze solidly in the rooting medium, as there are no heating facilities in the propagating structures.

In the spring the bare-rooted cuttings are lined out in the field. They are planted 10 inches apart in the row, with 30 inches between rows. Their survival in the field depends on rain as we have no irrigation facilities.

At the end of the first season's growth the young plants are trimmed back to a height of 2 to 3 inches above the ground. This induces branching of the second year's growth and we have a well-branched, heavy liner at the end of the second growing season. In mid-September the 2-yr old liners are transplanted; the tops and the roots are pruned back, the plants set 30 inches apart in the row and allowed to grow for another 2 years. At this spacing they develop into well branched, well budded plants for the nursery trade.

EFFECT OF TIMING AND WOOD MATURITY ON ROOTING OF CUTTINGS OF *COTINUS COGGYGRIA* 'ROYAL PURPLE'

JAMES D. KELLEY and JAMES E. FORET, JR.[1]

Iowa State University
Ames, Iowa 50011

Abstract. Softwood cuttings of *Cotinus coggygria* 'Royal Purple' rooted best when taken as early as June 11. Rooting response decreased on each subsequent date, to 33% rooting on July 24. On all dates, with the exception of June 11, rooting was best when immature, actively growing, terminal wood was used and when cuttings were treated with a rooting hormone and rooted under intermittent mist. Hormones influenced root quality more than cutting time or maturity of the wood. Results indicate that with *Cotinus coggygria* 'Royal Purple' rooting percentage can be at least 95% when attention is given to timing, wood selection, and the use of hormones.

Seasonal variation in the rooting response of cuttings can be an important factor influencing the successful propagation of many plants. Since the rooting response can be seasonal, this increases the importance of timeliness in propagation. The effect of timing and wood selection has been shown by Congdon (2) to be an important factor in successful propagation by cuttings. Others (1,4,5) have demonstrated the importance of timing in the successful propagation of a number of species. This work is concerned with the role of wood type, timing and auxins on the rooting of *Cotinus coggygria* 'Royal Purple'.

Hancock (3) has described the propagation of *Cotinus coggygria* by layering, while Sjulin (6) reported his method of propagation of 'Royal Purple' Smoke Bush by using softwood cuttings under mist. He found best results were obtained when terminal cuttings were taken from stock plants with 10 to 12 inches of new growth and when the wood was quite soft. This resulted in about a 60% stand going into the winter.

MATERIALS AND METHODS

Cuttings were taken from established stock plants growing in a nursery in Hamburg, Iowa. Cuttings of three wood types were collected on four dates. Cuttings were 5 inches in length. The three types of cuttings were immature, intermediate, and mature. The immature cuttings were terminal cuttings taken from shoots in active growth. This was readily visible since the leaves near the end of the shoot were immature and had not expanded. Looking at the immature cutting from the side it had a pyramidal outline. A mature cutting had all leaves including the very youngest fully expanded, while the intermediate type bore at least some leaves that were still expanding.

[1] Associate Professor and former Graduate Student, Dept. of Horticulture.

Cuttings of these three types were taken on June 11, June 25, July 8, and July 24. The auxin treatments consisted of a check and a quick dip (5 sec) of 1425 ppm IBA, 1425 ppm NAA and 50 ppm boron as boric acid. The lower 1-1/2 inches of the cuttings was placed in the quick dip. The above resulted in 6 treatments on each of the four dates. Each treatment consisted of 80 cuttings in 10 replicates or a total of 1,920 cuttings in the entire experiment. Cuttings were rooted in horticultural grade perlite under intermittent mist in the greenhouse. The cuttings were under mist for 10 weeks, then evaluated for percent rooting and root quality. Root quality was based on a scale of 1 to 5 with 1 considered poor and 5 excellent.

RESULTS

The effect of timing and wood maturity on rooting percentage and root quality is shown in Table 1. The data show a gradual decline in rooting percentage as the season progressed. The highest rooting percentage was obtained from cuttings taken June 11 and dropped to the lowest percentage on July 24. Immature wood resulted in the best rooting percentage on all three dates with the exception of June 11. The data suggest that as wood matures and the summer progresses rooting percentage drops dramatically.

Root quality was not as greatly influenced by wood maturity and cutting date as was rooting percentage. Best root quality was obtained on cuttings taken July 8 while the least quality was on cuttings taken July 24. Mature cutting were poorest in root quality at all cutting dates. These results indicate that cutting dates had a significant influence on root initiation but little or no influence on root development. Auxins influenced both root initiation and root development.

Table 1. Effect of time and wood maturity on rooting percentage (R.P.) and root quality (R.Q.) of *Cotinus coggygria* 'Royal Purple'.

	Cutting Date									
	June 11		June 25		July 8		July 24		Mean	
Wood Maturity	R.P.	R.Q.[x]	R.P.	R.Q.	R.P.	R.Q.	R.P.	R.Q.	R.P.	R.Q.
Immature	85	2.8	82	3.1	80	3.3	63	2.7	77	3.1
Intermediate	90	3.0	71	2.8	73	3.4	33	3.1	66	3.1
Mature	84	2.8	59	2.6	38	3.0	4	2.0	46	2.8
Mean	86	2.8	70	2.9	64	3.3	33	2.6		

[x] 1 = Poor, 5 = Excellent.

The effect of timing and auxin treatment on rooting percentage and root quality are shown in Table 2.

Table 2. Effect of timing and auxin on rooting percentage (R.P.) and root quality (R.Q.) of cuttings of *Cotinus coggygria* 'Royal Purple'.

	Cutting Date									
	June 11		June 25		July 8		July 24		Mean	
Auxin	R.P.	R.Q.[x]	R.P.	R.Q.	R.P.	R.Q.	R.P.	R.Q.	R.P.	R.Q.
Check	81	2.6	60	2.6	55	2.7	27	2.2	56	2.7
IBA and NAA	91	3.0	81	3.1	72	3.8	40	3.3	71	3.3
Mean	86	2.8	70	2.9	64	3.3	33	2.8		

[x] 1 = Poor, 5 = Excellent.

Cuttings treated with IBA and NAA rooted best on all cutting dates. The later in the season the cuttings were taken the greater the response to auxins. Cuttings taken June 11 showed the least response to auxins.

The relationship between timing and auxin on root quality is also shown in Table 2. Auxins had the greatest effect on cuttings taken the last cutting date, July 24, and the least on those taken June 11. The pattern is similar to that of the rooting percentage. As the season progressed root quality remained essentially unchanged.

The effect of wood maturity and auxins on rooting percentage and root quality is shown in Table 3. Rooting percentage dropped significantly when mature wood was used for cuttings. This was true for both check and auxin treated material. The response to auxin was least on immature wood and greatest on mature wood. Root quality was increased when auxins were used but maturity of wood had little or no influence on root quality.

Table 3. Effect of wood maturity and auxins on rooting percentage and root quality of *Cotinus coggygria* 'Royal Purple'.

	Rooting Percentage		Root Quality[x]	
Wood Maturity	Check	Auxin	Check	Auxin
Immature	67	88	2.9	3.3
Intermediate	61	72	2.8	3.4
Mature	31	53	2.3	3.3

[x] 1 = Poor, 5 = Excellent.

DISCUSSION

Softwood cuttings of *Cotinus coggygria* 'Royal Purple' taken early in the growing season rooted better than cuttings taken 4 to 6 weeks later. Hartmann and Loreti (4) found a similar response for leafy olive cuttings, from easy-to-root and difficult-to-root clones. Cuttings of Chinese fringe tree (*Chionanthus retusus*) were also found to root best early in the growing season (7). A lower level of auxins in the mature cuttings and later in the season may have been responsible for a lower rooting percent. Mature cuttings were most responsive to an application of growth regulators.

In general treatments had the greatest effect on root initiation as shown by rooting percent but had the least effect on root development as shown by root quality. However, root quality generally was least on immature and intermediate cuttings and on cuttings treated with a growth regulator.

Auxins were most effective in improving rooting as the season progressed but were beneficial on cuttings taken early in the season. Mature cuttings responded to auxins to a greater degree than immature cuttings. These results show that cuttings of *Cotinus coggygria* 'Royal Purple' root best from immature and intermediate cuttings taken early in the season and treated with auxin. If cuttings are made later in the season the propagator should select immature cuttings for best results.

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CASE HOOGENDOORN: How do you treat these cuttings to get them to survive?

JIM KELLEY: They are rooted in outdoor mistbeds and left in place until spring. The beds are protected in the winter; in the spring the cuttings are taken up and planted to the field with very good survival rates.

PETE VERMEULEN: We rooted them very successfully using direct stick methods with soil incorporated into the rooting medium. We've carried them over very successfuly in a deep frame and in controlled storage with temperatures between 33-38°F. In order to get a good supply of cutting wood we would top the new shoots about the time the wood is ready to mature and allow this to remain for another couple of weeks. The shoots would develop feathers 4-6 inches long, up and down the stem. These were then taken as a cutting with a heel and they rooted very well indeed.

JIM KELLEY: That should work; I don't believe you can take the cuttings of this plant too soft.

MIST NOZZLES

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Prior to the development of mist propagation, the turgidity of cuttings in the rooting bench was maintained by manual syringing and shading. Hand syringing during hot weather requires a considerable amount of time especially for the first few days to acclimate the cuttings to their new situation without roots. The use of shade during the acclimation period or during the entire rooting period helped to reduce the transpiration rate but also increased rooting time as a result of light reduction. Early studies involved the use of various systems of supplying water to the cuttings such as centrifugal humidifiers, atomizing, deflector and whirling nozzles to alleviate the hand labor. The advent of mist propagation not only greatly alleviated the need for manual syringing but also permitted cuttings to be acclimated without the need for shading.

Although it is important to maintain the turgidity of the cuttings, excess mist can cause problems by reducing the medium temperature and/or leaching nutrients from the foliage. For maximum effectiveness, uniform water distribution over the cutting bench area is desired. This would allow the on cycle to be kept to a minimum which would conserve water, prevent leaching of nutrients from the foliage and avoid a reduction in medium temperature. Ideally this would require a square pattern spray nozzle with uniform water distribution over the area covered. Mist nozzles, however, spray a circular pattern which requires overlapping of the pattern at some locations and thereby gives non-uniform wetting of the area.

MIST PROPAGATION NOZZLES

The two basic types of nozzles used in mist propagation systems are the oil-burner type, which has a whirling action and deflection nozzles where a small stream of water hits a flat surface. The whirling nozzles use smaller orifices and some-

[1] Assoc. Prof. of Horticulture, Professor and Exten. Agric. Engineer, respectively.

down the stem. These were then taken as a cutting with a heel and they rooted very well indeed.

JIM KELLEY: That should work; I don't believe you can take the cuttings of this plant too soft.

MIST NOZZLES

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what higher pressures to develop small droplets. The total water flow rate is generally less than for deflection nozzles. The deflection nozzles, since they have larger orifices, are less inclined to plug with fine sand or dirt particles.

The nozzles may be placed on vertical risers from a supply pipe located in the bed or they may be placed in a line suspended above the beds. The riser system nearly doubles the piping cost because of the extra pipe needed for the risers but it avoids dripping from the nozzles when the system is turned off and the pipe does not interfere with the water distribution pattern. With the overhead line system care is needed to keep the line level since water tends to drain out of the lowest nozzle due to gravity. When this occurs several nozzles may not be operating efficiently because air which has entered the line must first be forced out and the water pressure built up in the line to restore efficient operation at the nozzle. One advantage of the overhead system in addition to lower pipe cost is that it can be more readily disconnected and moved to a new location after a bed of cuttings are rooted.

EXPERIMENTAL TESTS

Ten nozzles were tested using the manufacturers recommended nozzle spacing and water pressure. Several of these nozzles were also tested at pressures other than that recommended to determine the effect of water line pressure on these nozzles. The nozzle types tested and their description is given in Table 1.

The tests were conducted on a 4 ft wide bed. The nozzles were connected to a water line suspended 18″ above the test bed. Two nozzles were used in each test. Round containers approximately 4 inches in diameter and 3 inches deep were placed side by side on the entire bench area. The mist system was activated for 5 to 10 min and the water collected in each container was weighed. The total weight was determined and an average weight per cup was calculated. The percent that the weight in each cup deviated from the average was then computed. Two sets of data were taken for each type of nozzle. The number of cups within plus or minus 20% of the average, plus or minus 50%, plus and minus 80% and greater or less than 80% were counted. The percentage of cups within each of these ranges was then determined. The water flow rate was also determined by collecting the total water discharged by a nozzle during a 5 or 10 min interval.

To provide an overall index of a nozzle's discharge uniformity, the percentage of cups in the ± 20% range was assigned a value of 4, those in the ± 50% range 3, ± 80% range 2, and greater or less than 80% range 1. The percentage value in each range was multiplied by the assigned value. These values were then summed and divided by 400 to obtain a "Uniformity Index" value. A value of 1 would indicate a water distribution where no cups had more or less than 20% of the average amount of water per cup.

RESULTS OF EXPERIMENTAL TESTS

The results of the experimental tests are given in Table 2. As indicated by the "Uniformity Index", nozzle #5, which is a deflection type nozzle, when operated at 40 psi provided the best uniformity. With this nozzle none of the bed had a water distribution which deviated by as much as ± 80% of the average. In fact, 88.2% of the bed had a uniformity of distribution within ± 20% of the average. The second best nozzle was one of the whirling types (No. 8) operated at 60 psi. For this nozzle 68.2% of the area had a uniformity within ± 20% of the average.

As a group the whirling type nozzles were better than the deflection type nozzles. This was true regardless of the pressure at which they were operated. The average uniformity index number for this type nozzle was 0.83 with a low value of 0.78 and a high value of 0.89. For the deflection nozzles the average index number when considering only the data for the pressures recommended by the manufacturers was 0.80 and for all deflection nozzle data it was 0.77. The range of uniformity index numbers for the deflection nozzles was 0.57 to 0.96 when considering all data and 0.70 to 0.96 when only considering the data which was consistent with the manufacturer's recommendations.

Since excess leaf wetting was not considered to be as serious as the lack of wetting, nozzles which tended to have significant regions of low water application would be particularly poor. A comparison of nozzles from this viewpoint could be made by summing the percentage of bed area where the water distribution was −80% or less than −80% of the average. Considering only the data for nozzles tested with 18.9 to 21.8% of the total area having water distribution low ranges. Nozzle #5 was the best in this respect with only 0.9% of the total area falling in these ranges.

For those nozzles having a relatively high percentage of the area over-wetted (high values in the +80% and > +80% ranges), a check of the data was made to determine the location of the high values. If it was between the two nozzles, spreading the nozzles further apart to reduce overlap might have merit. The data indicated that this was the case for nozzle #3 operated at 60 psi, nozzle #4 operated at 40 and 60 psi, nozzle #5 operated at 60 psi, and nozzle #7 operated at 40 and 60 psi.

As would be expected the discharge rate increased as the pressure increased and as the orifice size was increased. Considering the deflection type nozzles tested, the discharge at 40 psi varied from 4.18 to 15.34 gal/hr. The discharge of the whirling type at 40 psi varied from 3.46 to 7.70 gal/hr. Though the whirling type were generally somewhat lower in discharge than the deflection type, deflection type nozzles with discharge rates comparable to the whirling type are available. The low discharge deflection nozzle; however, gave the poorest overall uniformity and the highest discharge nozzle gave the best uniformity.

Table 1. Nozzle identification and description.

Nozzle Number	Trade Name	Orifice or Gap Setting	Spacing feet
1.	National Fog-Mist	Anvil at 0.10″	4
2.	Brighton Flora-Mist	Orifice 0.020	3
3.	Brighton Flora-Mist	Orifice 0.031	3
4.	Brighton Flora-Mist	Orifice 0.040	3
5.	Brighton Flora-Mist	Orifice 0.040	4
** 6.	IBG, Mist Propagation	62A, 0.012 slots	3
** 7.	IBG, Mist Propagation	63A, 0.018 slots	3
** 8.	IBG, Mist Propagation	64A, 0.020 slots	3.5
9.	National "Mister 100"	Orifice 0.040	3
10.	Brighton Mister Green	Orifice 0.040	*

* *Spacing was 3′ @ 20 psi, 4′ @ 40 psi, and 5′ @ 60 psi.*
** Whirling type nozzles; all other nozzles were the deflection type.

Table 2. Uniformity of water distribution from selected mist propagation nozzles.

Nozzle	Pressure psi	Flow rate Gal/hr	±20%	±50%	±80%	≶±80%	Uniformity Index
1	20	4.46	43.3	9.5	2.7	3.6	0.77
				19.1	18.2	3.6	
	40	6.12	19.5	13.2	5.9	13.2	0.57*
				9.5	17.8	20.9	
	60	7.78	29.1	20.9	5.0	4.1	0.68*
				9.5	20.0	11.4	
2	20	2.88	26.1	15.0	7.2	11.7	0.64*
				14.4	12.8	12.8	
	40	4.18	31.1	18.3	10.0	6.1	0.71
				13.4	21.1		
	60	5.11	28.4	17.2	8.3	7.8	0.69*
				12.2	23.3	2.8	
3	20	7.63	32.3	28.3	8.3	1.7	0.75*
				11.7	14.4	3.3	
	40	10.73	53.9	12.2	5.6	3.3	0.82
				11.1	13.9		
	60	12.31	63.4	12.2	3.9	3.3	0.88*
				15.0	2.2		

Table 2. (Continued)

Nozzle	Pressure psi	Flow rate Gal/hr	±20%	±50%	±80%	≤±80%	Uniformity Index
4	20	11.81	45.0	8.9	2.2	5.0	0.78*
				25.0	8.9	5.0	
	40	15.34	52.2	10.0	4.4	6.1	0.83
				23.3	3.9		
	60	17.50	35.6	13.3	7.8	5.0	0.79*
				36.1	2.2		
5	40	15.34	88.2	2.7	0.5		0.96
				7.7	0.9		
	60	17.50	52.1	7.1	5.0	1.2	0.82*
				27.5	2.1		
6	25	2.74	42.7	16.7	7.8	1.1	0.78
				25.0	6.7		
	40	3.46	52.2	18.4	3.3	1.1	0.84
				13.9	10.0	1.1	
	60	4.25	41.7	25.0	4.4	2.2	0.79
				11.1	13.9	1.7	
7	25	6.19	40.6	7.3	4.4	4.4	0.81
				39.4	3.9		
	40	7.70	51.1	20.0	2.8	4.5	0.84
				18.3	3.3		
	60	9.65	42.2	8.9	8.9	4.4	0.79
				26.1	8.9	0.6	
8	25	6.12	50.9	14.1	3.6	1.4	0.83
				19.1	10.0	0.9	
	40	7.63	62.3	13.2	2.3	1.8	0.87
				14.1	5.9	0.4	
	60	9.36	68.2	13.2	1.4	2.3	0.89
				7.7	7.2		
9	25	11.66	28.3	15.0	5.0	10.6	0.70
				22.2	17.8	1.1	
	40	14.11	31.1	15.0	8.3	7.8	0.72*
				20.0	17.8		
	60	16.49	45.6	14.4	5.6	3.9	0.81*
				24.4	6.1		
10	20	10.51	33.4	16.7	6.7	5.0	0.75
				24.4	13.3	0.5	
	40	15.19	56.3	5.4	2.9	7.9	0.83
				21.7	5.4	0.4	
	60	19.01	67.0	5.3	5.0	7.7	0.85
				9.7	4.0	1.3	

* Nozzles operated at pressures higher or lower than recommended by the manufacturer.

PETE VERMEULEN: We use a nozzle which you call Flora-mist and in testing them with cups as you have done, we find that the deflectors gradually wear out and give us too much water in certain areas. We buy the deflectors separately and replace them periodically. I also recall that Harvey Templeton plated the deflectors with a hard metal and this negated the wear from the constant force of the water against it.

LEN STOLTZ: How do some of you growers set the anvil height on nozzles which have an adjustable anvil?

DAVE BARKER: I use feeler-gauge but I don't recall what the setting is.

VOICE: After the mist system turns off, there will be a droplet of water hanging from the anvil; I turn the anvil down until the surface tension just releases the droplet.

VOICE: We adjust the anvil up and down to get the largest, continuous sheet of water before it begins to break into droplets, but we also use higher pressures than recommended.

PROPAGATION IN A HUMID CHAMBER

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A humid environment around cuttings is an essential requirement of propagation to prevent wilting. Humidity of air increases when exposed to warmer wet surfaces. The moist surfaces of leaves and the propagation medium serve to humidify the surrounding air during cool cloudy weather but are inadequate under hot, windy or sunny conditions. The amount of evaporative surface can be greatly increased by dispersing water droplets in the air. The surface of each droplet becomes an evaporative surface while air-borne or after impingement on another surface. The evaporative surface is greatest when the droplets are sufficiently small to remain air-borne and hence are defined as fog. The use of fog to maintain high relative humidity was tried and reported by Stoutemyer in 1942 (1). The heat accumulating in the enclosed humid atmosphere during midsummer led to shading which, in turn, led to the use of non-solar lighting (2). The consequential stagnant environment encouraged fungal growth resulting in an unpopular conception of high humidity propagation and it was nearly forgotten until 3 years ago. At that time, the concept was conceived of using supplemental humidification to cool as well as humidify through controlled ventilation.

MATERIALS AND METHODS

Cooling as well as humidifying the air around cuttings requires an exchange of air within the humid chamber. Humidifying without cooling involves the suspension of sufficient moisture in the air to restore 100% relative humidity (RH) as solar radiation heats and expands the air but the small amount of evaporation required to restore the humidity is insufficient for cooling the air. Increasing evaporation enough for cooling requires taking in ambient air which has a lower RH. During humidification of this ambient air, evaporation lowers its temperature sufficiently so that it can withstand solar heating without becoming too hot for cuttings. By suspending additional fog in the air, it remains at 100% RH during solar heating and expansion of the air as in a non-cooled high humidity chamber. The hot air is exhausted while taking in ambient air which helps to remove heat that otherwise would accumulate until dissipated more slowly through the walls of the enclosure. The rate of air flow must not exceed the humidification capacity of the fog generating units and this capacity must be adequate to maintain suitably low temperatures during the hottest weather anticipated throughout propagation.

Two types of fog generators were used, the centrifugal humidifier and the syphon nozzle*. The centrifugal humidifier was installed to draw ambient air through the humidifier and exhaust it intermixed with fog at the level of the cuttings. The heated fog rose and was forced through a vent at the highest point in the enclosure. This type of humidification and ventilation system was used in a 2.4 × 3.6 m quonset with a height of 2 m. The syphon nozzles were installed just above the cuttings to encourage air circulation among the cuttings. The above enclosure and two enclosed ground beds (of 0.6 m and 1.2 m width) were also operated with syphon nozzles. The quonset was vented with a thermostatically controlled fan. The wider of the two bed enclosures was vented with a 2 cm opening along the entire length of each side of the enclosure at 0.6 m height. The narrower bed enclosure was vented through a 15% shade cloth covering the end farthest from two terminally positioned nozzles. Syphon nozzles were also placed in front of a continuously operating intake fan which mixed the air with fog at the ratio of 30 ppm water v/v. The freshly humidified air was directed across the cuttings in the previously described quonset enclosure and the hot air was vented at the roof gable. Fogging equipment was operated only during daylight hours and was installed to distribute between 5 and 10 liters of water as fog per 10 m^2 of propagation area. The enclosed beds were not shaded except the larger one by a building and several tall trees during the late afternoon. the quonset was located in a fiberglass greenhouse transmitting 50% light and later removed and covered by 80% shading over the upper 50% of its periphery.

The temperature was measured in the quonset by a Honeywell multipoint temperature recorder and checked daily with a mercury thermometer. The humidity was measured with a sling psychrometer. At least 25 cuttings were propagated of 30 species either for determining their ability to root under this system or to acquire plants for other research. Performance of the ventilated high humidity chamber for propagation was measured in terms of temperature control and ability to propagate cuttings.

RESULTS

Droplet size and their distribution was found to be important to successful propagation with this system. Large droplets

* Delevan manufacturing Co. 811 Fourth St. West Des Moines Iowa 50265. The low pressure (15PSI), low volume (0.3 gal/hr) nozzle was used but should not be interpreted that other nozzles of similar specifications could not be used.

maintained the humidity below 100%. Whenever visible fog was suspended in the air, the humidity was measured to be 100%. Circulation of the cooler humidified air among the cuttings was necessary to prevent the humidity among the cuttings from dropping below 100% and scorching the foliage. The best circulation was maintained by mixing the fog with the incoming air stream. The force of the fog leaving the syphon nozzles was sufficient if the nozzles were carefully positioned to distribute the fog equally over the cuttings and the vents were adequate for removing the hot air without allowing excess cross ventilation from exterior wind currents.

Measurements of the temperature within the enclosures showed that temperatures above 46°C caused leaf scorch. The temperature was maintained below 38°C in each enclosure except on extremely hot humid days which did not seem to adversely affect the rooting of most cuttings. The ambient air temperature during the 2 weeks following Aug. 29 ranged between 20 and 35°C. The temperature of the propagation medium and the humidified air in the quonset enclosure are shown in Figure 1. Fluctuations of the temperature from the line of least squares is the consequence of variations in the daily humidity. The temperature of the propagation medium was warmer than the humidified air indicating that the propagation medium is the site of solar heat conversion. Circulation of the cooler humid air carried this heat into the current of exhausted air.

Root initiation of cuttings occurred within 2 to 4 weeks for most species and cuttings that were slower to root remained in good condition for much longer periods of time (Table 1). Additional shoot growth and the maintenance of healthy erected positioned leaves without the loss of natural luster was common among cuttings. Decline of cuttings followed any deterioration in operation of the system that resulted in low humidity or high temperature stress. Cuttings that were permitted to wilt or were stored for prolonged periods of time in preparation for propagation also declined rapidly. Larger cuttings than are customarily rooted under mist were easily rooted and when transplanted, adjusted rapidly to the natural environment.

DISCUSSION

The former view that humidified enclosures do not work well during mid-summer for propagation is no longer valid. The temperature within such enclosures can be controlled at acceptable and even beneficial levels through controlled ventilation. The temperature in non-ventilated sun exposed enclosures is always higher than the ambient air temperature and can reach 46°C during mid-summer. With ventilation and humidification the temperature can be reduced to lower and safer levels

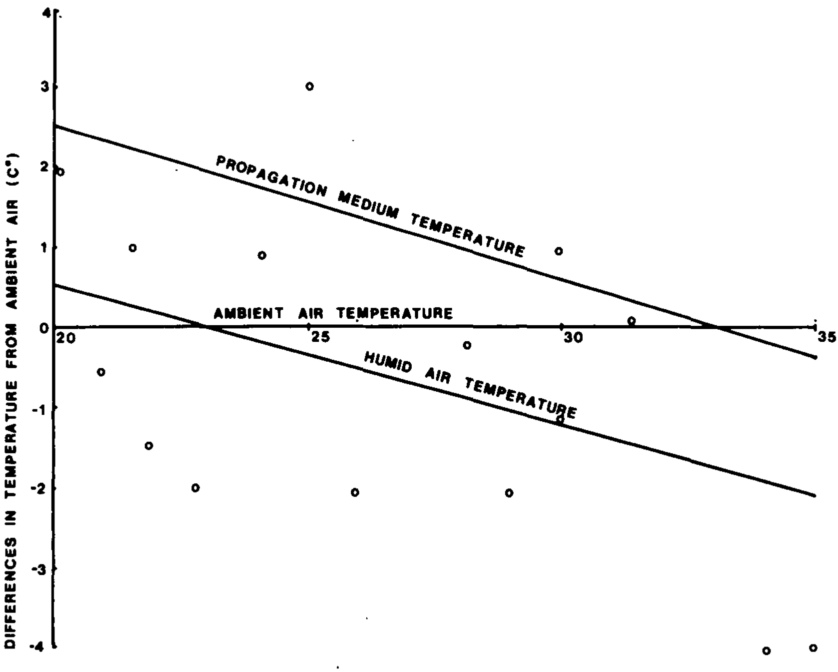

Figure 1. Temperatures of the propagation medium and enclosed air in relation to ambient air temperatures. Lines determined by the least squares method with deviation of individual temperatures being primarily due to differences in ambient air relative humidity.

Table 1. Percent rooting of cuttings under high humidity conditions.

Name	Percent Rooting	Name	Percent Rooting
Arundo donax	70	*Juniperus horizontalis* 'Wiltonii'	70
Betula nigra	100	*Juniperus procumbens* 'Nana'	43
Buxus sempervirens	100	*Lagerstroemia indica*	64
Camellia japonica	80	*Ligustrum lucidum*	100
Carissa grandiflora	90	*Malpighia coccigera*	95
Catharanthus roseus (syn. *Vinca rosea*)	60	*Pieris japonica*	73
Cotoneaster dammeri	83	*Potentilla fruitcosa*	90
Euphorbia pulcherrima	--*	*Prunus tomentosa*	--
Gordonia lasianthus	100	*Pyracantha coccinea*	87
Hydrangea macrophylla	100	*Pyrus calleryana*	60
Hypericum × 'Hidcote'	95	*Rhododendron* cultivars	--
Ilex aquifolium, 'Aureo-marginata'	--	*Salix matsudana* 'Tortuosa'	100
Ilex cornuta 'Burfordi'	--	*Taxus cuspidata*	--
Ilex crenata 'Helleri'	90	*Viburnum tinus*	75
Ilex × *attenuata* 'Foster No. 2'	90	*Vitis rotundifolia*	90

* Percent rooting not recorded.

for propagation. The capacity to cool is greatest during sunny days when heating and air expansion is greatest and greatly reduced when solar heating is reduced by cloudy weather. This moderating effect is most evident on the propagation medium which as a consequence, remains for extended durations within the temperature range considered beneficial for stimulating early root initiation of cuttings. The temperature factor which was formerly considered to be a disadvantage of this system has become beneficial in the ventilated high humidity propagation system.

The moderating effect of this system is also due to the interaction of naturally occurring factors and evaporative cooling. During the night hours, the air cools to the dew point (100% RH). As the air expands with rising temperatures of the early daylight hours, the humidity drops. If the temperature remains cool with its associated high level of humidity, evaporative cooling remains relatively inefficient and the temperature within the enclosure rises from solar radiation converted to heat. As the temperature rises. ambient air humidity drops and the greater capacity for evaporative cooling more efficiently removes the heat produces within the enclosure. Unlike misting, evaporative cooling in the enclosure does not reduce the temperature at the surface of the leaf or the propagation medium below that of the surrounding air. Therefore, the effects of bottom heating occur as a consequence of this type of cooling.

Night time dew point humidity was also used advantageously. While the fogging units were not operating, the air became stagnant in the enclosure and similar to Stoutemeyers system, water mold, *Pythium* sp., invaded the cuttings. This invasion was first controlled by weekly applications of fungicides such as daconyl, captan and benomyl but was later controlled more efficiently with ventilation. Opening the enclosure at sunset had no detrimental effect except on windy nights and effectively controlled the water mold. On the unit with forced air intake, the fan was operated continuously with equal results but without the need for windy night vigilance. While Stoutemeyer associated fungal problems with low light intensities and shading, our experiences indicate that they are due to inadequate ventilation and shading is an efficient means of assisting in temperature control during mid-summer.

This system of propagation has been used successfully in a variety of structures. Humidified enclosures have functioned within a greenhouse or fully exposed to the weather with success. While the experimental enclosures covered 10 m^2 or less in area, they varied in shape from a tunnel-like covering for a narrow bed to a nearly square quonset. The methods of ventilation were also varied. Its installation on a larger scale should also be successful if humidification and ventilation equipment is proportionately increased but this has not been done yet. In all installations, as with mist, successful operation is dependent on adequate and reliable equipment.

Propagation under this system produces a high quality rooted cutting. The roots are initiated and grown in a propagation medium that receives and looses very little water during propagation. While typical propagation media made from vermiculite, sand, peat and perlite were used in much of this research, growing media were also used which contained large proportions of field soil, leaf mold and well composted sawdust. The propagation medium appeared to be much less important to the success of rooting than has been observed for mist. In an extreme situation, individual cuttings developed root systems that thoroughly permeated 6 to 8 liters of medium before removal from the enclosure.

Because cuttings decline in vigor very slowly (unsuccessfully rooted cuttings have been maintained for 9 months before discarding), the leaves of large leafed cuttings were not trimmed and cutting sizes were increased from the customary 8 to 15 cm to 16 to 30 cm to obtain more mature foliage on rapidly growing new shoots of stock plants. When rooted, these cuttings quickly recovered from transplanting and continued vigorous growth. As with mist, cuttings of some species and cultivars were difficult or impossible to root under this system. The range of plants propagated easily under this system is expected to include most but not all plants now propagated under mist and a portion of those plants known to be difficult to root under mist including many of those which are native to dry climates.

In addition to propagation of cuttings, the ventilated high humidity system may be used for other purposes. It has been used successfully to maintain plants in a turgid condition that were field bare rooted during late summer and transplanted to containers. The recovered plants as well as rooted camellia cuttings were free of mineral deposits common from mist and were salable without developing new foliage. It should work equally well for B&B stock. It has been used with very good success for annealing both dormant and non-dormant grafts and for germination of seeds including fern spores. It also has the potential of providing the specific environment for adjusting tissue culture explants to natural conditions.

Three years of research has greatly improved the almost completely abandoned high humidity system of propagation for summer propagation. While it appears to have promise as a valuable addition to nurseries, it needs considerable research to validate these findings in other areas with different weather conditions and to adapt equipment for large scale commercial operation.

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2. Stoutemyer, V.T. 1946. Rooting and germinating seeds under fluorescent and cold cathode lighting. *Proc. Amer. Soc. Hort. Sci.* 48:309-325.

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DAN MILBOCKER: I doubt there would be an advantage to cooling it; in fact, there may be an advantage to heating it, because the cooler the water, the more energy it takes to make a fog droplet.

PROPAGATION OF *ARALIA ELATA* 'VARIEGATA'

JOERG LEISS

Sheridan Nurseries Ltd.
Oakville, Ontario

The white variegated form of the Japanese angelica tree, a plant of the genus Araliacea to which belong *Hedera* and *Acanthopanax*, is a most exotic looking plant that thrives under difficulties that would tax most other plants. City conditions, sun, shade, or drought prove no obstacle.

We obtained our first two plants from a Belgian nursery approximately twelve years ago. The price at that time was $7.50. When we lost one of the two, the cost per plant was well over $20.00. However, during the second season of growth, large double compound leaves more than one inch long, edged on each of the more than 150 leaflets with a creamy white, was worth any price.

PROPAGATION

After a thorough search of the literature, suggestions for root cuttings, grafting on established understocks or seeding were found. Since the plant was not on its own roots, root cuttings were out. Seeding showed that only green plants germinated; that left grafting. This was tried but proved unsuccessful because of a gumlike substance that seemed to prevent healing. Another problem arose because of the fact that scion material was between 3 and 4 cm thick and understocks of such proporconditions and to adapt equipment for large scale commercial operation.

LITERATURE CITED

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Oakville, Ontario

The white variegated form of the Japanese angelica tree, a plant of the genus Araliacea to which belong *Hedera* and *Acanthopanax*, is a most exotic looking plant that thrives under difficulties that would tax most other plants. City conditions, sun, shade, or drought prove no obstacle.

We obtained our first two plants from a Belgian nursery approximately twelve years ago. The price at that time was $7.50. When we lost one of the two, the cost per plant was well over $20.00. However, during the second season of growth, large double compound leaves more than one inch long, edged on each of the more than 150 leaflets with a creamy white, was worth any price.

PROPAGATION

After a thorough search of the literature, suggestions for root cuttings, grafting on established understocks or seeding were found. Since the plant was not on its own roots, root cuttings were out. Seeding showed that only green plants germinated; that left grafting. This was tried but proved unsuccessful because of a gumlike substance that seemed to prevent healing. Another problem arose because of the fact that scion material was between 3 and 4 cm thick and understocks of such proportions were hard to find. Also one scion had the potential of only one plant.

At this time, Dr. H.B. Howard of the East Malling Experiment Station described patch budding as a method of propagation for understocks that did not slip easily. This seemed to be the method for us to try. Patch budding not only would give us much more propagation material, but also we could use smaller understocks in a dormant condition. Our hunch proved correct. Plants knitted before the latexlike sap prevented healing. Understocks of *Aralia elata* are produced by seed, root cuttings and divisions.

Seed. Seed being the most obvious, it is produced on the terminal shoots in September; flowering occurs in August. The flower is a broad panicle, each flower producing a small, bluish fruit that contains two seeds. The seed is flat, oblong and measures 3 × 1 × 1 mm. Fall seeded, it produces a small plant of 20 cm height and of 10 to 15 mm stem diameter during the first summer. Germination usually does not exceed 5%. Seed is not expensive to collect and clean, and is an economical way to produce understocks.

Root cuttings. This method is probably the most common one used: 10 to 12 cm long by 8 to 10 mm diameter root pieces, or larger, will produce a 15 to 20 cm plant during one growing season. Roots are collected in the fall and made up during the winter. They are spring planted vertically into a warm sandy soil, 3 to 5 cm below ground level and kept moist.

Division. Division of plants and natural root suckers presents another way to produce instant understock.

PRODUCTION

Suitable understocks produced by any of the means described above are selected during the fall and stored in sawdust, frost free. Understocks are 15 to 20 mm thick with a good root system.

Scion wood is collected in February during a frost free period and only well ripened 1 year old wood is cut. Stem diameter is not too important as only the buds are used. The understocks are brought into the work room, roots shortened to about 5 cm and cleaned. The top is reduced to 15 cm.

A patch bud is prepared for the scion material and placed onto the understock. We use a straight 3 mm deep cut from above the bud starting about 1 cm above to 12 cm below the bud, cutting it off with a short, blunt cut. The identical patch is cut out of the understock, and the bud patch is substituted for the bark piece. We use rubber budding strips and wax all cuts with grafting wax. Grafted material is placed in a box with sawdust in the greenhouse at 15°C and kept moderately moist. The understock will show suckering within 2 to 3 weeks after grafting and the plants are then potted up into a light, well drained soil in 6″ pots. Shoot development during the first season seldom exceeds 3 to 6 cm. Success is between 10 and 60% for patch budding. Winter protection is advisable for the first winter.

In the following spring, the grafted plants are planted out into beds and usually 30 cm shoots develop. Wild shoots have to be removed periodically. When transplanting again, the plant is planted below the bud union and this prevents suckering of the understock best. The ultimate would be to have a variegated plant on its own roots. At present only a variegated seedling would accomplish this and production costs would be very cheap as root cuttings could be used. The plant, in our experience, is virtually insect and disease proof and hardy to Zone III.

MANIPULATION OF HERBICIDES AND EFFECT OF HERBICIDES ON ROOTING

BRUCE A. BRIGGS

Briggs Nursery
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Abstract. Ten herbicides were applied on *Cotoneaster dammeri* 'Lofast' in 1 gal containers in three different concentrations from low to medium to high ranges. While some of the low rates did tend to promote rooting and some of the excess rates did retard rooting, in general the normal dosages of herbicides which are adequate for weed control, showed little effect on the rooting of cuttings taken from the treated plants. The timing, condition of the wood, wounding and hormone treatment appear to be more critical factors than the normal rate of herbicide applied to the treated plants.

A second research project was set up to determine what properties the active herbicide would have on root formation when applied to the base of the cutting in a liquid solution. Eight different herbicides were applied to the base as a 5 sec dip in strengths of 5, 100 and 1000 ppm. The cuttings were then suspended through black poly and placed to grow under controlled conditions. They were observed and evaluated as to the effect on callus, root formation and hormonal reaction. While callus was slightly increased on some and decreased on others, no significant pattern developed. No attempt was made to correlate callus with rooting. In general, no hormonal reaction was observed that produces increased number or shorter roots.

The results of these two projects on *Cotoneaster dammeri* 'Lofast' seem to support other literature from former IPPS meetings, that a normal application of the herbicides tested to a stock plant, does not greatly affect the rooting ability of cuttings subsequently taken from that plant.

As many of our nurserymen have questioned the advisability of continued and repeated applications of herbicides on stock plants, the subject has come up several times in the past literature of the IPPS. In the early 1960's, Myhre (7) made refer-sawdust in the greenhouse at 15°C and kept moderately moist. The understock will show suckering within 2 to 3 weeks after grafting and the plants are then potted up into a light, well drained soil in 6" pots. Shoot development during the first season seldom exceeds 3 to 6 cm. Success is between 10 and 60% for patch budding. Winter protection is advisable for the first winter.

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As many of our nurserymen have questioned the advisability of continued and repeated applications of herbicides on stock plants, the subject has come up several times in the past literature of the IPPS. In the early 1960's, Myhre (7) made reference to taking cuttings from treated plants without much inhibitory effect. George Ryan, who succeeded Myhre, propagated most of his plant materials from herbicide-treated stock blocks with no apparent damage to the rooting of the cuttings. Ticknor (8,9) gave data showing that plants in his treated blocks were not materially affected in rooting capabilities when the herbicides were applied at normal rates, with some chemicals even enhancing the rooting. Andy Sherwood, now retired, but once a large grower of lining out stock in Oregon, was one of the first nurserymen in the West to use Simazine in very heavy applications. He applied up to 8 lb/A actual, to his stock blocks, with repetitions over a number of years. His records show that, even with visible damage to the large conifers in the stock block, there was no noticeable effect to the rooting of cuttings. Ahrens (1,2) and McGuire (5,6) report about the same results with some variations, depending upon time of application, cultivar or plant, and kind of herbicide.

MATERIALS AND METHODS

Cotoneaster dammeri 'Lofast' was chosen because it is easily rooted and we have research data about its hormonal reactions (4). In both projects, cuttings were taken from plants direct rooted in 1 gal cans and growing in a plastic covered pipe house.

In Project I the stock plants were treated with ten different herbicides, at three strengths. Two weeks later, cuttings were taken from the new growth tips. No wounding was done and no hormones were applied. The cuttings were inserted through black poly and allowed to root in air, (3) so that we could observe the callus and root formation.

RESULTS OF PROJECT I

Table 1 shows results taken after observation of about 6 weeks. This test was set up in September, and rooting was a little slower than it would have been earlier in the summer. Some treatments did increase callus and roots, while others reduced both callus and rooting. Simazine and Casoron acted as promoters at a low rate, while Ronstar stimulated rooting only at a high rate. Chloro IPC at mid to high rates was the most restrictive to rooting. The rate that callus and roots formed was not entirely consistent, but would not have been noticeable had the cuttings been put into soil under normal procedures. In general, the normal dosages of herbicides which are adequate for weed control, showed little effect on the rooting of cuttings taken from the treated plants.

Table 1. Effect on rooting of granular herbicides applied to *Cotoneaster dammeri* 'Lofast' in 1 gallon cans.

Herbicide	Rate lbs/A		
Simazine 5G	1 *	2	4
Casoron 4G	2 *	4	4
Ronstar 2G	2	4	6*
Goal 2G	1 *	2	4
Lasso 15G	3	6	9
Dymid 5G	2.5	5	10
Surflan 5G	3	6	9**
Devrinol 5G	2	4	6**
Lasso 8G + Simazine 2G	3	6	9**
Chloro IPC 10G	3	6**	12**

* = Improved rooting
** = Retarded rooting

MATERIALS AND METHODS PROJECT II

The cuttings used in Project II were taken from the same block of untreated *Cotoneaster dammeri* 'Lofast' in gallon cans as in Project I. They were taken from new growth tips in September, treated with eight different herbicides in liquid dips of 5 sec and inserted through black poly as in Project I for observation. Wettable powders of the herbicides listed in Table 2 were dissolved in water to 1000, 100, and 5 ppm. This gave us eight herbicides at three strengths to test.

Table 2. Effect on rooting of wettable powder herbicides applied to *Cotoneaster dammeri* 'Lofast'.

Herbicide	Rate in ppm 5	100	1000
Tenoran 50W	+	+	0*
Casoran 50W	0	0*	+*
Dacthal 75W	0	0	+*
Simazine 80W	0*	0*	0*
Kerb 50W	0	0	0
Atrazine 80W	0	0	–
Surflan 75W	0**	0	–*
2, 4-D Lithate	0	–*	–*

\+ = Increased rooting   * = Retarded callus
– = Retarded rooting   ** = Increased callus

RESULTS OF PROJECT II

No startling effects were observed as you can see in Table 2. We were looking for hormonal effects; no hormone producing fewer roots in a greater length of time; and higher concentrations of hormone showing reduced time for root initiation with more and shorter root growth. Little effect from herbicide application was observed. The lack of decisive effect of Lithate might be due to the fact that it tends to react better in combination with other hormones like IBA and the rate of application is very critical. The Lithate did tend to retard callus at the medium to high rates, but had no noticeable effect on rooting at the low rate. Tenoran was the only one that increased rooting at the low rates.

DISCUSSION

While the above research indicates little apparent direct effect of herbicides on rooting, we must be aware of possible indirect effects from use in combination with other chemicals (10) or under different physical conditions. Each new herbicide should be checked out and information kept to evaluate its impact on different crops in different locations.

Simazine can cause plants to temporarily stop growth, causing the wood to harden faster. By reducing the length of time we can take prime cutting wood, it might consequently reduce the number of plants we would root successfully. This is noticeable in plants such as *Rhododendron* 'Jean Marie du Montague', which is more difficult to root than some others on hard wood in hot weather. Some plants may be inhibited by a normal application of simazine because it temporarily closes the stomates.

Casoran applied with nitrogen sulphate in hot weather may cause herbicide burn on leaves. Atrazine can be converted to nitrogen by some conifers in our area. The Christmas tree industry uses this to advantage getting the fringe benefit of a better, brighter color along with the weed control.

Many chemicals are used in growing plants to maturity; other chemicals are applied to the cuttings taken from mature plants. More information is needed to be able to manipulate the use of herbicides to the best advantage as related to the rooting of cuttings.

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CAPILLARY IRRIGATION OF CONTAINER PLANTS[1]

EDWARD AUGER, CHARLES ZAFONTE and J.J. McGUIRE[2]

Abstract. Selected cultivars of rhododendrons and azaleas were grown in two container media under capillary and overhead irrigation and under five fertilizer regimes. Of the fertilizers incorporated into the container media at manufacturer's recommended rates, Osmocote 14-14-14 produced the best overall growth. The capillary system using the Chapin twin walled tubes on a sand base produced growth comparable to that obtained with conventional overhead irrigation but with only half as much water used.

Container plant production of nursery crops is of ever-increasing importance to the industry due to rising land values and labor costs in producing field grown (balled and burlapped) stock. It is important because it allows a greater efficiency of production per unit of land. Container plant production offers advantages including: extended sales and planting seasons, development of attractive sales packages, greater transportability, better control of environmental and cultural factors, and more efficient use of labor, production and sales areas (1).

Growing plants in containers, however, presents special problems of watering and fertilizing not experienced in field production. Frequent excessive overhead irrigation, besides being inefficient, can cause severe leaching of nutrients from containers (1). Therefore, the practice of subirrigation, whereby water is absorbed into containers by capillary action from a saturated substrate below, is proposed to provide a more efficient alternative irrigation system.

Subirrigation or capillary irrigation theoretically offers other advantages to the grower for increased plant growth. Capillary irrigation should reduce compaction of the growing

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media providing more pore space for better aeration of the mix. It should provide more efficient fertilizer usage by eliminating losses due to leaching. It should decrease the incidence of leafspot diseases because foliage remains dry during irrigation, and finally, by eliminating water stress at any time during the growing season there should be a resultant increase of higher quality plants.

Since water is the most important and limiting factor in the production of container grown nursery stock (2), rising municipal costs for water and recent water shortage occurrences have caused growers to reevaluate their irrigation techniques. The possibility of tremendous water losses from overhead irrigation is no longer acceptable. Furthermore, the environmental concern of lake and stream pollution by runoff water from agricultural land carrying excess plant nutrients may be reduced. Eventually, the fertilizer applied overhead which is not absorbed by plants is carried away in runoff water into lakes and streams where eutrophication may occur.

The development of twin wall trickle irrigation tubes by Chapin Watermatics, Inc. and ViaFlow, an ooze type tube manufactured by DuPont, along with various substrates, or "mats" to hold the water, on which the plant containers are placed, have provided the necessary technology and economy to make this practice feasible.

Two aspects of capillary irrigation are considered in this study. One is the comparison of growth of various rhododendron and azalea cultivars grown under conventional sprinkler irrigation with those grown via capillary irrigation. The other is a comparison of slow release fertilizers incorporated into the potting mix for use in the capillary irrigation system.

MATERIALS AND METHODS

A capillary irrigation system was installed at each of two sites: 1) Forest Hills Nurseries, Inc., Exeter Road, Slocum, R.I. and 2) The Rhode Island Agricultural Experiment Station, East Farm, Kingston, R.I. Conditions were not equal at both sites. Plants at site #1 were grown in a plastic covered greenhouse (30 × 200 ft) with one side open for ventilation. These plants were not exposed to drying winds and they received no rainfall. The plants at this site were closedly spaced so containers were touching. Plants at site #2 were uncovered, in full sun and were spaced 8-12" apart. These plants were exposed to summer rainfall.

The capillary system at both sites was installed by placing approximately 1" of sand on a continuous film of black plastic (1.5 ml). The sand was slightly less than 1" at site #2. Water was applied to this surface through twin walled Chapin trickle irrigation tubes 8 ml (4 × 24 hole spacing) placed 4 ft apart and running the entire length of the growing surface (30 × 100 ft). The tubes were connected to a 3/4" PVC header which was connected to a 3/4" solenoid valve and an electric clock.

Frequency of irrigation was regulated so that the sand was always saturated but no run-off occurred. At site #1 this required 30 min applications approximately 4 hours apart during the day. At site #2 it required four applications of 45 minutes each applied during the day. No water was applied at night.

Plants used in the experiments were all one year old liners of rhododendron or azaleas. Azaleas were planted in 1 gal containers and the rhododendron were planted in 2 gal or 8" containers. Fifteen plants of each cultivar were used for each treatment. These were arranged in three replicates of five samples each.

Fertilizer Comparison Experiment. This experiment was conducted at site #1. All plants were grown in one container medium consisting of 2 parts shredded softwood bark, 1 part coarse sand and 1 part sphagnum peatmoss. Cultivars of rhododendron used were: 'Chionoides', 'English Roseum', 'Mrs. Peter den Ouden', and 'P.J.M.'. Cultivars of azaleas used were: 'Hershey's Red', and 'Mother's Day'.

The slow release fertilizers were incorporated into the medium at the manufacturer's recommended rate. They were: Osmocote 14-14-14 12 lbs/cu yd, Osmocote 18-6-12 13 lbs/cu yd, Mag Amp w/K 7-40-6 12 lbs/cu yd, and ProGrow 31-5-3 3 lbs/cu yd. An overhead irrigation application of liquid fertilizer of Peters 20-20-20 was used as a control at the rate of 200 ppm NO_3 applied twice each week.

Linear growth of plant tops was measured on July 1st and October 1st. Rootball weight and diameters were measured in late October, 1977.

Comparison of Irrigation Methods. This experiment was carried out at both sides. Plants contained only Osmocote fertilizer. Rhododendron plants were treated with Osmocote 18-6-12 (13 lbs/cu yd) and azaleas were treated with Osmocote 14-14-14 (12 lbs/cu yd) incorporated into the medium as before.

Treatments were:

1. Capillary irrigation on sand, medium with Osmocote.
2. Overhead irrigation with water, medium with Osmocote.
3. Overhead irrigation with water alternated with water and 20-20-20 at 200 ppm NO_3 (the control).

Plants used in the experiment were from two sources so two container media were used:

Medium #1 contained 2 parts shredded softwood bark, 1 part coarse sand, 1 part sphagnum peatmoss.

Medium #2 contained equal parts of sphagnum peat moss coarse, sand, and coarse perlite.

Perlite in medium #1 were *Rhododendron* 'Boule de Neige', *R.* 'Scintillation', and *R.* 'Nova Zembla'. Azaleas were: *Rhododendron* 'Firedance', *R.* 'Stewartsonian', and *R. obtusum* var. kaempferi. The plants grown in medium #2 were *Rhododendron* 'Mrs. Peter den Ouden', *R.* 'Nova Zembla', and *R.* 'English Roseum'; and the azaleas: *Rhododendron* 'Rosebud', *R.* 'Hinocrimson', and *R.* 'Kaempo'. All cultivars were represented at both sites and there were 15 plants of each cultivar in each treatment.

Linear growth was measured on July 1 and October 1, 1977. Dry weight of rootballs and rootball diameter was measured October 31, 1977. A water meter was installed at site #1. The exact volume of water used in each type of irrigation was measured. Plants were observed periodically for foliage color and general appearance.

RESULTS

The results of the fertilizer comparison experiment are summarized in Table 1. Of the slow release fertilizers tested, Osmocote 14-14-14 yielded the greatest total average increase in plant growth designated as "Fertilizer Effect". This was followed by Osmocote 18-6-12, ProGrow and Mag Amp, respectively. However, the best top growth was found with the Peters liquid fertilizer. When observing rootballs and recording their weights an interesting correlation is noted (Table 4). Osmocote 14-14-14 consistently stimulated greater root growth than any of the other treatments including the conventional overhead with Peters liquid fertilizer. The Osmocote 18-6-12 yielded about the same response as the Peters and both ProGrow and Mag Amp showed less root growth.

In the comparison of irrigation methods (Tables 2 and 3) the plants grown by the capillary watering system at site #1 did considerably better than those grown via the same system at site #2. With the rhododendron cultivars, total growth at site #1 under capillary irrigation matched that of the overhead controls (Table 2). A similar response was observed with the azalea cultivars (Table 3). The capillary irrigation system at site #2 and the overhead irrigation with slow release fertilizer incorporated, generally, were not as efficient in stimulating growth.

Of significance, however, is the efficiency of water usage. On the average, the amount of water used by capillary irrigation

Table 1. Effect of four granular slow release fertilizers on the growth of rhododendron and azalea cultivars grown in containers watered by capillary irrigation.

	Control[a] Peters 20-20-20			Osmocote[b] 14-14-14			Osmocote[b] 18-6-12			ProGrow[b] 31-5-3			MagAmp[b] 7-40-6		
	Increase in average heights in inches for 15 samples															
Rhododendron Cultivar	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.
'Chionoides'	4.5	11.5	7	4.5	9	4.5	5.5	8.5	3	5	10	5	4.5	9	4 5
'English Roseum'	7.5	17	9.5	8	18.5	10.5	7.5	13.5	6	7.5	14.5	7	6.5	13	6.5
'Mrs. Peter den Ouden'	5	9	4	5	9	4	6.5	10	3.5	4.5	7	3.5	5.5	9	3.5
'Hershey Red' azalea	3	7	4	3	5.5	2.5	3	5.5	2.5	3	5	2	3	5	3
'Mother's Day' azalea	4	8	4	4	6	2	4	6	2	4	5	1	4	5.5	1 5
'P.J.M.'	3	8.5	5.5	3	7	4	3	9	6	3	7.5	4.5	3	5.5	2.5
Fertilizer Effect[c]			34			27.5			23			22.5			20.5

[a] Liquid feed through overhead irrigation sprinklers.
[b] Applied according to manufacturer's recommendations.
[c] Sum of increase due to each treatment over all cultivars used.

Table 2. Effect of capillary irrigation on growth of rhododendron cultivars with Osmocote 18-6-12 incorporated into the potting mix.

		Capillary Site 1			Capillary Site 2			Overhead Site 2			Control Peters 20-20-20 Site 1 & 2		
Rhododendron Cultivar		July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.
'Mrs. Peter den Ouden'	a	12.5	13	0.5	13.5	14.5	1	15	17.5	2.5	13	15	2
'Nova Zembla'	a	15	19.5	4.5	15.5	19	3.5	15.5	18	2.5	15.5	21	5.5
'English Roseum'	a	15	22.5	7.5	18.5	21	2.5	17.5	19	1.5	18	19	1
'Boule de Neige'	b	9	11	2	6.5	9.5	3	9.5	9.5	---	8	10	2
'Scintillation'	b	9.5	13	3.5	6	8	2	7.5	7.5	1	7	8	1
'Nova Zembla'	b			21			15			10			21
Total				21			15			10			21

[a] 1 sand:1 peat:1 perlite mix
[b] 2 bark:1 sand:1 peat mix
[c] Sum of increases due to each treatment over all cultivars used.

at Forest Hills Nursery was 2,300 gal/week, but for an equal area and amount of plants, the overhead sprinkler irrigation required over 5,000 gal/week. Therefore, even if significant differences in plant growth were not achieved by capillary irrigation, a substantial saving of water was realized for equal plant production.

DISCUSSION

The results indicate that capillary irrigation may be feasible for container plant production. Increased water costs and recent water shortages have made it necessary to be more efficient in container plant production. Some problems connected with the system still remain to be worked out. One of the biggest appears to be fertility. Generally the plants growing with an incorporated slow release fertilizer could not compare in color to plants which received liquid applications. Some cultivars showed chlorosis more than others and in some cases it was quite severe. Possibly a periodic liquid overhead application may be necessary to maintain the quality of the plants.

Table 3. Effect of capillary irrigation on the grown of azalea cultivars with Osmocote 14-14-14 incorporated into the potting mix.

		Capillary Site 1			Capillary Site 2			Overhead Site 2			Control Peters 20-20-20 Site 1 & 2		
		Increased Average Height (in.)											
Rhododendron (Azalea) Cultivar		July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.	July 1	Oct. 1	Inc.
'Rosebud'	a	5	10.5	5 5	5	6.5	1.5	5	8.5	3.5	5	13	8
'Hino Crimson'	a	4	10.5	6.5	4	6	2	4	7.5	3.5	4	8.5	4.5
'Kaempo'	a	4	6	2	4	5	1	4	5	1	4	8	4
'Firedance'	b	3	10.5	6.5	3	7.5	4.5	3	7. 5	4.5	3	10	7
'Stewartsonian'	b	3	12	9	3	8	5	3	7.5	4.5	3	10	7.5
'*R. obtusatum* var. kaempferi	b	3	11.5	8.5	3	8	5	3	7.5	5.5	3	10.5	7.5
Irrigation Effect	c		38			19			21				40
Total Irrigation Effect	d		59			34			31				61

[a] 1 sand:1 peat:1 perlite mix.
[b] 2 bark:1 sand:1 peat mix.
[c] Sum of increases due to each treatment over all cultivars tested.
[d] Irrigation effect for azaleas plus that for rhododendrons (Table 2).

Table 4. Comparison of dry root weights of rhododendron and azalea cultivars as affected by four granular slow release fertilizers watered by capillary irrigation and Peters 20-20-20 applied by overhead irrigation.

	Overhead Irrigation	Capillary Irrigation			
	Peters 20-20-20	Osmocote 14-14-14	Osmocote 18-6-12	ProGrow 31-5-3	Mag Amp 7-40-6
Rhododendron Cultivar	Weight (grams)				
'Mrs. Peter den Ouden'	259	487	207	320	199
'Chionoides'	770	1089	780	861	119
'P.J.M.'	171	235	153	10	64
'Mother's Day' azalea	117	428	139	65	43
'Hershey Red' azalea	236	518	141	66	143

There also exists the problem of location for the capillary irrigation system. A covered or partially covered plastic house gave greater water efficiency, but whether a deeper layer of sand or close spacing of containers in the open area would increase efficiency remains to be shown. There was obviously more leaching of the medium in the unprotected site due to rain.

The frequency and duration of irrigation has to be worked out for each situation, but an essential fact remains: the containers must never be allowed to dry out since this breaks the capillary water film that allows water to be continuously drawn into the container from the saturated substrate. Along with this, it should be noted that the containers should be thoroughly watered initially to establish the capillary channels. The system should be monitored periodically to make sure it is operating properly.

The type of plant material to be grown with this capillary irrigation system should also be considered. In these experiments, rhododendron cultivars, which have a fibrous root system, were used which did not root out of the containers. Plant materials such as junipers or deciduous shrubs might not be recommended for growing on this system because they form roots more likely to grow out of the container and into the substrate.

SUMMARY

Capillary irrigation proved effective in meeting the water requirements of 1 and 2 gal container rhododendron and azalea plants. Comparable, if not increased growth was realized with capillary irrigation as opposed to conventional overhead irrigation. Since capillary irrigation required less than half the amount of water applied by overhead sprinklers, this literally translates into substantial reduction in water usage with little or no surface runoff.

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2. McGuire, J.J. 1972. *Growing ornamental plants in containers; a handbook for the nurseryman. Univ. Rhode Island, Coop. Ext. Ser. Bul. 197.*

VOICE: Did you find root growth in the bottom inch of the can?

EDDIE AUGER: No, the growth was fairly uniform throughout the can. The secret is to keep the mat damp not water logged.

JOERG LEISS: If the Osmocote is incorporated into the growing medium for the first year, how are you going to fertilize the plants the second year?

EDDIE AUGER: We will probably have to rely on overhead liquid feeding or possibly adding it to the capillary system. We won't be able to top dress because the surface of the medium stays dry which is an advantage in that it restricts the growth of weeds to a great extent.

CHARLIE PARKERSON: How soon after you added the fertilizer to your mix were the plants canned and irrigation started? Some of these materials are pretty hot.

EDDIE AUGER: These were mixed into the medium as we were canning them.

ANN MOLES: In some work done at North Carolina State University using different levels of Osmocote we found that with subirrigation the growth at half the manufacturers recommendation was far better. I was wondering what rate you used?

EDDIE AUGER: We used the manufacturer's recommendation for all the material.

MIKE DODGE: One of the problems in using mats is the buildup of algae, did you have any problem with this?

EDDIE AUGER: Algae didn't seem to be a problem and of course can to can there is little chance of it to build up.

MINIATURE ROSES BY OASIS ROOTCUBES

RICK R. ALLRED

Spring Hill Nurseries Company, Inc.
Tipp City, Ohio 45371

CUTTING PREPARATION AND STICKING

We start by taking 4 to 5 inch cuttings directly below a node using hand clippers. For convenience we use Clorox sterilized 2 gal buckets, which are used by our mail-order picking department, for collection of cuttings. While collecting cuttings, we try to keep them shaded and cooled with water to maintain turgidity. The average cutting is medium soft with six nodes and approximately 5 inches in length depending on cultivar. We find that we have a greater percentage of rooting and much less disease problems if we cut out the soft tip growth. Leaving two nodes with leaflets, we strip the rest of the cuttings and put them in bundles of 50. We have found it critical that the cuttings be cut within 1/8″ below the node, for if more of the stem is left below the node a larger percentage of cuttings are lost due to rotting off. The cuttings are dipped in a quick-dip solution of: 10 grains of IBA (K salt), 20 cc isopropyl alcohol and 1 gal water. The cuttings are now prepared to stick.

To prepare the Oasis Rootcubes, a sterilized plastic shallow flat which measures 1-1/2″ × 11″ × 21″ is filled with 1″ of potting mixture which consists of 1/2 #7030 Choice Mix, 1/4 #2 won't be able to top dress because the surface of the medium stays dry which is an advantage in that it restricts the growth of weeds to a great extent.

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To prepare the Oasis Rootcubes, a sterilized plastic shallow flat which measures 1-1/2″ × 11″ × 21″ is filled with 1″ of potting mixture which consists of 1/2 #7030 Choice Mix, 1/4 #2 vermiculite and 1/4 Canadian peatmoss. This is the same consistency of mix these cuttings will be potted in 21 days from sticking. I feel this is an important detail; the cuttings will root down into the mix that they will later be grown in, giving us a much stronger, vigorously growing cutting to pot off. Also, with the use of soil in the flats, when the production schedule lags, these cuttings have the same mixture to feed on as they will be potted in and will not reach a nutrient deficient stage until they can be potted.

The block of cubes is laid on the soil and watered in; in the process we sterilize and fertilize the cube by injecting at 200 ppm Banrot, Peters 20-20-20 and Sequestrene 330 FE, with Aqua Gro wetting agent, which cuts our time in half wetting the cubes. By following this procedure at the time of sticking, our percentage of rooted cuttings is much higher with more uniform, stronger root development and with minimal disease problems. When using the 3/4" cube, care must be taken as to depth the cutting is stuck. We have had best results by sticking the cutting 2/3 of the way through the cube. Cuttings that are stuck too deep tend to rot off. We have also found that an application of 4 oz. of Osmocote (19-6-12) per flat at the time of sticking will save 4 to 7 days in the rooting process. Contrary to literature printed on mist cycles with the use of Oasis, I have found on typical rooting months of May, June and July, days when the temperature can reach the 90's, we can set our 10 sec, 15 min clock to run from 9:00 a.m. to 5:00 p.m. without injury from wilting. In general I have found the least amount of excess moisture on the foliage, the more enhanced the rooting process and naturally less disease problems. Obviously we alter the mist cycle on cloudy days, usually misting only twice a day. Depending on the cultivar the time from a cutting to salable plant ranges from 7 to 11 weeks.

We prefer to use the 3/4" rootcubes eliminating the root breakage which occurs when sticking four cuttings in 1-1/2" rootcubes. We do not actually need the depth of the 1-1/2" cube because we just want to use the Oasis as a rooting medium and then get roots down into the soil, which will result in much stronger growing cuttings.

Rootcubes are sterile and safe to use as received from the manufacturer, but if exposed for a period of time must be sterilized before a reuse. Oasis Rootcubes contain very small amounts of fertilizer that will supply a minimum fertilization during the rooting period, thus the reason for the application of Osmocote (19-6-12) at time of sticking.

POTTING

Rootcubes should not be potted below normal growing depth. When this was done we had as high as 40% loss in transplanting due to cuttings rotting off. Keep the cutting and Oasis cube up out of the pot and let the soil filter in around the roots, with the top half of the cube exposed when finished. This procedure gives 95 to 100% transplant success. We also run all of our transplanted cuttings in a shaded house for 10 days after being potted.

We are producing 31 cultivars of miniature roses at Spring Hill, 16 of which are for our mailorder catalog. We have four main growing houses for miniatures and one propagation house.

INSECTS AND DISEASE PROBLEMS

While working under Mr. Geid Stroombeck, he taught me to have a keen eye for problems as they arise and to find prompt, correct solutions to those problems. One of the main insect problems of miniature roses is the two-spotted spider mite. To control spider mites we use several insecticides some of which are Omite, nicotine, Pentac, Kelthane, Plictran, Orthene, and Temik.

One of the main disease problems of miniature roses is powderly mildew, which thrives when the air is saturated with moisture. One of the best devices we have used to help control powdery mildew is the sulfur burner, which operates by a 60 watt light bulb inside a canister, which vaporizes the sulfur. I don't profess to have complete control of powder mildew, but fungicides I have seen used are Karathane, Pipron, Benlate, Phaltan and Acti-dione. In my opinion Pipron is the best to eradicate the problem and Benlate sprayed regularly to keep it in check.

PROGRAMMED OVERWINTERING FOR SPRING CUTTINGS

From mid-November to mid-December we strip all the leaves off our miniatures and trim them back about 2/3 to get a well-branched plant about 6 inches high with no foliage and no debris in the pots. From December 15 to March 1, the miniatures will be kept at 35 to 40°F. Starting on March 1 we raise the temperature to 50°F the first week, to 55°F the second and 65°F the third week.

Fertilization with Osmocote (19-6-12) at 2 lbs/1000 sq ft provides supplemental feed for the plant roots during the dormant period. On the fourth week of February we fertilize at 200 ppm using Peters 9-45-15 along with some iron chelate. This in combination with the Osmocote and rising temperatures in

March gives us the highest quality and quantity of disease free cuttings that I have seen on any single crop anywhere.

CONTROL OF DISEASE PROBLEMS AS IT RELATES TO PLANT PROPAGATION

C.C. POWELL, JR.

Department of Plant Pathology
The Ohio State University
Columbus, Ohio 43210

Control of all diseases relates to propagation. Propagation is where general nursery disease control programs begin. Programmed, i.e. successful, plant disease management is based on propagation of only healthy plant material in an environment free of disease.

Achieving an environment free of disease is the same as saying controlling diseases during propagation. Active disease at this stage of the game means we will lose cuttings or seedlings. Disease means we will lose control of crop management and rooting or seed germination programs. Finally, disease means that we will be producing a certain amount of lower quality material that may actually be infected already. This infected material will be impossible to adequately program later on. It may eventually die after you've invested time, space, and money into it!

DISEASE AND THE PROPAGATION ENVIRONMENT

Why does disease sometimes become active during propagation? It is because the environmental conditions inherent in propagation programs tend to favor the spread and survival of pathogens. These are warm, humid situations in whch water is sometimes splashed about. The key to the control of propagation diseases rests in part in altering these conditions. For instance, misting programs that allow the foliage to dry by nightfall would be a good idea for botrytis control. Moving seedling flats or changing the environment to cooler, drier situations as soon as seeds emerge will help control damping off. Spacing or removing foliage of cuttings in flats to allow more air movement will aid in disease control. The rooting medium can also affect the percent rooting of cuttings of several woody plants. Changing the rooting medium can change the pathogen environment.

REDUCING PLANT STRESS TO CONTROL DISEASE

Cuttings without roots are highly stressed plants. That is, they are subject to invasion by organisms that would, in the

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REDUCING PLANT STRESS TO CONTROL DISEASE

Cuttings without roots are highly stressed plants. That is, they are subject to invasion by organisms that would, in the forest, invade and rot sticks in or on the ground. It is our job to prevent this natural process from occurring. Environments that reduce stress on the plants will help achieve propagation disease control. Table 1 indicates the effect of temperature on rooting percent. You can get too hot or too cold, and this will vary for different plant types. However, there are temperatures that will result in optimum rooting and a minimum of disease. The mechanism here is probably that of reducing stress on the host.

Table 1. Effect of medium temperature on rooting of evergreen cuttings.

Plant and Medium Temperature	Rooting Percentages
Taxus × *media* 'Hicksii'	
80°F	30
75	63
70	86.5
65	92
Juniperus chinensis 'Pfitzeriana Hills Blue'	
80	19
75	21
70	31
65	6
Buxus microphylla var *koreana* 'Wintergreen'	
80	67
75	73
70	70
65	49

FUNGICIDES AND THE CONTROL OF PROPAGATION DISEASES

It has been my experience that chemicals will provide little disease control without attention to anti-pathogen and pro-host chemicals! Table 2 shows some results of fungicide drenches on rooting of *Prunus*. In many cases, the fungicides were worse than nothing at all! Why was this? I can think of two reasons. First, the environment in this experiment was not well controlled and failure to control stress was dominant in causing disease. Second, fungicides may often be involved in damaging plant material producing even more stress.

This damage to plant material from drench fungicides has been studied by us in more detail with seed and seedling systems. We first got into this when evaluating materials for damping off control. You can increase seedling stands by providing fungicidal drench protection. However, we often see a decrease in plant height. Thus, we are dealing with fungicide toxicity to the seeds or seedlings. The toxicity seems to be slowing the rate of growth of seedlings as well as lowering the percent seed germination. For instance, Captan slows rate of germination (growth rate) as well as percent germination of tomato seed as dose rate is increased. We have found that this phenomenon is relatively widespread. It can occur with several of our soil drenched chemicals. Many plants can be affected, but not necessarily all. For instance, Benlate treatment of seeds of eight different bedding plants produced severe stunting on two, mild stunting on four, and no effect on two. The phytotoxic effect is cumulative to an undetermined degree as well. Snapdragons were more severely stunted when given two applications of fungicidal drenches (at seeding and at transplanting) as opposed to just one.

Table 2. Effects of fungicide drenches on the rooting of softwood cuttings of three Prunus species. Drenched at 2 weeks and 6 weeks from sticking.

Plant and Treatment	Rooting Percentages (Out of 300/Treatment)
Prunus 'Halle Jollivette'	
Control	62
Benlate/Truban	47
Dithane M-45	74.5
Captan	81
Prunus cerasifera 'Newport'	
Control	11.5
Benlate/Truban	7
Dithane M-45	3
Captan	16
Prunus glandulos 'Rosea'	
Control	96
Benlate/Truban	73
Dithane M-45	56.6
Captan	94

CONCLUSIONS

Fungicides can provide useful protection against diseases in propagation. However, they must be used with caution. More important controls to these diseases involve environmental manipulations that favor rapid seed germination or rooting of cuttings by reducing stress on the plant material. Further, sanitation and environmental changes that work against pathogen survival and spread are quite basic to controlling diseases in propagation.

PROPAGATION OF *KALMIA LATIFOLIA* BY CUTTINGS

ALFRED J. FORDHAM

Weston Nurseries, Inc.
Hopkinton, Massachusetts 01748

During the Quesion Box Session at last year's IPPS meeting, the subject of *Kalmia latifolia* (mountain laurel) propagation by cuttings was discussed. While at the Arnold Arboretum, I worked on propagation of *Kalmia* by cuttings and have prepared a table showing the outcome of that effort. It gives data drenched chemicals. Many plants can be affected, but not necessarily all. For instance, Benlate treatment of seeds of eight different bedding plants produced severe stunting on two, mild stunting on four, and no effect on two. The phytotoxic effect is cumulative to an undetermined degree as well. Snapdragons were more severely stunted when given two applications of fungicidal drenches (at seeding and at transplanting) as opposed to just one.

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Many cultivars of *Kalmia latifolia* have been selected as natural variants either in the wild or from nursery rows. Oddly enough, *K. latifolia* 'Rubra', one of the first cultivars of this native American plant to appear in the records of the Arnold Arboretum, came from the English nursery firm of Veitch and Son in 1886. From native sources, the Arboretum received such *Kalmia latifolia* cultivars as 'Obtusata' (1886), 'Polypetala' (1870), and 'Myrtifolia' (1885).

Despite the fact that good garden forms were first described more than a century ago, few are carried in nursery lists. This can be explained by the fact that they were considered difficult to propagate from cuttings.

In the early 1940's, Edmund Mezitt of Weston Nurseries became interested in mountain laurel selections, particularly those with deep red buds, pink flowers, etc. Plants of similar kind were planted side by side to insure cross pollination. Seeds of these were sown and plants grown on for further selection. This program has led to some spectacular clones. I am now associated with Weston Nurseries and one of my involvements will be an effort to put these into commercial production.

POLYETHYLENE CHAMBERS

Much of the mountain laurel propagation was carried out in polyethylene chambers which have some distinct advantages. Nutrients do not leach from the cuttings as can happen under mist. The chambers are carefree and can be left for long periods of time without attention. There is little chance of loss through human or mechanical failure. Many subjects normally considered difficult can be rooted in high percentages.

The chambers were constructed on benches with side walls about 5 inches high. They were first lined with 2 mil polyethylene film. Bottom heat was provided by heating cables, so about 1 inch of medium was placed in the bench and cables were installed at that level. To disperse the heat more evenly, 1/2 inch galvanized hardware cloth was placed in contact with the cable. The bench was then filled with medium consisting of equal parts of horticultural grade Perlite and sphagnum peat moss. Welded joint wire of 2 by 4 inch mesh was shaped to form supporting frames which hold the 2 mil plastic covering about 8 or 10 inches above the rooting medium. Bottom heat was maintained at about 75°F.

CUTTING PREPARATION

Mountain laurel cuttings are made from the current year's growth and can be taken as soon as the growth ripens. The stems are cut to a uniform length, (any leaves that would be below the rooting medium are removed) and they are wounded so they will produce well distributed root systems. This is accomplished by slicing two silvers of rind downward for a distance of 1 to 1-1/2 inches on opposite sides at the base of the cutting. This procedure removes physical barriers to root emergence and exposes more surface to the action of root inducing substances. Wounding both sides of the cutting is important to prevent a lopsided root ball. Mountain laurel roots slowly, usually taking from 4 to 6 months.

ROOT INDUCING MATERIALS

Some of the most effective treatments in our previous experiences were 5-sec dips using IBA plus NAA at various strengths or treatment with 2,4,5 TP powder formulations. Because of clonal variation, there were instances where IBA plus NAA was superior, while in other cases, 2,4,5 TP proved better. In the course of our current work at Weston Nurseries, a number of formulations are being tested. When sufficient propagating wood is available, we use as many as eight treatments.

We are grateful to the Research Department, Agricultural Chemicals Division, Amchem Products, Inc., Ambler, Pennsylvania, for providing the experimental materials being used. The "quickdip" preparations are diluted from concentrated solutions while the 2,4,5 TP formulations were in talc.

MOUNTAIN LAUREL SELECTIONS

In the Boston area, mountain laurel blooms about June 1st and its course of flowering is longer than that of most woody plants. The span between bud opening and flower drop covers about 3 weeks. Flowers of red budded forms and those with banded corollas tend to flower later and to persist for greater periods. At Weston Nurseries, there are several mountain laurel blocks from which selections are made. Those thought to have merit are moved to an areas where they can undergo further observation. In order that evaluations be uniform, only one person is involved in making judgments. During the last few years Wayne Mezitt has undertaken this responsibility.

IMPORTANCE OF CHARACTERISTICS OTHER THAN FLOWERS

In seedling populations of mountain laurel, one finds plants with widely varying characteristics. Some with special horticultural merit display bright red, yellow or orange stems which on many plants are contrasted against dark-green leaves. One particularly striking specimen is characterized by compact growth habit, red stems and dark green leaves with red midribs. Some of these beautiful features are prominent throughout most of the year and therefore should receive special consideration when selections are being made.

PROPAGATION OF *KALMIA LATIFOLIA* BY CUTTINGS

Taxa	Time Taken	Number of Cuttings	Treatment	Rooting Percentage	Evaluation of Roots	Remarks
'Rubra'	3 Mar 66	10	IBA — 1% 5-second dip	100	Excellent	Plants of same clonal line forced in greenhouse — wood very firm — under polyethylene
'Rubra'	3 Mar 66	10	IBA — 2% 5-second dip	90	Excellent	Plants of same clonal line forced in greenhouse — wood very firm — under polyethylene
'Rubra'	3 Mar 66	10	IBA — NAA 500 ppm ea. 5-second dip	100	Excellent	Plants of same clonal line forced in greenhouse — wood very firm — under polyethylene
'Rubra'	3 Mar 66	10	IBA — NAA 1,000 ppm ea. powder	100	Excellent	Plants of same clonal line forced in greenhouse — wood very firm — under polyethylene
'Rubra'	3 Mar 66	10	245 TP 5,000 ppm powder	90	Excellent	Plants of same clonal line forced in greenhouse — wood very firm — under polyethylene
'Rubra'	30 Mar 67	10	245 TP 1,000 ppm powder	90	Excellent	From 1-year old rooted cuttings in greenhouse — wood starting to firm — under polyethylene
'Rubra'	30 Mar 67	10	245 TP 1,000 ppm powder	30	Fair to Good	Wood as above — placed under mist; leached badly
'Rubra'	30 Mar 67	10	IBA — NAA 1,000 ppm ea. 5-second dip	90	Excellent	Wood as above — placed under polyethylene
'Rubra'	30 Mar 67	10	IBA — NAA 1,000 ppm ea. 5-second dip	50	Fair	Wood as above — placed under mist; leached badly
'Rubra'	4 Aug 66	6	245 TP 5,000 ppm powder	83	Excellent	Cuttings from 8-year old plant in nursery row — under polyethylene
'Rubra'	23 Jan 67	22	IBA — NAA 5,000 ppm ea. 5-sec dip	91	Excellent	Cuttings from 9-year old dormant plants in cold storage unit — all same clone — under polyethylene
'Rubra'	23 Jan 67	22	245 TP 1,000 ppm powder	86	Excellent	Cuttings from 9-year old dormant plnts in cold storage unit — all same clone — under polyethylene

Taxa	Time Taken	Number of Cuttings	Treatment	Rooting Percentage	Evaluation of Roots	Remarks
'Rubra'	20 Dec 67	93	245 TP 1,000 ppm powder	91	Excellent	Cuttings from 22-month old rooted cuttings in nurser row — under polyethylene
Selection	27 Aug 70	15	245 TP 1,000 ppm powder	73	Excellent	From large plant, Beverly, Massachusetts — darker than normal foliage — under polyethylene
Selection	27 Aug 70	15	IBA — NAA 2,500 ppm ea. 5-second dip	100	Excellent	From large plant, Beverly, Massachusetts — darker than normal foliage — under polyethylene
'Rubra'	4 Aug 66	6	.8% IBA — Thiram powder	50	2 Good 1 Excel.	From 7-year old plant in nursery — under polyethylene
'Rubra'	4 Aug 66	6	none — control for above	66	Excellent	As above
Compact form	29 Nov 68	6	245 TP 5,000 ppm powder	100	Excellent	From plant in nursery — under polyethylene
'Rubra'	20 Dec 67	30	245 TP 1,000 ppm powder	87	Excellent	From older plant in nursery — under polyethylene
'Rubra'	20 Dec 67	30	IBA — NAA 5,000 ppm ea. 5-second dip	84	Excellent	As above
Selection	17 Dec 74	12	.8% IBA — w/Thiram powder	100	Excellent	From older plant in nursery — under polyethylene
'Fuscata'	28 Jun 67	11	245 TP 1,000 ppm powder	82	Excellent	Under mist — later removed to under plastic because of leaching
'Fuscata'	28 Jun 67	11	245 TP 5,000 ppm ea. powder	100	Excellent	Under mist — later removed to under plastic because of leaching
'Fuscata'	28 Jun 67	11	IBA — NAA 2,500 ppm ea. 5-second dip	100	Excellent	Under mist — later removed to under plastic because of leaching
'Fuscata'	28 Jun 67	11	IBA — NAA 2,500 ppm ea. 5-second dip	82	Excellent	Under mist — later removed to under plastic because of leaching
'Polypetala'	20 Dec 67	12	non	50	Excellent	Taken from very old plant received at Arnold Arboretum 1885 — under polyethylene
'Polypetala'	20 Dec 67	12	IBA — NAA 2,500 ppm ea. 5-second dip	80	Excellent	As above
'Polypetala'	20 Dec 67	12	245 TP 1,000 ppm powder	66	Excellent	As above
'Silver Dollar'	17 Dec 74	8	.8% IBA — w/Thiram 15% powder	100	Excellent	From 2-foot grafted plant — under polyethylene

Thursday Morning, December 8, 1977

The Thursday morning session convened at 8:30 a.m. with Kathleen Freeland serving as moderator.

DEEP PIT STORAGE OF NEWLY PROPAGATED PLANTS

CASE HOOGENDOORN

Hoogendoorn Nurseries, Inc.
Newport, Rhode Island 02840

A couple of years ago we showed a few pictures of a deep frame we were building 6 ft in the ground. It was referred to as a "hole in the ground" at that time. Since then we have been able to come up with a suitable name, "Deep pit storage for newly propagated plants".

The deep pit storage is now completed and during 2 years of operation we have been able to work out the bugs that have cropped up and it is now working to our satisfaction. The purpose of the deep pit storage is to prevent the splitting of more sensitive cuttings and grafts, yet allowing the plants to receive a little frost to get the proper dormancy. On the ground where the plants are stored we maintain a temperature of 28°F. During the first winter the storage was in use, the temperature outside was 14°F and the temperature at the base of the pit, where the plants were stored, was also 14°F, which led us to believe that the whole project was a disaster. The blue hydrangea cuttings were as black as coal; when rubbed they were like mush. The plants started to show fungal growth so Victor kept spraying with fungicides. The people from the College advised us to throw the hydrangeas away to prevent the fungus from spreading throughout the pit. At this point I was disgusted and lost interest in them, so I just left them where they were. We were afraid that the cuttings and grafts were split even if we could not see it at the time. The spraying continued. When spring arrived, the plants started to grow, even the blue hydrangeas, right out of their terminal buds. I can attest that miracles do happen even though this was one of our mild winters. However, the experience was too close for comfort. At this point, I remembered a lecture given by G. Stroombeek a few years ago with reference to a blanket of heat in a poly storage house. It sounded like a good idea and I decided to try it out. We purchased a heater, overhead poly tube, thermostats, oil tank, etc., etc. to carry out our plans. This past winter was one of the most severe we have had for many years, which put the deep pit storage to a real test. We now know that it works and are glad to relate our experiences to you.

The pit is 16 ft wide inside, 100 ft long, 6 ft deep and it is 11 ft from the floor to the ridge. The roof is constructed of 4 × 10 ft Filon sheets. The walls are 1 ft thick with 5/8 inch steel reinforcing rod set on a 2 ft wide footing. A 3 ft fan set in one end provides ventilation when needed.

EDITOR'S NOTE: Mr. Hoogendoorn showed slides of how the plant materials are placed into the deep pit storage and what they looked like when removed. Plant materials which have been over-wintered in the deep pit are grafts of *Viburnum carlesii* 'Compactum', *Hamamelis* × *intermedia* 'Arnold Promise', *Cedrus atlantica* 'Glauca', *Cedrus atlantica* 'Glauca Pendula', *Cornus florida* 'Rubra', *Cornus kousa* var. *chinensis*, *Cornus* 'Rochester', *Magnolia* 'Balleriniana', and cuttings of *Acer griseum*, *Hydrangea* macrophylla 'Nikko Blue' and *Pyrus calleryana* 'Bradford'.

CLAY BERG: When do you take your 'Bradford' pear cuttings and how do you treat them?

CASE HOOGENDOORN: We take them in early July and treat them with Hormex #30 and stick them in sand.

NEW AND NOVEL COLD HARDY RHODODENDRONS

DAVID G. LEACH

North Madison, Ohio 44057

I've done a lot of work for the handicapped — the nurserymen. You fellows who sell rhododendrons are a unique industry dealing in living antiques. My colleagues and I have been producing 1977 style rhododendrons for cold climates, and I'm here to persuade you to give up your horticultural Stanley Steamers for new Buicks, whether they come from my production line or somebody else's. Nearly all of the rhododendrons you are selling were introduced in England just as our Civil War was ending 110 years ago. They were designed for spacious estates and large gardens, for mansions and three-story Victorian houses. They were intended to be grafted, and to bloom only within a 10-day period at the end of May. They were not produced for American growing conditions. All told, they're about as well suited for the last quarter of the 20th century as the spinning wheel is for the production of nylon. Times have changed.

I joined the Plant Propagators' Society either the year it was founded, or the year after, because I was then doing some experiments with rhododendron propagation. I have continued my membership through the years but in some ways I feel like an illegitimate son at a family reunion. It seems to me that nurserymen are busily grinding out the great gray world of 1984 whereas the industry professes to be dedicated to the amenity of the living environment, to the addition of a varied grace and

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Most consumers today are urban, or suburban, and they live in a house with a standard lot 60 × 150 ft. A couple gets married, buys a house in a development, plants one of the old hardy rhododendron hybrids and by the time their children have graduated from college, they have a plant that covers most of their back yard. Today, a couple with a new home could plant 'Rangoon'. It's hardy, grows happily in a container and having been bred from dwarf species, will never get more than about 4 ft tall. The original seedling from the cross stands about 3 ft after 23 years. 'Small Wonder' is another dwarf which blooms at a different season. It flowered fully after −20°F. All of the new hybrids I will discuss have been through $-35°F$ in the mountains of western Pennsylvania, and are bud hardy to $-15°$ to $-20°F$. Both 'Rangoon' and 'Small Wonder' make good, solid mounds of attractive foliage throughout the year.

The old rhodendron hybrid called 'Catawbiense Album' was introduced by Anthony Waterer in 1865. He gave it a Latin name because that was a sign of education and erudition at the time. There's nothing very much wrong with this rhododendron, except that it never entered Waterer's head to test it for easy rooting, and a lot of propagators have trouble with it. Waterer did not care how quickly it made up into a salable plant. When planted into the average small garden today, it will quickly grow out of scale. For the same planting purposes, a modern rhododendron hybrid called 'Swansdown' is noticeably superior and has larger flowers. It roots very readily, is more heavily foliaged, and produces a budded, salable plant more quickly. For large gardens, monumental buildings and parks it is much more profitable to grow, and altogether a better bet, than the 110-year-old 'Catawbiense Album'. Other semi-dwarfs for the small garden would be 'Anna H. Hall', or 'Alaska', a pure white which has the added bonus of an unusual and distinctive foliage providing variety in the landscape.

The all-time best selling pink was introduced 110 years ago and in my judgment is one of the ugliest rhododendrons in flower ever created. It's a dirty pink with a lot of blue in it; the name is 'Roseum Elegans'. True, it roots like a weed, and it grows under all sorts of conditions, and it has a good plant habit, but judged on the quality of its flowers, it's a real dog. It is not even available in milder climates, to the best of my knowledge. As a matter of fact, it's been so overdone in the east that in some areas consumer resistance has developed to it. Well, what are the alternatives? For a bright pink rhododendron, there is 'Bravo', just as hardy, just as free blooming, just as easy to root, just as adaptable, just as densely foliaged, but with a vast improvement in flower color. Tony Shammarello's 'Pinnacle' is ironclad-hardy and a big advance in flower color over 'Roseum Elegans'. The second best-selling pink is probably 'Everestianum', introduced by Anthony Waterer in England in the 1840's. It's a color my grandmother would have called "common", meaning it lacks style and distinctiveness. An alternate from my own breeding, just as hardy and just as easily grown, is 'Bangkok'.

Nurserymen have said for years that men will buy almost any rhododendrons so long as it's red, and they've been selling almost any rhododendron with red flowers. The most popular for the last 20 years or so has been 'Nova Zembla'. One just as hardy is 'Scarlet Blast', another more of a cherry red is named

'Bengal'. Both are of conventional large size. But, to my mind, the wave of the future is typified by 'Singapore', a semi-dwarf scarlet rhododendron which will never get more than about 4 ft tall.

Now let us consider blooming seasons. With the exception of *Rhododendron* 'Boule de Niege', all of the standard hybrids in commerce were bred to flower within about a week at the end of May, and that was because the old Knap Hill Nursery in England which produced them, was subject to frequent late frosts. Our conditions here in America are different. For years the landscape architects have been asking for pink rhododendrons that would bloom early, with the dogwoods and the daffodils. I would think garden center operators and nurserymen would like to have a big splash of color, such as only rhododendrons can give, when spring has newly arrived and gardening interest is approaching its peak. 'Longwood' comes into bloom at this season. This is also the season for the small, scaly leaved rhododendrons, of which the best known are 'Pioneer' and 'P.J.M.' 'Pioneer' loses its leaves in winter when it gets a little older, it is not bud hardy in really cold climates, and its creator, Joe Gable, didn't like its color. An advanced generation descendant of 'Pioneer' is 'Malta'. 'Malta' is a much better, clearer color; in addition, it is sterile so it sets no seeds and therefore covers itself with flowers every spring. It is evergreen throughout the winter, and much more bud-hardy than 'Pioneer'.

'P.J.M.' is hardy as an oak, and it has fine winter foliage which turns purple as it gets colder. But its rose color has a lot of blue in it and I don't imagine Eddie Mezitt would claim it to be the ultimate in flower color. 'Wally' is a Mezitt hybird rhododendron, just as hardy, but the color is a vivacious, clear pink. It has done very well for me, and I think Eddie has made a great improvement over 'P.J.M.' 'Balta' is another Mezitt hybrid at the same season as 'P.J.M.' with white flowers.

How about late-blooming rhododendrons? With one exception, my introducers have disclaimed any interest in rhododendrons that bloom after the first of June. But just maybe they'll turn out to be wrong. We have relatively cheap swimming pools, hibachis and gas-fired grills, reflecting the great American migration to outdoor patios in the summer. It seems reasonable that a market could be developed for color from woody plants to decorate outdoor living areas when the use is so heavy. 'Bali' is one which blooms its head off at the end of June, and 'Summer Snow' which helps to celebrate the Fourth of July.

We don't have any ivories in the trade now. But one I called 'Ivory Tower' is the most free flowering rhododendron I know. This was released a few years ago. But the longer you continue breeding, the greater your resources become for further improvement, and the more rapid the progress becomes. The problem always is, where to draw the line; release the best you have, even though you're reasonably sure that the next several years will produce something better still. A perfect example is one that presently bears the appealing name 66-LL-50. It has a large flower truss and has bloomed fully this past spring after the coldest winter in Cleveland's history. If it holds up well for another 3 or 4 years it will be tested for ease of rooting. If it passes that test, propagation will be limited by the number of cuttings available, so it will take 4 or 5 years to produce 3 stock plants for each of my 6 introducers. These fellows are inclined to be skeptical, so they may delay introduction to see how the hybrid will perform under their nursery conditions. It may be 6 to 8 years before they sell the first plant.

A wild species from Tibet called *Rhododendron wardii* has been my best source of yellow color. It's so tender it is hard to keep it alive even in a cold pit in my area. I began the search for hardy yellows nearly 40 years ago, crossing *R. wardii* with a white *R. catawbiense* from the mountains of North Carolina. The first generation hybrids were pale pink and tender, but the genes for yellow and hardiness had to be there. Now I have a true yellow in combination with hardiness. The color is not as deep as I'd like but the glossy green foliage and good plant habit of *R. wardii* has been recaptured. The testing and propagation of stock plants for the introducers is yet to come. By the time the introducers are satisfied with it and have propagated enough stock to begin selling, 15 years will have passed since the seedling first bloomed in the field. In all 41 years will have passed from the start of the breeding project until the final product is offered for sale. It is almost impossible for a hybridizer to live long enough to see his productions become popular and widely distributed in the trade. The first hybrid I released was bred in the 1930's. Ted Van Veen sells it, as do about 30 other nurseries in the United States, Canada and overseas. It's name is 'Janet Blair', and after 40 years from its first bloom it is still a long way from being widely available at the friendly neighborhood garden center.

But back to the search for yellow-flowered rhododendrons. What's the competition? 'Goldsworth Yellow' has been the only thing that even approaches being yellow. It's more of a pale apricot color, a lanky grower, and it won't keep its buds over winter even in a Zone 6a climate. 'Sahara' is a much better color than 'Goldsworth Yellow'; it is ironclad-hardy, and it makes a dense plant, well furnished with foliage, whereas 'Goldsworth Yellow' does not. 'Peking' is more yellow, but there's a question in my mind whether consumers in the East will accept the loose, informal flower truss as they do on the West Coast and in England. 'Limelight' has the full, firm truss but not with the color saturation of 'Peking'. I'd be interested to know, if the two were side-by-side in bloom in a salesyard whether buyers would go for the deeper yellow or the fuller truss.

'Good Hope' is the best seedling from the breeding project described above. My introducers got it last year. So we're getting closer all the time to the intense yellow color of the tender West Coast hybrids. Yellows and oranges are the hardest to breed in combination with real subzero hardiness, which undoubtedly accounts for their absence from the marketplace. There have been no oranges at all for eastern growers, but there are now some close approaches. I thought I had an orange winner in one I named "Virginia Leach.' It rooted easily and grew vigorously, but 2 years ago I discovered that the leaves of young plants stick straight up in the air when the temperature gets below about 20°F. I had never seen anything like it before and I haven't since. If it happened to most hybrids I would have thought it was a rather funny quirk. But nobody wants a rhododendron with vertical leaves in midwinter, so it had to be discarded. This illustrates the importance of testing over a period of at least 5 years. The most unlikely defects can suddenly appear, and there is no way to anticipate what they might be. Another example is a hybrid I called 'Tahiti'. It propagated routinely for me in a Nearing frame. But when cuttings were put in a bench with mist and bottom heat in a greenhouse, they soon dropped all of their leaves. So I have learned to expect the unexpected in testing new hybrids. 'Poppinjay' is probably the best of the oranges. The leaves twist a bit and some think this is a fault; others don't. Personally, I prefer a smooth leaf which is green and bright.

There are many failures and many disappointments in breeding woody plants. I thought it would be nice if hobbyists had in hardy form something approaching the large leaved species and hybrids grown in mild climates on the West Coast and England. I got pretty close to what I wanted in 'Spellbinder'. I never expected it to have any commercial appeal. It has huge leaves and its appearance is entirely different from any other rhododendron I have ever seen in a cold climate. It bloom very early. Its appearance is so exotic that it probably arouses more comment than any other rhododendron at my hybridizing and trial grounds, whether it's in bloom or out of bloom. But the disappointment is that anything so unusual refuses to root. The stems of cuttings are nearly half an inch in diameter. About one in ten root for me. Others who have tried it with bottom heat have rooted about 25%, and Lanny Pride using some kind of a witches' brew made up for him by a friend, got 50%. The failure to root is just one of many unseen defects that plague the rhododendron breeder.

In recent years there has been at least a small market for truly dwarf rhododendrons, the small leaved kinds that used to be called dooryard or rock garden rhododendrons. These are generally not over 2 ft tall. 'Ramapo', Guy Nearing's hybrid, is the best I know of these, and I see it in nurserymen's lists fairly frequently. A newer hybrid from Nearing is 'Mary Fleming'. It's a blend of yellow and pink, and I've never met anyone who didn't like it. Zone 6a is the limit of its bud hardiness. Ted Van Veen imported 'Pink Drift' from Holland, and it turned out to be much hardier than I expected, but it's a very satisfactory rhododendron in Zone 6a. One of my contributions which I called 'Tow Head' is of about equal hardiness. It lost its buds last spring, for the first time after a winter that converted Zone 6a to about 4b. At times, the chill factor was −70°F.

Finally, how does a hybridizer's workshop differ from a commercial nursery? For one thing, considerable space has to be found for the selections made each year. They have to be moved into an area where they can be watched individually for a few years. I have a woodland, where I plant out the preliminary selections for observation. At an early age, a good many will show foliage or other defects, or limited bud hardiness, so they are dug out and discarded. Plants must prove that they are worth the space they occupy or they are destroyed. Hybrid seedlings, transplanted from flats, are grown for 2 years in ground beds; they're protected the first year, and then they're on their own. From the ground beds they go into the field, under a mulch of wood chips. They're watched for signs of being superior or dinstinctively different from anything in commerce. That is the first basis of selection. They must be better, and they must be different than anything now available. I must have grown about 250,000 seedlings since I first began breeding. The worthless are destroyed and others take their place. A breeder always has in his mind's eye the most sensational rhododendron ever produced, preferably one with red, white and blue flowers which will shoot off skyrockets and play the Star Spangled Banner on the 4th of July.

Thursday Afternoon, December 8, 1977

Dr. Harrison Flint served as moderator for the New Plant Forum.

MODERATOR FLINT: Our first speaker on this portion of the program will be Ray Evision from the GB&I Region.

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RAY EVISON: *Clematis* 'Niobe' is a new large flowered cultivar raised in Poland. It has bright red sepals with yellow anthers. This free flowering cultivar produces its first flowers from the old wood during late May/June and continues to produces flowers on the new growth until the beginning of October.

MODERATOR FLINT: Tom Pinney has two birches he would like to tell us about.

TOM PINNEY: Two new birches which have apparent resistance to bronze birch borer are *Betula platyphylla* var. *japonica*, Japanese white birch and *Betula platyphylla* var. *szechuanica*, Szechuan white birch. The Japanese white birch has flat, light green shiny foliage. It has a medium growth rate with fine twigs which give it a somewhat drooping habit. It has a white bark but the bark is not exfoliating. This birch does not tolerate wet areas very well.

The Szechuan white birch has leaves which are deep green and are more leathery than the Japanese white birch. The leaves are wavey as opposed to flat. It is a vigorous grower which tolerates wet areas very well. The twigs are heavier than the Japanese white birch which gives the plant a more upright habit.

Both of these birches have good apparent resistance to bronze birch borer, excellent white bark and a wide range of adaptability. Dr. Whitcomb has reported that they do well in Oklahoma and they have survived −25°F winters in Wisconsin. Dr. Santamour of the U.S. National Arboretum has confirmed that our seed of *B. platyphylla* var. *japonica* is from "true to name" plants. We are reasonably certain *B. platyphylla* var. *Szechuanica* is also true to name.

MODERATOR FLINT: Ralph Shugert has five plants which he would like to tell you about.

RALPH SHUGERT: *Fontanesia fortunei* is an excellent hedge plant which requires no trimming: good foliage, willow-like, to the ground, very drought resistant and grows in sun or half shade. Ultimate height is 15 ft. Borderline hardy in Zone 4, but took −17°F in Southern Ohio, January, 1977. Hardy and adaptable to the Central Rocky Mountain Region. Tends to be open as a mature shrub so it is important to pick seed from well-shaped parent plants. Best landscape use is anticipated as a trimmed hedge with minimum of one shearing annually.

Rhamnus caroliniana, Carolina buckthorn is also known as Indian cherry. Large shrub or small tree, to 30 ft, with outstanding glossy-green foliage holding well into November. Bright red fruits turning black when ripe. Native of America as far north as Southern Ohio. Foliage holds later in the fall than any *Rhamnus* we have tested.

Pyrus fauriei, Korean pear, is more dwarf, to 30 ft, than any *Pyrus calleryana* selections. Foliage is glossy green, with good fall color, fruit is russet color, twice the size of 'Bradford' pear. Profuse white blossoms cover this variety in early spring. The variety is completely thornless. Our trees are progeny from a specimen at Morton Arboretum.

Lindera angustifolia, an Asian spicebush, is not listed in Rehder's Manual, but was recently identified for us by Arnold Arboretum. Outstanding hedging shrub. Foliage persists over winter with lovely pastel shades of pink and orange in fall. Side branching to ground level. Propagation from seed, or softwood cuttings taken very early. Progeny from our plants are now at the Arnold Arboretum.

Betula maximowicziana, monarch birch, is the largest-leaved of all the birches. Leaves are heart-shaped, up to 6 inches long. Bark color is orange-brown, finally turning greyish-white. The trees shown in the slides are hybrids — *B. maximowicziana* pollinated with an unknown *Betula* species. Resistant to bronze birch borer. Hybrid trees allow the white-bark of one parent, and the bronze birch borer resistance of the other parent.

MODERATOR FLINT: Our next speaker wishes to tell us about some nursery plant introductions from Canada.

NURSERY PLANT INTRODUCTIONS FROM MANITOBA

WILBERT G. RONALD

Agriculture Canada, Research Station
Morden, Manitoba

The Agriculture Canada, Research Station, Morden, Manitoba, is located in Zone 3b of the U.S.D.A. and the Canadian Plant Hardiness Zone maps. To place us geographically, we are located approximately 450 miles northwest of the Minneapolis-St. Paul area, or 70 miles southwest of Winnipeg. Plants introduced by the Morden Station are most useful for the northern great plains and prairie region and colder regions of northeastern U.S.A. and eastern Canada. The following introductions are available for propagation through the Canadian Ornamental Plant Foundation, P.O. Box 725, Durham, Ontairo, NOG, 1R0. Propagators who belong to this organization and pay a small royalty may propagate any COPF introduction.

'Jacan' elm is a 1977 introduction of Japanese elm (*Ulmus japonica* (Rehd.) Sarg.) which holds promise as a replacement for American elm. This new cultivar has a vase-shaped growth form, strong branches and demonstrated tolerance to inoculum

Pyrus fauriei, Korean pear, is more dwarf, to 30 ft, than any *Pyrus calleryana* selections. Foliage is glossy green, with good fall color, fruit is russet color, twice the size of 'Bradford' pear. Profuse white blossoms cover this variety in early spring. The variety is completely thornless. Our trees are progeny from a specimen at Morton Arboretum.

Lindera angustifolia, an Asian spicebush, is not listed in Rehder's Manual, but was recently identified for us by Arnold Arboretum. Outstanding hedging shrub. Foliage persists over winter with lovely pastel shades of pink and orange in fall. Side branching to ground level. Propagation from seed, or softwood cuttings taken very early. Progeny from our plants are now at the Arnold Arboretum.

Betula maximowicziana, monarch birch, is the largest-leaved of all the birches. Leaves are heart-shaped, up to 6 inches long. Bark color is orange-brown, finally turning greyish-white. The trees shown in the slides are hybrids — *B. maximowicziana* pollinated with an unknown *Betula* species. Resistant to bronze birch borer. Hybrid trees allow the white-bark of one parent, and the bronze birch borer resistance of the other parent.

MODERATOR FLINT: Our next speaker wishes to tell us about some nursery plant introductions from Canada.

NURSERY PLANT INTRODUCTIONS FROM MANITOBA

WILBERT G. RONALD

Agriculture Canada, Research Station
Morden, Manitoba

The Agriculture Canada, Research Station, Morden, Manitoba, is located in Zone 3b of the U.S.D.A. and the Canadian Plant Hardiness Zone maps. To place us geographically, we are located approximately 450 miles northwest of the Minneapolis-St. Paul area, or 70 miles southwest of Winnipeg. Plants introduced by the Morden Station are most useful for the northern great plains and prairie region and colder regions of northeastern U.S.A. and eastern Canada. The following introductions are available for propagation through the Canadian Ornamental Plant Foundation, P.O. Box 725, Durham, Ontairo, NOG, 1R0. Propagators who belong to this organization and pay a small royalty may propagate any COPF introduction.

'Jacan' elm is a 1977 introduction of Japanese elm (*Ulmus japonica* (Rehd.) Sarg.) which holds promise as a replacement for American elm. This new cultivar has a vase-shaped growth form, strong branches and demonstrated tolerance to inoculum of the Dutch elm disease fungus. Recommended propagation is by budding or grafting on Siberian elm understock.

'Fallgold' black ash (*Fraxinus nigra* Marsh.) is a seedless (staminate) selection of this native ash species. Black ash gives excellent performance throughout the Canadian prairies; the availability of a seedless cultivar with superior foliage and golden fall color adds new interest in the species. A seedless cultivar of green ash has also been recently introduced by Patmore Nursery Sales of Brandon, Manitoba. The 'Patmore' ash is a good replacement for the less hardy 'Marshall's Seedless' cultivar. Both 'Fallgold' and 'Patmore' ash are propagated by budding on green ash understocks.

'Morden Amorette' is a miniature rose introduction of the Parkland series bred by Dr. H.H. Marshall of the Morden Station. This cultivar combines quality of the floribunda roses with hardiness of the prairie rose. It readily propagates from softwood cuttings resulting in own-rooted plants free of objectionable suckering.

'Walker' caragana is a fine-leafed weeping peashrub (*Caragana arborescens* Lam.) suited to growing as an own-rooted ground cover or as small shrubs when grafted on a standard.

Further information regarding Morden introductions is contained in a recently issued bulletin, "Hardy Fruits and Ornamentals from Morden, Manitoba". Copies of this bulletin can be obtained by writing to the Agriculture Canada Research Station, P.O. Box 3001, Morden, Manitoba, R0G 1J0.

MODERATOR FLINT: Our next speaker needs no introduction to this group and he is going to tell us about a new *Pieris*.

PIERIS FLORIBUNDA AND ITS PROPAGATION

ALFRED J. FORDHAM

Weston Nurseries Inc.
Hopkinton, Massachusetts 01748

Pieris floribunda 'Millstream', was selected from a seedling lot by H. Lincoln Foster of Falls Village, Connecticut. It forms a compact mound which produces an abundance of flowers each year even though the previous year's spent flower heads are not removed. The Arnold Arboretum is the registering authority for *Pieris*, so in 1963 Mr. Foster registered *P.f.* 'Millstream' and also provided an 8 inch layered plant. It has since developed into a compact plant about 18 inches tall and over 5 ft in diameter. It appears that 18 inches will be its ultimate height.

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For observation and possible selection, seeds of *Pieris floribunda* 'Millstream' were sown and a seedling population comprising several hundred plants were raised. However, none showed improvement over the parent plant. *Pieris* seeds have no barriers to germination. When sown in late winter or early spring they will germinate and grow with the lengthening days.

Although other species in the genus *Pieris* root readily from cuttings, *P. floribunda* has been considered difficult or impossible to propagate by cuttings. While at the Arnold Arboretum, I undertook a program of experimental testing and the table which follows shows rooting that resulted from this effort. The cuttings were treated in a manner similar to that used for rhododendrons. They were wounded heavily on opposite sides at their bases and a rooting medium consisting of sphagnum peat moss and horticultural grade perlite in equal parts was used. Bottom heat of 75°F was maintained.

Plant	Time Taken	Treatment	Rooting Percentage	Evaluation of Roots
Pieris floribunda	27 March	.8% IBA w/ Thiram 15%	70	Excellent
P. floribunda	7 July	.8% IBA w/ benomyl at 10%	80	Excellent
P.F. 'Millstream'	14 December	.8% IBA w/ benomyl at 10%	73	Excellent
P.f. 'Millstream'	6 November	2,4,5 TP* at 5,000 ppm	83	Excellent
P.f. 'Millstream'	19 December	.8% IBA w/ thiram 15%	57	Excellent

The lot dated July 7th was placed under mist; all others were propagated under polyethylene plastic.

* 2,4,5 TP = 2,4,5-trichlorophenoxypropionic acid

VARIATION IN SEEDLINGS OF *PIERIS FLORIBUNDA*

Among *Pieris floribunda* seedlings one finds plants with widely varying characteristics. Leaves can differ in shape, size and autumn color while the plants may exhibit a diversity of growth habits. The upright terminal flower panicles vary in structure, size, shape and color of their flower buds. These features are prominent for 9 months of the year and therefore prime consideration should be given them when selections are made. Through the years Edmund and Wayne Mezitt of Weston Nurseries have made selections of such seedlings from nursery rows. Recently further selections were chosen and planted in an area set aside for the observation and evaluation of plants with possible horticultural merit.

HARDINESS OF *PIERIS FLORIBUNDA*

Pieris floribunda is presently undergoing trial in the University of Vermont's hardiness testing program, and during the past 8 years has tolerated temperatures of −30°F at three different locations. Vegetatively propagated selections of *P. floribunda* should therefore make excellent additions in climates where many ornamental plants cannot survive the cold. Also, cultivars propagated from single clones would provide the uniformity that is so often desired in landscape design.

QUESTION BOX

The question box session was convened at 3:30 p.m. with Mr. Ben Davis II and Mr. Ralph Shugert serving as moderators.

MODERATOR SHUGERT: Have any useful fruiting (not just ornamental) cultivars of *Malus* been rooted?

PETE VERMEULEN: Yes, we rooted a number of cultivars several years ago and I believe these were reported in the *Proceedings*. We are not doing it now because we have quit growing the crabs. If the person who posed this question will search through the past literature and especially that of the *Proceedings* I am sure they will find quite a bit of information.

MODERATOR SHUGERT: Charlie Heuser, what compounds can be used for the promotion of adventitious buds on root cuttings?

CHARLIE HEUSER: The three most common materials used are kinetin, benzyl adenine, and 2-IP.

MODERATOR SHUGERT: When cuttings of some deciduous contoneasters are taken late in the season with the foliage still on and green, they root well and quickly under mist, but after hardening off they gradually drop all their leaves and never come back again. What takes place here?

PETE VERMEULEN: This sounds like a question of how they were handled after they were rooted. If they were kept in a warm greenhouse their dormant period would not have been satisfied. If, however, they were put in cold storage they would probably go through the winter and break normally in the spring.

MODERATOR SHUGERT: Are clematis cuttings made of soft, intermediate or harder growth; what is the best hormone, time of year, etc.? Bill Cunningham has reported on this and it is in the *Proceedings*.

RAY EVISON: In England we use juvenile tissue selecting the cuttings where the leaves have just fully formed and before the wood has started to harden up at all. You can use slightly harder wood, but then it takes longer to root and you don't get past 8 years has tolerated temperatures of −30°F at three different locations. Vegetatively propagated selections of *P. floribunda* should therefore make excellent additions in climates where many ornamental plants cannot survive the cold. Also, cultivars propagated from single clones would provide the uniformity that is so often desired in landscape design.

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RAY EVISON: In England we use juvenile tissue selecting the cuttings where the leaves have just fully formed and before the wood has started to harden up at all. You can use slightly harder wood, but then it takes longer to root and you don't get as many roots. We use single noded cuttings, while here in the States I notice that double noded cuttings are used. We treat the cuttings with Seradex #2.

MODERATOR SHUGERT: Is anyone successfully rooting the following *Juniperus chinensis* cultivars: 'Mountbatten', 'Ames', 'Maneyi'? What procedures are used?

JOERG LEISS: We take cuttings of 'Mountbatten' in September and get about 70% rooting, we restick the unrooted ones and get a total of about 90% rooting. As a group the *J. chinensis* cultivars don't respond to bottom heat so it is best to take the cuttings in September and stick them in an unheated greenhouse without bottom heat; if you use bottom heat you just get a lot of callus.

MODERATOR SHUGERT: What is the best way to propagate *Fothergilla gardenii*?

VOICE: I root them by taking softwood cuttings in early summer, treating them with Hormodin #2, and sticking them in peat-perlite under mist.

MODERATOR SHUGERT: How do you root *Acer griseum*?

CASE HOOGENDOORN: If you take cuttings from an old tree practically none of them will root. I bought some 2 year old seedlings and we took cuttings off of them. We take the cuttings about June 26 when they have just about stopped growth. The first year we got about 80 to 90% rooting, but in later years we get 50 to 60%. I think if you can get 50% rooting you are doing very good.

MODERATOR DAVIS: Bruce Briggs' how do you propagate *Acer palmatum?*

BRUCE BRIGGS: From seed. We pick the seed in the fall before it is fully ripe. You can sow the seed immediately or stratify for 60 days, but don't let the seed get dry; either way you should have a good stand in the spring. We don't graft maples anymore; we checked our costs on this and found we were not making any money.

MODERATOR DAVIS: On what understock can *Pinus pumila* be grafted with good success?

DAVE PATERSON: We grafted on *Pinus strobus* with very good success.

MODERATOR DAVIS: When we graft the long needle form of *Pinus pumila* on *Pinus strobus* it takes well as a graft but then dies out for some reason when planted out, particularly in the second year after grafting from an apparent incompatibility. Any ideas?

BRUCE BRIGGS: I'd say you should go back to *Pinus contorta* or *Pinus cortorta* var. *latifolia*, which is the Lodgepole pine. We find that these two are compatible with almost all of the pines and we graft them with no indication of incompatibility.

MODERATOR DAVIS: When grafting spruce and other conifers, what is the accepted timing on cutting back the understock? Is it cut off completely after the scion has callused or is it cut gradually as the scion grows?

CASE HOOGENDOORN: We cut part of it back at the time of grafting and then when they come out of the bench we cut back a little more and when they go into the cool house we cut back the rest of it. We cut them back gradually.

PETE VERMEULEN: Some people cut back at time of grafting, at lifting, and at time of cutting. We cut back only 2 times; we take off about half at the time of grafting and we remove the remainder at the time of transplanting.

MODERATOR DAVIS: What is being done to reduce the adventitious shoot production and basal sprouting of crabapples which is a tremendous maintenance problem in the landscape?

BRIAN HOWARD: Because of the tremendous labor involved in rubbing out the eyes on understocks of crabs there is some work being done now to control this with chemicals; primarily NAA, is being sprayed on the trunks to control suckering.

MODERATOR DAVIS: Would Case Hoogendoorn discuss grafting *Cornus florida* 'Rubra' during the month of September?

CASE HOOGENDOORN: We graft on *Cornus florida* on stocks that were potted the previous spring and the grafts are made in September or during the winter. We cut off the stock about 1 or 1-1/2 inches high and take a scion that has just about stopped growing and graft it in. The grafts are put in a grafting case and covered with sand and they callus very rapidly.

MODERATOR DAVIS: Is successful grafting possible for *Acer griseum* and *Acer micranthum?*

CASE HOOGENDOORN: I tried grafting *Acer griseum* on the green Japanese maple; they callused but they they all died. I tried about a half dozen other understocks but none of them worked. Roger Coggeshall told me that several years ago he tried 26 different understocks and none of them worked.

MODERATOR SHUGERT: Mr. Van Slooten would you describe your hardening-off conditions and are the plants completely dormant when they are planted out?

MARION VAN SLOOTEN: The plants are dormant when they are planted out. We chill them for 6 weeks by dropping the temperature 5°F per week from 70° to 40°F. They are held at the 40°F temperature for 2 months before outplanting.

MODERATOR DAVIS: Would chip budding work if done in winter in place of bench grafting?

BRIAN HOWARD: We hope that it can be used in place of bench grafting and think it is well worth trying. The problem comes in handling them; you have to work out a system of being able to use the knife on them in the bench the next spring to cut them back. For bench chip budding or spring chip budding we use a narrower tie and leave the bud exposed so they can grow through. I didn't point this out in my paper.

MODERATOR DAVIS: How are budders remunerated for their services?

RALPH SHUGERT: In Southern Ohio the piece rate for contract budding is $45 per thousand; the budder gets $23.50 and the tyer gets $21.50.

MODERATOR DAVIS: What is the best time to bud weeping cherry?

JOERG LEISS: We graft rather than bud but I would assume budding could be done in August.

MODERATOR DAVIS: Dale Maronek, can a mycorrhizae population be established and maintained in the root system of a properly fertilized plant?

DALE MARONEK: We found that it is necessary to reduce the fertilizer rate since high fertilizer rate tends to inhibit the growth of the mycorrhizae; this is especially true for high phosphates.

MODERATOR SHUGERT: Plants of *Cornus nuttalli* that I received from the West Coast appear to be grafted on *Cornus florida*; why is *C. florida* used as an understock for propagating clones of *C. nuttalli?*

BRUCE BRIGGS: To get a better root system; it is compatible with *C. florida* which gives a much better root system.

MODERATOR SHUGERT: What is the best way to grow *Euonymus alata* 'Compacta' in cans; mix, fertilizer, etc.?

BILL CURTIS: You have to be very careful when fertilizing in containers, we've experienced fertilizer burning of the roots.

VOICE: We've grown them in cans using Osmocote with 60% bark and 40% sand and had very good results. We've also raised them using Peters 20-19-18 with good results.

MODERATOR SHUGERT: Has anyone had any experienced (good or bad) with the "spaghetti" tube system of automatic watering containerized plant materials?

VOICE: We've had very satisfactory results using the 0.60" × 3 ft Chapin tube system on 3 and 5 gal containers of 18" *Cotoneaster praecox* and *C. apiculata*. We've also used it on several of the dwarf junipers; our losses were about 2%.

MODERATOR SHUGERT: Mr. Van Slooten, in your accelerated growth program did you use a commercially packaged fertilizer or mix your own; do you use micronutrients with each watering, and what ppm of N, P and K do you use? Does this have to be monitored very closely?

MARION VAN SLOOTEN: We use packaged fertilizers and mix our own. As to micronutrients, we use Peters 20-19-18 which, according to the company, has micronutrients in it; they are not listed on the label but the company assures us they are in there. The ppm of N, P and K varies with the species we're growing and, yes, it does have to be monitored very closely.

MODERATOR DAVIS: Has anyone heard of the use of Tobasco sauce as an animal repellant?

FRANK GOUIN: There is a report in HortScience discussing the use of Tobasco sauce to keep deer and mice from eating plant materials. Tabasco sauce is a little expensive and Louisiana hot sauce does just as well; the current recommendation is to use 40 oz/100 gal of water. You do have to be careful of the sticker you use; the usual spreader stickers do not work. We are currently using Vapor Guard at 2 parts per 100 for winter protection and 1 part per 100 for summer protection. Where growers have used Tabasco and reported unfavorably I have found that they used the conventional spreader stickers and they just don't work. I have a new hot sauce that was sent to me and it is really potent; at present I am down to 2 oz/100 gal but it is still doing a good job.

MODERATOR DAVIS: Bruce Briggs, how do you use Clorox for sanitation of your cuttings?

BRUCE BRIGGS: We use it at the rate of 1:15; this is just to be sure the water is clean. When the water gets dirty we mix up a new batch, usually one in the morning and one in the afternoon. If it gets much stronger than this there is a chance of doing some damage to the cuttings.

MODERATOR DAVIS: How good is Kerb herbicide and can it be used around dormant deciduous shrubs for quack grass control?

RALPH SHUGERT: It is a fine product but there are few plants on the label. I think it has good potential for use on those plants that can't take Princep. I have heard of no damage from its use but also no control is obtained if it is put on after February 1. It must go on in early to mid-November.

VOICE: For quack grass I have to get it down in November or I get no control.

MODERATOR DAVIS: That completes all the questions in the Question Box. I thank every one of you for your cooperation and kind attention.

THE HORTICULTURAL REVOLUTION OF THE LAST 25 YEARS IN AUSTRALIA

MILTON B. SPURLING

Roseworthy Agricultural College
Roseworthy, South Australia

You may have thought at first sight that the title was chosen because it is the "in thing" to be involved in, or promoting, a revolution of some sort. However, I believe "revolution" is the most appropriate way to describe the order of the changes which have occurred in horticulture in Australia over the last 25 years.

Amenity horticulture and the associated propagation of plants has been largely neglected in the past but there is currently an upsurge of interest in this aspect. It may be useful for propagators to review the changes that have occurred during the "revolution" so that they may avoid some of the pitfalls during the present period of rapid change in their industry.

I want to define the manner of changes which have occurred, illustrate these by some specific examples of significant changes over that period in whole horticultural industries, in the management of individual crops and, finally, to draw attention to the consequences of these changes in research, extension and horticultural education.

Changing attitude. The changes which have occurred over the last 25 years might be described in terms of changes in attitude to fruit growing as an occupation, with parallel changes in the apparent needs of the industry with respect to research, extension and education. Three stages can be identified during this evolution — the traditional period when horticulture was an art, which gave way to the day of the scientist who, in turn, was displaced by the accountant. Each of these three stages saw a distortion of horticultural industries by over-emphasis, in turn, on traditional skills, on scientific investigation of detailed problems, and then on financial controls.

The future viability of horticulture lies in a rational integration of horticultural experience, strengthened by an appreciation of the scientific principles behind plant growth, using business management skills as an aid in decision making.

The traditional period — Horticulture, an art. Twenty-five years ago, horticulture was regarded as an art and many of our horticultural practices, and the general attitude of the fruit industries, were traditional. At that time, the successful fruit grower was the one who planted his trees or vines so painstakingly that even the diagonal rows were perfectly straight. He was a grower who made every pruning cut a major decision, and then trimmed the edges of the larger cuts with a pen knife. He was a grower who ploughed deeper, straighter and more often than other growers.

Pruning and training of trees and vines often lacked understanding of the growth habits of the plants, and methods used were determined by tradition rather than being based on scientific principles. Similarly, methods of soil management often lacked an understanding of the principles behind what we were doing. Success in pruning competitions or show exhibits was the ultimate goal of the horticulturist and his orchard was always neat with soil clean cultivated and trees hard pruned to the traditional shape.

Inefficiencies in financial management of the horticultural enterprise were often excused on the grounds that fruit growing was a way of life.

Research and extension workers had to cope with a tremendous resistance to change from the traditional horticultural practices and horticulture as a vocation could only be learned by an apprenticeship.

Problems seen in isolation — Horticulture, a science. The late 1940's saw the decline of this traditional attitude to horticulture. Fruit growing came to be regarded as a science rather than an art during the 1950's, and the emphasis turned to the application of science to individual problems. It was a period when factors affecting production were looked at in isolation, and research and extension were directed at detail.

The most suitable crop and most efficient irrigation method were determined for each individual soil type and the fruit salad block was the result of this emphasis on the choice of crop and irrigation design for each micro environment.

The rapid development of new chemicals to control pests and diseases was a very significant scientific advance, but the tendency was for each pest and each disease to be looked at in isolation. Without a proper understanding of biological control agents and emphasis in screening pesticides on reducing the incidence of a particular pest from 10% to 1% to 0.1%, some new pest species exploded into prominence with disastrous results.

DDT came available just in time to control the codling moth that had developed resistance to lead arsenate, but the two-spotted mite that was released from biological control soon rivalled codling moth as a pest species. The aerial application in the irrigation areas of South Australia of broad spectrum insecticides like carbamates and organic phosphates was accompanied by the appearance of San Jose Scale and Vine Scale as major pests.

During this period, plantings of trees and vines were still regarded as long term — to be there for a lifetime. So the field experiments with rootstocks or fertilizers were put down on research centres with the assumption that after 15 to 20 years, when the results became available, the structure of the industry would not have changed greatly and results would still be applicable. The fallacy of this assumption is illustrated by the impact on the citrus and stonefruit industries of the change from furrow to sprinkler irrigation, and then to under tree sprinklers and drip irrigation as the salinity situation of the water in the Murray River deteriorated. Not only did fertilizer requirements change, but entirely new systems of soil management accompanied the changes in irrigation methods, and many long term field trials, commenced before the changes, became irrelevant before they were completed.

The mark of the successful horticulturist at this time was an ability to cope with the technical details of newly identified pests or diseases, and the newly developed chemicals for pest or weed control, and for blossom thinning or fruit sizing. Sometimes those associated with fruit industries found themselves overwhelmed by the technical detail that went with a change from a simple choice between lead arsenate, nicotine sulphate, sulphur, or oil and between Bordeaux mixture and lime sulphur, to a choice between literally hundreds of insecticides and fungicides.

Fruit growers relied heavily on the research and extension workers for technical advice and they, in turn, got a lot of satisfaction from being able to come up with answers to new problems.

Horticultural education was stimulated by the need for an adequate training in the sciences to cope with new technology in fruit growing, but the traditional horticultural skills were often neglected.

Outside financial interests — Horticulture, a business. During the early 1960's, investment in the horticultural industries by North Terrace/Collins Street/Pitt Street farmers was accompanied by a significant change in attitude towards fruit growing as an enterprise. A new measure of success was introduced into horticulture, that of the balance sheet for the whole enterprise at the end of the year. The most significant consequence of this period to the horticultural industries was that decision making was freed of the constraints of 'experience' and 'tradition'. While acknowledging the need for science to cope with the technical problems, fruit growing was seen first and foremost as a business enterprise.

With the decision makers responsible for property management demanding recommendations backed by information on costs and returns, the research worker found he must carry out his field experiments and assess his results in the framework of the whole orchard or vineyard. Fruit quality characteristics to meet specific market demands was recognized as a necessary consideration in research work and the assessment of results.

The extension worker found his clients more amenable to change, but more critical in their evaluation of his recommendations — they looked at costs and profits rather than conformity with previous tradition. They demanded demonstrations rather than opinions, and the regional research centres became much more important to the extension services.

In horticultural education, the demand was for training in financial management. This was a stimulating period for the horticultural industries — a period of critical review of our traditional horticultural practices and an opportunity for research workers to test out ideas that previously could not have been even considered. Just one example — the idea of a meadow orchard — instead of growing apples on trees planted at 250 to the hectare, why not plant at a density of say, 125,000 per hectare, such as we normally use in the nursery, and harvest the fruit after the second year by mowing off the orchard with a combine type harvester. Field trials of this idea are now in their tenth year.

A blend of skills, science and economics — Horticulture, an agricultural science. It was not unexpected that the substantial investment of finance in horticultural industries by businessmen with little horticultural background resulted in some cases of excessive control of the management decision making by the accountants. For example, some expensive lessons were learned during the establishing of new properties when business acumen rather than horticultural skills was the principal criterion in selecting managers.

The economic advantage of the large area of one crop compared with the small fruit salad blocks has resulted in the establishment, during the last 15 years, of mono culture enterprises of up to 500 hectares in one unit. Entirely new techniques, such as mechanical harvesting and aerial spraying, accompanying this trend and required the application of new technologies by the research workers. Developmental projects were initiated involving engineers and economists cooperating with horticulturists. At the same time, the large areas of single crops demanded a high level of managerial skills.

The stimulus to horticultural education has been good. At Roseworthy Agricultural College for example, specialist courses in horticulture and viticulture have been introduced, research grants have been attracted for work on mechanical pruning and fruit quality. Horticulture is no longer just the poor relation in agriculture.

The climate of rapid change encourages those involved with horticultural education to place more emphasis on training people with an understanding of the principles of soil science and plant nutrition, plant growth and fruit production, insect ecology and plant pathology. However, the experience of the last 25 years has ensured that the horticultural skills are not neglected in educational programs.

The future stability and economic viability of the horticultural industries requires a blend of the traditional horticultural skills based on an understanding of the scientific principles of plant physiology and biology, using business management procedures as a tool to assist in making decisions, but not to the exclusion of good horticultural management.

We must be flexible enough to consider any modification of what we have regarded as a traditional practice if an economic advantage can be demonstrated for it. Our planning of plantings for the future must be guided by market trends, including changes in quality demands. We cannot ignore the need to change to new crops and new cultivars and even improved clones of standard cultivars if necessary. The research and extension workers must look wider than the individual problems, and work within the context of the whole orchard or vineyard property, not forgetting the context of properties as a part of communities.

Horticultural education must also look wider and, besides the obvious plant and soil sciences, courses must include training in business management and marketing. A sound basic training in the traditional horticultural skills, from plant propagation to pruning, must be given. Finally, we must meet the future needs for people trained to cater for rapidly increasing demands in the field of horticulture, as it contributes to environmental improvement in industralized areas, to recreation in the individual home garden and the community, and to the therapeutic use of horticultural skills.

The plant propagation and nursery industries need to keep in tune with these changes. Not only are there scientific advantages, such as new propagation techniques which they can use, but the changing demands of their consumers must be followed. Changes in cultivars, improved clones, different rootstocks for replanting, virus-free scions and rootstocks are but a few of the new demands by the fruit growing industries. The recreation and amenity horticulture industries open up entirely new fields for Australian horticulturists.

The last 25 years has seen a real revolution in the horticultural industries in Australia, but with a rational integration of skills, science and economics in our horticultural education, research and extension, the horticultural industries can look forward to a productive and profitable future.

Plant propagation will play an increasingly important role in this future of horticulture with the change in emphasis from fruit and vegetable production to include amenity horticulture. By considering the sorts of changes we have seen in fruit production we should be able to maintain a more balanced development of the propagation industry by ensuring integration of all the inputs (skills, science and economics) in our education and in our industry.

WHERE IS THE NURSERY INDUSTRY GOING IN YEARS TO COME?

IAN GORDON

Department of Agronomy
Queensland Agricultural College
Lawes, Queensland

The progress made in the Australian nursery industry over the past 25 years has been quite remarkable. There is no reason to suppose that this same rate of progress will not be maintained in the future but the industry will need to adapt to new social, cultural and economic situations which will exist in the future.

I have no crystal ball and am reluctant to predict what the future holds for the industry. Instead, I would like to pinpoint some of the areas where developments can be made in the industry. There are six which I think deserve attention: Education; Research and development; Business management; Nursery efficiency; Specialization; Marketing.

Education. Education and training are of vital importance at all levels within any industry, including the nursery industry. At management level there is a great need for more graduates who can integrate basic plant sciences and business efficiency to develop sound nursery production techniques. At supervisory level there is a need for more personnel with a detailed knowledge of nursery production techniques; and at nursery worker level it is vital that we can recruit and train workers to a high standard in routine nursery operations.

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The educational institutions in most Australian states are becoming more aware of the need to provide specialist courses for the nursery industry and I am quite certain that this trend will accelerate in the future. In looking to the future I am confident that adequate numbers of well trained personnel will be produced to meet the needs of the industry at management and supervisory levels. The problem area in education in future years will probably be centered around the training of nursery workers. It is virtually impossible for the Colleges to undertake the realistic training of large numbers of nursery workers, even if the industry would be prepared to release them from work for this purpose. Speaking as an educator, I would question whether it is the job of the Colleges to train nursery workers. I believe that the employer must ultimately accept the responsibility for training his own staff. Educational institutions are well suited to developing knowledge and understanding of basic principles, teaching people to think for themselves and to integrate information from different sources. They are not so well suited to developing practical skills and the best place to develop these is on the job.

One possible solution to the problems of staff training is for several nurseries located near each other to cooperate and employ a qualified training officer whose job is to carry out training of nursery workers in all practical aspects of nursery production, irrespective of age or experience. The great advantage of this system is that the training is carried out in the nurseries in which these people work, using the machinery and equipment in use in that nursery. Group training officers are widely used in several overseas countries with a great deal of success, but it does place the onus for training directly on the employer.

Research and Development. Of all the primary production industries, the nursery production of plants has traditionally been the Cinderella, with very little of our resources being allocated to nursery research; therefore little or no research information has been generated from within Australia. In trying to improve production techniques, nurserymen have been forced to adapt research information obtained from overseas, principally the U.S.A.

This situation is changing and there are now research establishments carrying out several very useful research projects but, in looking to the future, the present level of research is by no means enough. This is not intended as a criticism of the existing research stations and I am sure that the research staff will agree with me that their numbers must be increased and they must have more and better facilities to enable them to tackle the highly complex problems which face the industry.

Industry organizations such as the federal and state nurserymen's associations must continue to press strongly for a better service to the industry. These associations are already making a significant contribution of funds and support for existing research and this may, perhaps, be expanded in the future.

Nurserymen should also expect a better service from the fertilizer and plant protection companies than they have received in the past. Research and development work on nursery crops must be given a higher priority by these companies.

Business Management. Many nurserymen originally entered the industry because of their love of plants and because they enjoyed working with plants and over the years they acquired a working knowledge of business management. I think it fair to assume that the nurseries of the future will be much more sophisticated and will have to be run as efficient business units. In a small nursery, one man may be able to manage both the plant production and the business side of the enterprise, but in the larger nurseries it will become more and more necessary to separate these two sides of the enterprise and have one person with responsibility for the finances and one person responsible for plant production.

Nursery Efficiency. The development of other industries may give some indications for the future development of the nursery industry. At present we have a very large number of comparatively small nursery units operating within Australia. I have been unable to find reliable figures but the number of nurseries cannot be far short of 1000. This is an incredible number for a country the size of Australia and it is a situation which must give cause for alarm. Quite simply, there are too many small nurseries. Many of these nurseries produce high quality plants and operate very efficiently but I am sure that you are all aware of many badly run nurseries which produce very poor quality plants. The people who produce poor quality plants do not just harm themselves, they harm the industry as a whole.

I am convinced that a drastic rationalization must occur within the industry to rid us of these bad apples. This would lead to the elimination of some existing nurseries but the ones which remain would be left in a much stronger and healthier state. This pattern has been seen in a number of other industries and I am certain that it will occur in the nursery industry. Perhaps it has already started.

Today's somewhat haphazard methods of growing will gradually be replaced by precision growing techniques which are designed to increase the quality and uniformity of produce. Nurserymen must take more advantage of new production techniques such as plant tissue culture and virus-free clonal propagation material. They must make more use of advances in plant protection to reduce the percentage of plant losses and research information must be made available to the industry and must be utilized.

In the minds of many people, nursery efficiency is directly associated with nursery size, the idea being that the bigger the nursery the most efficient it can become. Concepts of what efficiency is are changing dramatically, basically because we have not been including all the factors in our calculations. Consideration of absolute availability of resources, energy and sociological factors must be considered, so the small unit may be more efficient in future. Many large organizations become extremely inefficient and either fail or persist by monopoly and political influence rather than by efficient operation or by providing what the consumer wants.

Nursery Specialization. Perhaps one of the major causes of poor quality plants being produced by nurseries is that many nurseries attempt to grow too diverse a range of plants. Growing too many types of plants means that insufficient attention is given to the needs of individual plant types. Many nurseries already specialize in a small range of plants and these are usually the nurseries which can turn out the best quality plants. Undoubtedly, specialization increases nursery efficiency and also enables growers to build up a reputation for supplying quality plants. The trend towards specialization will continue and it is quite likely that many nurserymen will operate what is virtually a mono-culture.

In Australia, a large proportion of the production nurseries are located in the southern states, obviously because the largest concentration of potential plant buyers reside in this area. Climatically, these nurseries are probably in the worst part of the country and this necessitates the construction of elaborate and expensive propagation and growing on facilities. Winter heating bills and other operating costs are constantly rising and these nurserymen are caught in a vicious circle of spiralling costs.

Australian nurserymen do not make enough use of the natural climatic advantages which part of the country offers them. The tropical and sub-tropical areas of central and north Queensland and parts of Western Australia are much more favorable for the rapid growth of plants and nurseries located in these regions could utilize simpler and cheaper growing structures without the crippling fuel bills. There is a parallel with the U.S.A. where a large proportion of indoor flowering plants are produced in the favorable climates of Florida and California and distributed throughout the country.

I am not advocating the elimination of the large southern production nurseries but I do think that much of the basic plant propagation could be carried out in the more climatically favorable parts of the country with small plants being shipped to the southern nurseries for growing on to a salable size. This is simply another form of specialization, but instead of specialization simply on the basis of plant species grown, there is also specialization at the different growth stages of the crop.

Marketing. There are many improvements in all forms of plant marketing constantly being introduced and these have a major impact on the industry. The garden centre concept and the retail plant supermarket are two areas where massive expansion has already taken place but there is still scope for considerably more expansion in the future.

The primary aim in plant marketing must be to create an expansion in the potential plant market. Australians in general are not nearly as plant conscious as the citizens of many other countries but a great deal can be done to improve this by constructive advertising.

There is no real difference between a plant nursery and most other types of manufacturing industry. In all cases a product is manufactured (or grown) and then it must be sold. The nursery industry can learn a great deal by studying the advertising methods and sales techniques employed in other Australian industries. Sales promotion must play a much greater part in creating a demand for our nusery products.

I also feel that some retail plant outlets tend to alienate many potential customers by charging exhorbitantly high prices for plants. To quote two examples: during the recent Toowoomba Carnival of Flowers, a local retail nursery was charging $18.50 for 12" high *Phoenix roebelenii* palms in 8" pots. The nurseryman who grew the plants probably received around $5 per plant. I also heard of another instance where a garden centre bought in container grown citrus trees for $3 and immediately sold them for $10.50. No doubt all of you could quote similar examples of gross overpricing. I firmly believe that both wholesale and retail sectors are entitled to a fair profit on stock which they sell, but rip-offs such as these do considerable damage to the industry as a whole. If we are really trying to expand the potential market for our produce then we must make greater efforts to secure export markets. If the New Zealand nursery industry can expand in that direction, why not the Australian?

GREENHOUSES

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The purpose of a greenhouse is to provide protection for crops from climatic extremes such as rainfall, hail and temperature. In general the greater the degree of protection provided the higher is the cost of this protection.

There are so many different types of greenhouse structures, covering materials and accessory systems for environmental control that it is difficult to decide what is the best to use in any given situation. The decision is a compromise of many factors including the crop or crops to be grown in the greenhouse, their management, environmental requirements, the climatic conditions in the area where the greenhouse is to be built, the availability of capital and the cost of maintenance of the greenhouse.

A greenhouse can be designed specifically for one crop or so that it remains flexible and can be used for several different types of crops, should the economic viability of the enterprise change. Certain aspects of crop management such as the arrangement of beds and watering systems are also important to allow efficient use of the space inside the greenhouse.

Choice of Site. As greenhouses are an expensive capital item care should be taken to choose a suitable site. The area should be level with a high natural light intensity and sheltered from severe winds. Preferably, the area should be well drained with a soil type of medium to light loam. Soils with poor drainage and physical characteristics can be improved but this involves additional cost. An adequate supply of water and electricity is required on the site as well as good road access in all weather conditions.

Spacings and Land Use. Greenhouses should be spaced to avoid mutual shading. Spacing is determined by the height of the ridge and the elevation of the sun in winter, and must be balanced against the economic use of land and the cost of other services, such as transport and heating.

Design. Regardless of its use every greenhouse must meet certain functional requirements. It must be designed to withstand the wind loads imposed on it without failure or significant deformation. Since no Australian standard exists for wind loadings on greenhouses, reference should be made to Australian Standard 1170 which sets out the minimum design loads on structures.

The Design Wind Velocity is obtained from the Regional Basic Design Wind Velocity (Table 1) adjusted for (i) mean return period (expected frequency of occurence of the wind velocity), (ii) geographic location, (iii) terrain category, (iv) shielding and (v) height above the ground.

Table 1. Values of regional basic design wind velocity (m/s) for major centres for a 25-year mean return period.

Centre	Regional Basic Design Wind Velocity (m/s)	Centre	Regional Basic Design Wind Velocity (m/s)
Adelaide	40	Melbourne	37
Brisbane	45	Mildura	31
Cairns⁺	50	Perth	37
Hobart	39	Sydney	41

⁺ Tropical cyclone area.

For structures built in tropical cyclone areas (coastline north of latitude 27°S and extending 50 kilometres inland) the regional basic design wind velocity must be multipled by a factor of 1.15.

Some of the factors which influence the wind load on buildings are the height to width ratio, shape and orientation. The wind generally hits the surface of the building at an angle and an aerodynamic effect develops which causes a suction, or uplifting force on some building surface (Figure 1). Hence adequate foundations and footings must be provided to resist uplift, overturning and downward acting loads. Standardization of greenhouse designs to meet local building requirements would be useful to ease the problems currently being experienced by nurserymen when building a new greenhouse.

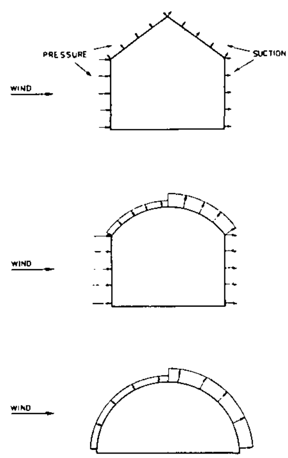

Figure 1. Wind pressure and suction effects on various structure shapes.

Structural Materials. The most common structural materials are wood, galvanized steel and aluminum. Decay resistant wood species or treated lumber should be used if a reasonably long life is desired.

Galvanized steel pipe is popular for greenhouse use due to its ease of construction. Aluminum is being used more extensively by commercial greenhouse manufacturers, due to its light weight and excellent durability.

Structural Influences on Ventilation and Heating. The final success of a greenhouse will generally depend upon the ability of the operator to control the environmental conditions within the greenhouse. Although any shape structure can be successfuly ventilated or heated, some designs greatly increase the difficulty or cost in providing an adequate system. In these cases, a less than optimum system is often installed, which then creates problems in management.

Natural ventilation is achieved by the chimney effect created by warm buoyant air in the structure and the wind. The amount of ventilation achieved is dependent upon the location and the area of the vents, the air temperature differentials in and around the structure, and the wind speed and direction. In some structures, such as a, low polyethylene tunnel and in many of the large multipan structures, it is sometimes difficult to achieve adequate natural ventilation (Figure 2). Where the efficiency of natural ventilation is low, positive air movement and controlled ventilation rates can be achieved by fan forced ventilation and evaporative cooling systems.

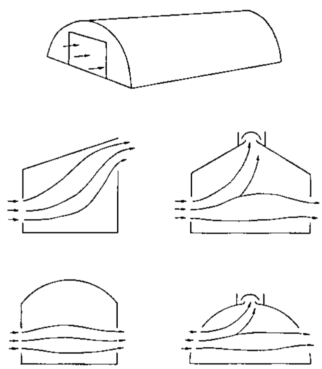

Figure 2. Natural ventilation effects on various structure shapes.

For economical heating the structure should be as air tight as possible as unwanted ventilation is a source of heat loss. Badly fitting ventilators and doors and spaces between the walls and roof or floor should be avoided as these result in considerable increases in running costs.

Height of Greenhouse. The height of the house in the work areas should never be less than 2m. Houses lower than this are difficult to work in and hence a loss in efficiency of labor results. For tall crops, the height of the greenhouse would have to be greater than 2m. An increase in roof height improves natural ventilation during still conditions and allows the desired environment to be more easily obtained.

In terms of heating costs, the important factor is the amount of exposed wall or ceiling area (since heat passes through the covering material) rather than the volume of air in the greenhouse. An increase in height of a greenhouse does increase the wall area, however this increase is small in comparison to the total surface area of the greenhouse.

Roof Slope. The roof slope affects the runoff of condensed water from the ceiling. Slopes of 28°C are generally considered as minimum, if runoff without severe dripping is to occur.

Access. In most greenhouses it is necessary on occasions to remove large quantities of old plants, soils or rooting media. In order to use labor more efficiently, large doorways at least 2.5m wide and 2m high should be provided to permit the use of tractors and large equipment for tillage operations. The doorways should be in the most suitable positions for the easy flow of materials and produce.

The Future. As the greenhouse chosen may influence the management and cropping of your enterprise for 10 to 20 years and, as the costs of construction continue to rise, the need for informed judgment in the choice of a greenhouse becomes greater. It is impossible to forecast all the developments which will occur in greenhouse technology in the future, but there are indications that low energy usage greenhouses or those using solar energy will become popular. Hence the general aim should be to build a structure which will allow changes to be made to cropping, management or mechanization with the minimum of expense.

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DESIGN CRITERIA FOR LIGHT ADMISSION

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Plants do not live by light alone. There are other factors which affect their performance, among which are air, water and nutrients. But it is to the intensity of light that the levels of supply of all these other factors must be balanced.

So if the intensity of light which is admitted to the planthouse can be automatically adjusted to the "ideal" intensity at all times, it becomes easier to maintain the levels of supply of the other factors (air, water and nutrients), in balance with the intensity of light and in balance with each other. Rewards measured by the plant's performance will follow accordingly. The intensity of light applied to the plants is, therefore, the prime item for consideration in planthouse design.

To every plant on earth Nature provides an ever-changing intensity of the sun's radiation — light. At any point on earth the sun's radiation is different every second of the day. It is different on every day of the year. It is also different at any two points on earth. Since time began plants have been accustomed to this ever changing intensity of light and, for best results, they still perform best under such conditions. So the first criterion in the design of a planthouse is to provide an ever changing intensity of light admitted to the plants throughout the whole of the day and it should increase or decrease slightly for each day throughout the year. There are no constants in Nature.

Planthouses are built in Adelaide to culture plants which have a genetic makeup accustomed to the relatively constant light (and heat) of the tropics. They are built also to culture plants in their juvenile stage, a time when they require more constant levels of supply of light, air, water and nutrients, than those provided by our climate. So the second criterion for the planthouse design is that it should automatically modify the sun's radiation of our latitudes to be more akin to the relatively constant light of the tropics.

All plants grow their leaves, modified in form within the limits of their genetic makeup, to suit their climate, in particular to suit the intensity of light applied to them at the solstices. They are accustomed to a gradual change between these times and, therefore, do poorly under sudden changes in the cycle, such as when temporary shading is applied or removed. Such practices reduce the plants' yields accordingly. So the third criterion for light admission is that only gradual changes in the intensity of light are to occur between the solstices.

We know that the tropics are always hot and that the polar regions are always cold. We also know that our own winters are cold and dull and our summers hot and bright. The causes of these extremes are the effects of two natural phenomena:

(1) The sun's changing apparent path in the heavens throughout the year.

(2) The light transmission co-efficients of the atmosphere, the transparent barrier which surrounds the earth.

THE SUN'S APPARENT PATH

The sun's apparent path at our Southern Hemisphere winter solstice is over the Tropic of Cancer, 23-1/2° north of the equator. On this day the sun's maximum altitude at noon solar time, when its bearing is true north, is but 31-1/2° above the horizon. The point of apparent sunrise is 28-1/2° north of east and apparent sunset is a corresponding point north of west (See Figure 1).

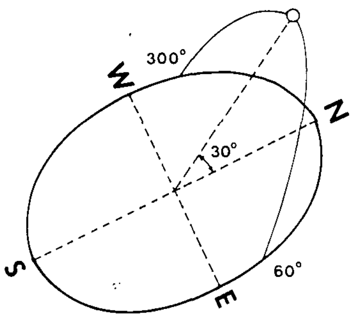

Figure 1. Sun's Apparent Path — winter solstice, Adelaide latitude, −35.030°.

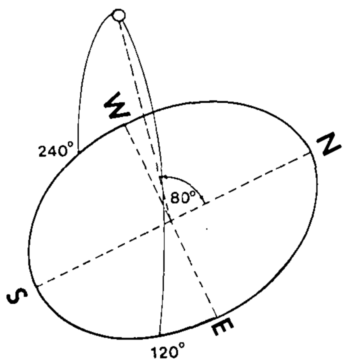

Figure 2. Sun's Apparent Path — summer solstice, Adelaide latitude, −35.030°.

At our summer solstice, the sun's path is over the Tropic of Capricorn, 23-1/2° south of the equator. It has moved 47° from its winter path and its maximum altitude is 78-1/2° with apparent sunrise at 28-1/2° south of east and apparent sunrise at 28-1/2° south of west (See Figure 2).

Note also, by counting the number of days elapsed between the equinoxes when the sun's apparent path is over the equator, that the earth takes but 179 days to travel through its lower apsis compared to 186 days for its higher apsis. Accordingly, the summers of our Southern Hemisphere are hotter, brighter and of shorter duration than are the cooler, milder, longer drawn-out summers of the Northern Hemisphere. Planthouses are therefore considerably more difficult to operate all the year round in the Southern Hemisphere than are similarly constructed planthouses in the Northern Hemisphere.

The light transmission co-efficients of the atmosphere are such that, at Adelaide, for the month of July, the daily amount of solar radiation which reaches ground level is expressed as 7.22 megajoules per square metre. For the month of January, the daily amount is 26.2 megajoules/m^2. That means there is almost four times greater solar radiation daily near the summer solstice than there is daily near the winter solstice (See Table 1).

Table 1. Mean solar radiation at ground level in Adelaide, Australia, for the years 1959 to 1975.

MONTH	MEGAJOULES M^2/Day	INCREASE July = 1.0
January	26.92	3.8
February	24.02	3.0
March	19.03	2.7
April	12.93	1.8
May	8.71	1.2
June	7.42	1.0
July	7.22	1.0
August	10.34	1.4
September	14.65	2.0
October	19.65	2.7
November	23.71	3.0
December	26.04	3.8

Fortunately, all transparent barriers have somewhat similar light transmission co-efficients. Sheet glass transmits 90% of the sun's light (the maximum transmission) when the radiation is normal to the surface of the glass. As the angle increases from normal to normal + 45° the percentage transmission remains constant at 90% but then falls off rapidly as the angle increases further from Normal to be nil at normal + 90° (See Figure 3).

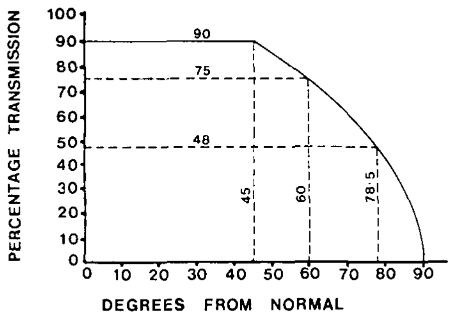

Figure 3. Light transmission of window glass.

Calculating from the light transmission co-efficients of glass it is noted that the transmission through glass fixed horizontal (normal + 90°) is:

- at noon day winter solstice = 75%
- at noon day summer solstice = 90%

And for glass fixed in the sides of a 30° pitch gable roof with the gable ends facing north and south (normal − 60°, facing east and normal + 60°, facing west) averages over the total floor for all day are:

- at the winter solstice = 75%
- at the summer solstice = 90%

This is the complete reverse to that which is required. But for glass fixed normal facing true north, the light transmission at Adelaide (−35.030° Latitude) is:

- at the winter solstice = 90% almost all day
- at the summer solstice = 48% at noon (See Table 2).

Table 2. Solar radiation transmission for glass fixed normal and facing true north.

SOLAR TIME HOURS	PERCENT TRANSMISSION Winter Solstice	Summer Solstice
0800	84	00
0900	87	11
1000	90	32
1100	90	45
1200 (noon)	90	48
1300	90	45
1400	90	32
1500	87	11
1600	84	00

Fixing glass normal, facing true north, gives nearer the desired relatively constant light admission to the planthouse throughout the whole year but it is still excessive at and near the summer solstice. To overcome this some additional shade can be incorporated in the building. An arrangement of east-west rows of glass fixed Normal facing north, joined with an opaque material fixed at 31-1/2° to the horizontal (the maximum altitude of the sun at the winter solstice), gives the desired effect (See Figure 4).

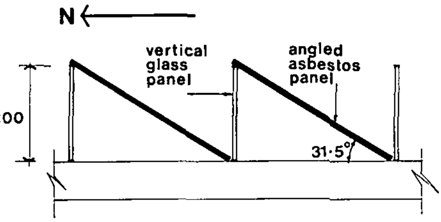

Figure 4. Horizontal roof — glass and asbestos.

So far we have planned only the roof of the planthouse. The walls of the planthouse for practical and economic purposes in building should be vertical. But from the table of the light transmission co-efficients of glass we note that vertical glass without additional shade transmits too much light in summer. What is needed is glass fixed normal minus a number of degrees but not so many degrees as to interfere with the winter radiation.

In practice it has been found that glass fixed normal −15° is adequate to offset the excessive radiation of summer. Fixed in such manner it will admit all the winter solar radiation as the effective angle between the sun and the glass is almost within the bounds of normal +45° (See Figure 5).

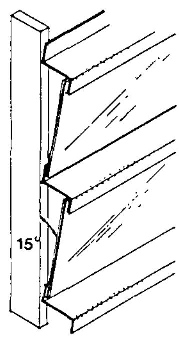

Figure 5. Vertical wall, glass and metal glazing bars.

Similar light admission effects as achieved with glass can be had with fibreglass reinforced plastic sheets having clear vertical surfaces and screened adjoining sloping surfaces. The sloping sections are fixed at 31-1/2° to the horizontal, the maximum altitude of the sun at the winter Solstice, so that the sloping sections offer no shade at this time of the year. The percentage screen of these sloping or adjoining surfaces can be varied to give other than relatively constant light admitted to the plant-house throughout the year (See Figure 6).

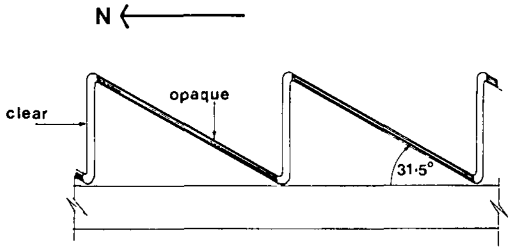

Figure 6. Horizontal roof — translucent formed sheets.

Used as cladding for the vertical walls of a planthouse, translucent sheets should have the screened surfaces fixed in a horizontal plane and the adjoining, sloping, clear sections will be normal, minus the number of degrees calculated to admit the desired proportion of the solar radiation (See Figure 7).

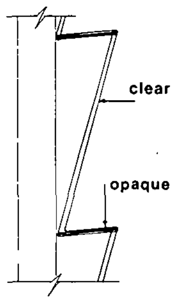

Figure 7. Vertical wall, translucent formed sheets.

Over 200 planthouses using glass and asbestos cement sheets to these designs have been built in Adelaide, Australia. They are used to culture orchids, indoor plants, tropical plants, juvenile plants, vegetables and flowers out of season and many plants which produce annual crops of flowers, seeds or fruit. They are in use on every day of the annual cycle without additional shading required (See Figure 8).

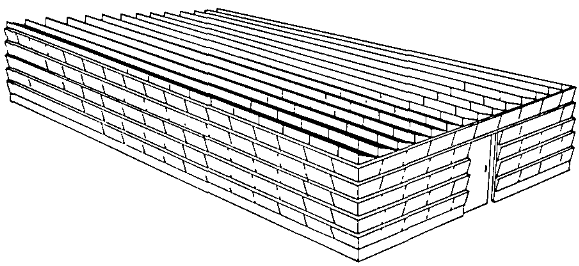

Figure 8. Controlled light admission planthouse.

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GREENHOUSE COVERING — WHAT CAN BE USED?

ALAN J. NEWPORT

Dundas Nursery Supply Co. Pty. Ltd.
Dundas, New South Wales

The number of greenhouse covers are almost as varied as the crops grown within. Some of the covers are polythene (polyethylene), both ultraviolet inhibited and, for short term crops, non-treated material, clear polyvinyl chloride, Mylar (Dupont), certain nylon reinforced polythene and vinyl sheets (e.g. polyscrim).

In the rigid sheet we have polyvinyl chloride (e.g. Vinlon Tuflite), acrylic and, of course, fibreglass, either with or without tedlar (Dupont) coating. There are, of course, variations of these and other materials. Finally there is glass.

The following more common materials being used will be discussed, namely glass, fibreglass, rigid P.V.C., and polythene. In these we have a range of coverings that will meet the needs of growers over the whole of the climatic regions of the continent and the horticultural crops they grow. They also represent the materials currently most widely used.

Glass. The oldest covering used in horticulture and, in Australia, still one of the most popular. Glass has the advantage over all other materials in having a known life expectancy; the structure will give out long before the glass wears too thin. Light transmission is high and suitable for all crop growth. It is easy to paint and comparatively easy to clean. It is not flammable and, in Australia, is reasonably priced.

There are, however, some disadvantages, namely the design limitations and the need for structures to carry the weight. To ensure a tight house the structure has to be well designed, usually using extruded aluminum and featuring large glass sizes and plastic mastics to give a good seal to the glass and ridge and side vents. These houses are not made in Australia. Imported models, however, are available and represent excellent structures. The locally available houses are constructed to the size of the glass sheets available — ranging in size from 16″ × 14″ to 24″ × 24″, the largest. The glass is carried in rafters, usually galvanized steel, and a simple glass clip is used to support

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In heavy hail belt areas hail guards are usually a good insurance. Roof leaks are fairly prevalent after a few years with the local small pane type house due to cracks in the glass, usually at the clips, etc., caused in the whitewash cleaning. As well, the small gutters in the rafters become clogged with dust and whitewash and cause quite extensive leaks.

Fibreglass. This material is becoming very popular in Australia following its growth pattern in the U.S.A. It is a very flexible product which allows for dome type houses. This adds strength to the material, allowing it to withstand quite heavy hail. It is extremely easy to fix. The structure of the house can be much lighter. Light transmission is quite good in the standard sheets in the first few years, deteriorating after this. White fibre glass can be used for lower light intensity crops — thus saving on painting, etc. The standard sheets have to be cleaned and recoated after about five years. This time can be extended if the painting is done on the outside thus protecting the resin. If tedlar (polyvinyl fluoride) is bonded to the fibreglass during the forming of the sheet it does away with this light transmission deterioration already referred to. However in Australia the manufacturers of this process will not give any guarantee. This is most disturbing and until that can be extended the additional cost involved in questionable.

The heat loss from fibreglass is minimal compared to glass because the structure generally is very tight; however a disadvantage is that the material does burn.

Rigid Polyvinyl Chloride. In Australia this material is known as Vinlon or, more recently, as Tuflite. It has ultraviolet inhibitors added during its forming and has an acrylic finish on the weatherside to give long life.

This material has had a manufacturer's guarantee on its life of 15 years. Earlier sheets of Vinlon did break down and light transmission was considerably reduced. The acrylic coating has prevented this in the material that is currently in use. Its characteristics for construction etc., are similar to those described for fibreglass.

Polythene (Polyethylene). Many and varied structures are being used in Australia with this versatile film. The single film of .004 or .006 (that is 100μ or 150μ) ultraviolet-inhibited sheets provide an excellent material for igloo structures of a temporary or permanent type. In the single form with no sophistication, it is desirable to have doors at either end and, if no other ventilation is provided, it is best to keep the length as short as possible, 40 to 50 ft., being the maximum. The larger the structure in height and width the better for plant quality. A simple vent along the ridge is also practical.

The more sophisticated houses can feature double skins with a constant bag of air providing good insulating properties for both heating and cooling. Fan jet heating and cooling can be provided — as well as exhaust fans and pans, space heaters, etc. Aluminum cover clips are available to carry the two skins. These accessories also can take single skins with shade cloth to provide a shaded greenhouse if desired.

The use of this versatile material is extensive and gives a very reasonably priced greenhouse. The life of ultraviolet-treated polythene is approximately 2 years with some growers getting more than this. Light transmission is good and plant growth is also very good. Double skins do restrict the light transmission a little; however, very few, if any, crops would be affected.

Costs. These represents only the approximate costs of a square foot of the material desired. Consideration should be given to the factors that make up the completed greenhouse. For example, a polythene house, may be a temporary or permanent structure, carrying heating and cooling equipment, etc., and it may be a single or multi-bay structure. Lighter structures are needed for fibreglass or rigid P.V.C. as compared to the heavier structures required for glass. Note also that in the glass cost the price of rafters are included in the square foot price. Prices quoted are Sydney, N.S.W. prices and are approximate only.

Glass and rafter	32.5¢ to 37¢ per sq.ft.
Fibreglass — standard	30¢ per sq.ft.
Fibreglass — Tedlar treated	54¢ per sq.ft.
Rigid P.V.C. — Tuflite	
Industrial	89.2¢ per sq.ft.
Domestic	44¢ per sq.ft.
Polythene (ultraviolet inhibited) .002	0.75¢ per sq.ft.
Polythene (ultraviolet inhibited) .004	1.50¢ per sq.ft.
Polythene (ultraviolet inhibited) .006	2.25¢ per sq.ft.

LIGHT EFFECTS ON PLANTS

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What we call light comes to us from the sun and is the product of countless nuclear reactions occurring on the sun's surface. Each second the sun emits energy equivalent to 1 million times all of the known and used supplies of the earth's coal, natural gas and petroleum. The energy produced by the sun passes through space as electromagnetic radiation of varying wavelengths and the spectrum of much of it is indicated in Figure 1. In relation to the total energy spectrum, the visible portion is quite small. Because of the relative size of the earth and its distance from the sun we receive only a small proportion of the energy emitted by the sun; two very obvious ways in which it is utilized is in heating our atmosphere and in stimulating and controlling plant growth.

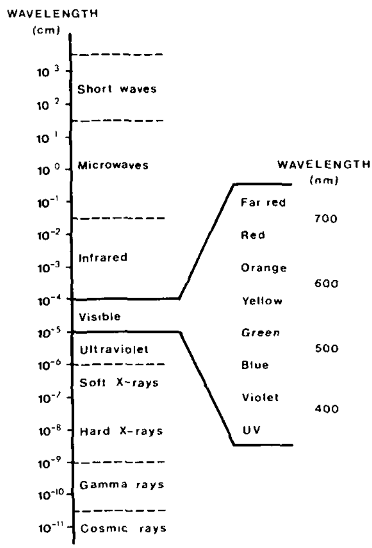

Figure 1. Electromagnetic radiation spectrum.

By far the most important light reaction of plants is photosynthesis. The green coloring matter in plants, chlorophyll, absorbs two colors of light (Figure 2) and through the absorption of radiant energy enables the plant to take carbon dioxide from the air and water from the soil and convert them, together with absorbed minerals, into all of its many parts. The light that's absorbed is in the red and blue parts of the spectrum, and the more light that's provided to the plant, the more it will use in growth. In general, photosynthesis requires more than 100 foot-candles of light before anything happens, and an increasing response is observed up to about 10,000 foot-candles. It is impossible to overemphasize the importance of photosynthesis. It is the starting point for all plant growth and, since all animal and marine growth is ultimately dependent on plants, photosynthesis is the key photo-reaction for all life on our plants.

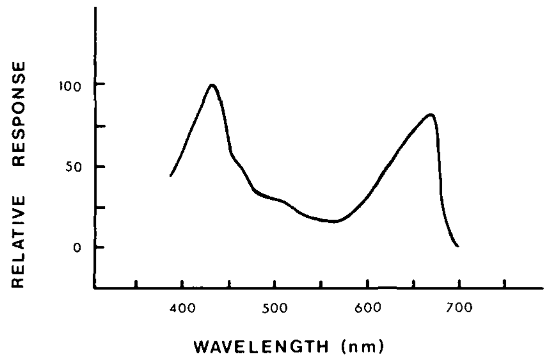

Figure 2. Relative photosynthesis response to light of different qualities.

In addition to photosynthesis, there is a second photoreaction in plants, called photoperiodism. It differs from photosynthesis in several ways and is frequently the reason plants behave the way they do. While the pigment or receptor for photosynthesis is chlorophyll, and is green, and is present in large amounts in almost all plants, the pigment or receptor for photoperiodism is called phytochrome, is blue, and occurs in very small amounts in all plants (Table 1). As indicated above, photosynthesis requires light intensities of between 100 and 10,000 f.c. before carbon dioxide and water can be converted into sugars in the plant. Photoperiodism, on the other hand, only requires light intensities of up to 5 or 10 f.c. Thus, the maximum response of this light system is produced by about 1/1000th the amount of light that saturates the photosynthetic system. Interestingly, on very clear, bright nights, the intensity of moonlight may be just enough to cause at least a partial response. Both photosystems are similar in that red light is a major part of the effective spectrum.

But what does photoperiodism do — why is it important? Table 2 indicates some of the processes in many plants that are controlled by phytochrome. It is obvious that activation of the photoreceptor pigment, phytochrome, affects plants during their very earliest stages, like germination and hypocotyl hook opening, through the vegetative and growing stages, and even affects aspects of the termination of growth, such as initiation of dormancy, leaf abscission, coloration of fruit, and onset of the reproductive phase itself, the initiation of flowering. An important aspect of this is that not all plants necessarily have the same process controlled in the same way. For example, although the germination of seeds of some plants is sensitive to light, many others are not. Bud dormancy is another process which is controlled by different systems in different plants, and so are others on the list.

Table 1. Comparison of photosynthetic and photoperiodic light systems.

	PHOTOSYNTHESIS	PHOTOPERIODISM
Photoreceptor	Chlorophyll	Phytochrome
Color of photoreceptor	Green	Blue
Amount of photoreceptor present in plants	Large	Small
Effective wavelengths	Red and blue	Red and far-red
Light intensities required	100-10,000 f.c.	0.01 - 10 f.c.
Nature of mechanism	Quantitative	Trigger or threshold
Action	Converts CO_2 and H_2O to sugars	Regulates time measuring ability

Table 2. Some phytochrome-mediated photoresponses.

1. Elongation (leaf, petiole, stem)	9. Leaf abscission
2. Hypocotyl hook unfolding	10. Epinasty
3. Unfolding of grass leaf	11. Succulency
4. Sex expression	12. Enlargement of cotyledons
5. Bud dormancy	13. Formation of leaf primordia
6. Root development	14. Seed germination
7. Rhizome formation	15. Flower induction
8. Bulb formation	16. Differentiation of primary leaves

The name of this light reaction, photoperiodism, implies an ability to measure, or be influenced by, the length of the exposure to light. This is again different from the photosynthetic light system, in which the amount of light, rather than the length of the light period, is measured. If the list of processes in Table 2 is examined closely, it can be observed that all of them are usually influenced by the time of the year, or the time of the day. Thus, any seasonal response of plants which is sensitive to light, probably involves the phytochrome system and this change in the seasons is detected by measuring the change in the daylength or, in reality, the change in the nightlength. The length of the night has been identified as the crucial factor because, although interruption of the light period with a brief period of darkness does not alter the response, interrupting the long dark period with light for even as short a time as a few seconds or minutes can change the response dramatically. Thus, the shortening nights of spring, or the lengthening nights of autumn are the triggers which alter the growth and development of responsive plants, and some plants can detect differences in nightlength as small as 20 minutes.

Of the many phytochrome-controlled photoperiodic responses indicated in Table 2. the most important is probably flowering. Many, though not all, plants have a definite flowering season and, in the majority of cases, the plants are reacting to changes in the length of the dark period rather than to temperature, or moisture availability, etc. Some plants are known as longday plants, and others are shortday, and the responses of barley and *Chrysanthemum*, good examples of the two types, are indicated in Figure 3. It is obvious that barley, a longday plant, flowers very much more quickly in long, than in short days, whereas *Chrysanthemum*, a shortday plant, behaves exactly the opposite. Not all plants are responsive to daylength in the control of flowering; some, like tomatoes, are called day neutral and flower when they reach a certain stage in development. Some plants also have a temperature requirement mixed in with their light requirement.

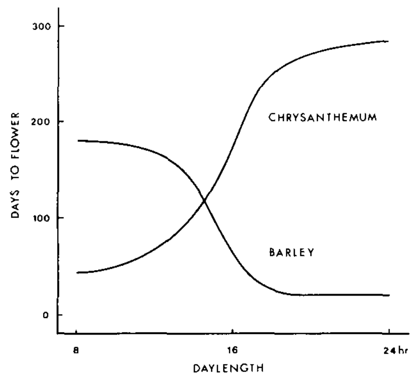

Figure 3. Effect of daylength on the time taken by *Chrysanthemum* and barley plants to flower.

As indicated in Figure 3, *Chrysanthemum* flowers when exposed to long nights. So, if it is desirable to keep *Chrysanthemum* vegetative in autumn, supplementary lighting can be used to shorten the night. An important aspect is that the amount of light required is very low, no more than 5 to 10 foot-candles, well below the energy level necessary for photosynthesis. In this way we can keep *Chrysanthemums* vegetative in winter and, by lengthening the nights during summer, we can make them flower completely out of season. These responses are illustrated in Figure 4. The light and dark periods (which add up to a 24 hr day) are indicated above the plants, and the short-day-requiring *Xanthium* behaves opposite to the long-day-requiring *Hyoscyamus*. In addition to this, Figure 4 also shows something else. If the short-day *Xanthium* is exposed to long nights (the first column), it flowers. However, if those long nights are interrupted by a very brief flash of low intensity light (the last column) flowering is not induced, and the plant stays vegetative. Just the opposite happens with the long-day *Hyoscyamus*. It requires long days and thus doesn't flower when the night is long. If that long night is interrupted by a flash of light, even though the night is essentially the same length, *Hyoscyamus* will flower.

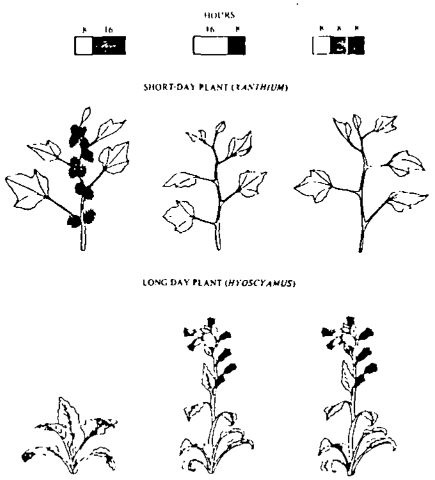

Figure 4. Photoperiodic control of flowering. Bars above plants indicate light and dark periods in a 24 hr. day.

These results and many others have increased our level of scientific understanding of how and why plants grow and behave the way they do. In addition, they have given us a second way to commercially control the behavior of plants through altering their light environment. Not only can we use low intensity light to extend the daylength, or cover plants with shades if it is desirable to shorten the daylength, but it is also possible to interrupt the long nights of winter and produce summer-type responses.

In fact, that's at least part of what plant physiology is all about, a study of the normal growth and development of plants, with the eventual aim of understanding it well enough to be able to control it, to maximize the benefits for mankind. One of the most important plant processes to control, in fact, is flowering. If there were ways to promote it or delay it in a wide range of plants, and particularly in crops, food production would be facilitated. Control in this respect is not limited only to the production of ornamental flowering plants, but also to the ability to prevent crops from going to seed, or making other crops flower sooner or more uniformly, or all year round, etc.

But flowering is not the only part of the photoperiodic system it would be useful to be able to control. For instance, many woody plants or trees are stimulated in their growth as the daylength is lengthened. An example of the effect of photoperiod on the growth of Douglas fir is illustrated in Table 3. As the daylength was increased, branch and elongation growth were all stimulated. The table also shows that if a 12 hr night period was interrupted with a low intensity light break of 1 hr, the seedlings grew as if they were in a 16 to 20 hr day. Figure 5 illustrates this more clearly.

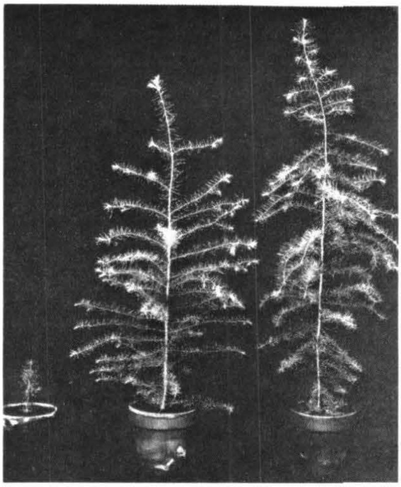

Figure 5. Growth of Douglas fir after 12 months on photoperiods of 12 hr, 12 hr plus 1 hr interruption in the middle of the dark period, and 20 hr, from left to right.

Table 3. Effect of photoperiod on growth of Douglas-fir (adapted from Downs, 1962).

Photoperiod (Hours)	Length: Main Axis (Centimeters)	Length: Branches (Centimeters)	Length: Total Growth (Centimeters)	Branches (Number)
10	8.4	0.7	9.2	1.9
12	9.4	2.8	12.2	3.2
14	19.7	9.6	29.3	3.8
16	38.9	91.2	140.4	16.0
20	47.9	227.1	274.9	29.5
24	52.9	190.3	243.2	24.2
12 + 1*	41.7	176.0	217.7	23.0
LSD (5%)	7.7	77.0	81.5	8.3

* A 1-hour interruption near the middle of the dark period, using an illuminance of 40 foot candles from incandescent-filament lamps.

Douglas fir is not the only tree species to respond. A large number do, for example, yellow poplar, loblolly pine, Scots pine, to name just a few. If tree seedlings could be irradiated during the winter nights for short periods with low-intensity effective wavelengths, it might be possible to effectively enhance tree seedling growth, provided, of course, that the temperatures were not too low.

In addition to flowering and woody tree growth, runner production in some strawberry cultivars, root growth and development in some root crops, like potatoes and onions, etc., are controlled by the phytochrome-photoperiodic system. The sex of cucurbit flowers is also strongly influenced by photoperiod.

In spite of the many ways in which plant growth and development might be controlled through a night interruption, a most important consideration is the cost. The price of setting up fluorescent or incandescent lights for night interruptions is high, partly because only a small proportion of the light produced by these sources is of the right wavelengths. Another reason for the high expense is that the light intensity from normal light sources decreases very greatly with distance and, as a consequence, many light fittings are needed.

There is one kind of light source, however, that's quite different from incandescent, or fluorescent sources, and that's a laser (*l*ight *a*mplification by *s*timulated *e*mission of *r*adiation). Two of the chief characteristics of lasers are that the emission is coherent, which means that it can travel quite long distances without decreasing in intensity to any great degree, and also that it's monochromatic (or light of a very narrow wavelength).

At this point it seems reasonable to ask whether, if the laser light source differs in any way from other kinds of light sources, will it cause the same effects, and, in particular, whether it will activate phytochrome, the photoperiod pigment? Figure 6 demonstrates the ability of a Helium-Neon laser (which produces red light of 632.8 nM) to inhibit flowering through an interruption of the long night of Japanese Morning Glory (*Pharbitis*).

The results are of duplicate experiments and demonstrate that 100 secs. night interruption with this laser almost completely inhibited flowering of these *Pharbitis* plants. And what about distance? How far can the light go and still be effective? The results in Figure 7 are also with *Pharbitis* but with a less powerful laser. In this experiment 1000 secs. night interruption eliminated flowering, and these values were obtained at a distance of about *one quarter of a mile*. In addition, control of flowering with a highly commercial crop, *Chrysanthemums*, can also be obtained with a laser. The results in Figure 8 are of *Chrysanthemums* that were given six long nights to induce them to flower. The left curve is the course of floral development with time. If plants got less than 6 inductive nights they had a slower rate of floral development. On the right-hand side the effects of interrupting those 6 inductive nights with the laser are indicated. Obviously 1000 secs. night interruption completely prevented flowering. It can be concluded that a Helium-Neon laser is effective in controlling at least some photoperiodic responses, can operate at distances of at least 1/4 mile, and can work on commercially important crops.

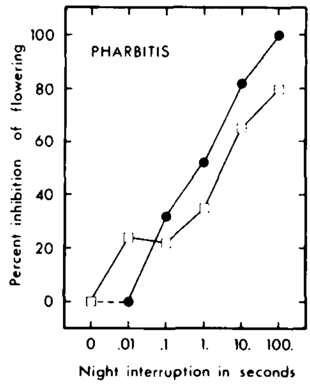

Figure 6. Results of duplicate experiments with different length night interruptions with a 50mW Helium-Neon laser on floral development of *Pharbitis* (intensity at leaf surface about 8 mW/cm^2).

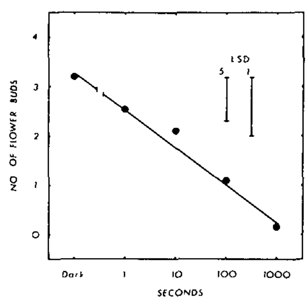

Figure 7. Inhibition of flowering of *Pharbitis* induced by different length night interruptions with an 8 mW Helium-Neon laser at a distance of 1,230 feet (intensity at leaf surface about 0.15 mW/cm^2).

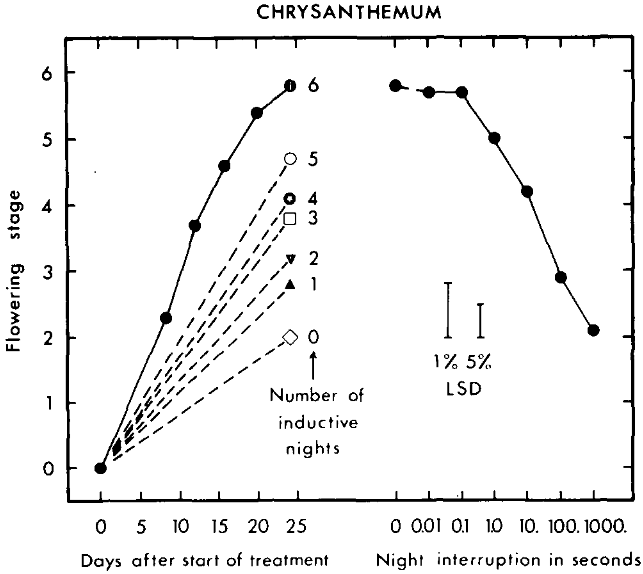

Figure 8. Rate of development of floral apex of *Chrysanthemum* with different numbers of inductive nights, and effect of different length night interruptions with a 50 mW Helium-Neon laser on flowering stage after 24 days of plants receiving six inductive nights.

However, there are important problems to be solved before lasers can be used in commercial operations. For example, the absolute limiting factor in any contemplated use of night interruption is the requirement of the plant. Let's consider a plant, for example, whose flowering, or fruit coloration or leaf or stem growth can be controlled by a night irradiation sometime during a 4 hr. period. In 4 hrs. there are 240 mins. or 14,400 biologically effective secs. during the potentially effective interruption period. If it were possible to disperse the laser light as a constantly scanning spot, moving at a controlled speed, the maximum area that could be irradiated each night would be determined by the least effective amount of irradiation applied for the shortest effective period. The last factor contributing to the calculations is the spot size. As the intensity of lasers increases, the biologically effective dose can be kept constant by increasing the size of the spot. It should be pointed out that the control and integration of these factors is a relatively simple engineering problem. The major missing factor is the relevant biological information.

Finally, how would one use a laser for these effects? Well, one might envisage circular glasshouses or glasshouses arranged like the spokes of a wheel to facilitate maximum use of a single laser. One can also picture a laser beam reflected up a pole or tower to a mechanically- or electronically-controlled mirror which could be preset to scan different size fields at different rates of speed for differing lengths of time.

At the moment, the capital cost of high intensity lasers is high, but the energy inputs are quite small for the amount of biologically active light produced. It seems likely, however, that when a commercial use requiring reasonable production numbers is found, the cost per laser will be drastically reduced.

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THE USE OF SAWDUST AS A GROWING MEDIUM

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North Springwood, New South Wales

The word "sawdust" is simple, but complexities arise when the grower finds that variables are present when using sawdust, and that one cannot copy another grower's "recipe" and have immediate success (not usually anyway). Some of these variables are:

Initial pH of the sawdust; age source, i.e., tree type and area from which it comes; particle size; sensitivity of the crop to be grown in it; length of time the plant is to be grown in it before planting out, etc.; pot shape (surface area in relationship to depth); temperature of medium at planting time; composting procedure; mixing procedure; local environment conditions, e.g. evaporation rate, rainfall, etc., and quality of irrigation water; and, very important, the method and approach of fertility maintenance.

When one discovers these variables from practical experience, it must be realized that the grower should be prepared to put into operation his own experiments. Much good information has come from various research workers here in Australia and overseas, and their findings and recommendations must be treated with high regard and respect, but unfortunately, I've never yet used their exact recommendations with complete success. The reason for this failure is simple. The research worker usually does not have your exact sawdust, your water supply, your local conditions, your range of plants, your pots, etc., so therefore, the grower must learn from the researcher and set up his own experiments. I will list a few points which I believe to be of importance to successful plant culture in containers:

1. Water supply. A knowledge of your water supply pH and salinity, etc. If it is too far from neutral, you must find out what is in it before you can formulate a base mix.

2. A basic knowledge of plant nutrition.

3. A basic knowledge of the fertilizer elements added to a medium and some idea of how they are held or leached from the medium.

4. The medium (sawdust). Does it drain properly when placed in the container which you have chosen to use? Does the lower part of the container stay too wet for too long? Does the top dry out too quickly? Does it need some other well aerated aggregate in the base of the container or should it be mixed through the entire medium?

SUGGESTED EXPERIMENT

(a) Deliberately over-lime a measured amount of the medium, and label all the containers that have been treated in this way, and place them in your growing area (with a plant in it, of course).

(b) Under-lime a measured amount of medium and treat as above.

(c) Measure out and lime correctly a given amount of medium and leave out a major plant element:
   1. One for nitrogen
   2. One for phosphorus
   3. One for potash
   4. One for magnesium

   Label these securely and carefully, and place in growing area, but away from the possible inadvertent addition of the element in which we wish to observe a deficiency.

(d) You may now proceed to experiment with all the test media in appropriate ways.

(e) Over-limed ones may exhibit micro-nutrient deficiency. Try foliar sprays, etc., of the different metals that are suspect.

(f) The under-limed ones may exhibit toxicities and deficiencies. Experiment with the surface addition of lime etc., but weigh or measure and record the materials used in each experiment.

(g) Experiment with the ones where elements have been deliberately omitted with small and progressive amounts of the elements to determine their effect on your crop.

All your results will be visible and, what is more, you will now be able to formulate your medium to suit your crop, in your own growing conditions, and based on sound practices.

PREPARATION OF BARK POTTING MIXES

RAY WADEWITZ

Wadewitz Nursery
Willunga, South Australia

We first started using bark as a component in our potting mix in a small way, using a shovel to mix it by hand. As it proved to be a successful mix and its usage increased, a paddle type cement mixer was used for mixing. Finally we have gone to a front end loader for mixing to fulfill our own requirements and for custom mixing of media for others.

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Our present system is as follows: Bark is transported from the mill to Adelaide in 78 cu.yd. loads. It is hammer milled and screened into four sizes for use in landscaping and nursery potting media. To make the media, the fine screenings are spread on the ground and sand or loam is added according to the specific requirements of the client. This is mixed by a series of picking up and dropping with the front end loader. This mix is returned to the vibrating screener and the required amount of premixed fertilizer is added to the top and vibrated down through the mix. To reduce the dust problem and improve handling of the mix, water can be added to the bark. With this system we can handle 40 to 50 cu.yds per hour. (During this talk an 8 mm film was shown explaining the processing of bark and soil mixing as it is done today.)

COMMERCIAL APPLICATION OF TISSUE CULTURE IN ORCHID NURSERIES

SYD MONKHOUSE

Adelaide Orchid Pty. Ltd.
P.O. Box 1
O'Halloran Hill, South Australia 5158

Since 1960 tissue culture has revolutionized the orchid industry, both in making top show cultivars available in great quantity and also in revolutionizing the cut flower section of this industry. French tissueculturist, Prof. Georges Morel, together with the orchid firm of Vacherot and Lecoufle, realized the commercial prospects in this field and quickly established the first orchid tissue culture commercial laboratory in the world from which they produced plant divisions by meristematic tissue culture and offered them for sale. The word, "mericlone", was coined to describe plants propagated by this method. This has been a most successful venture for this French firm and naturally most other orchid propagating nurseries in the world have followed suit.

Further advances in tissue culture technique have enabled the production of virus-free plants from infected stock; however, this expensive process has been limited to very few cultivars. With tissue culture for virus eradication in orchids, there is also a very large degree of luck, as the procedure is by no means foolproof.

Of late, the treatment of orchid tissue with chemicals such as colchicine has allowed ploidy doubling in many clones and this is proving an advantage to orchid growers, especially the hybridists. It is now possible to convert very desirable diploid parent stock to tetraploid stock by this process. The actual me-

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Of late, the treatment of orchid tissue with chemicals such as colchicine has allowed ploidy doubling in many clones and this is proving an advantage to orchid growers, especially the hybridists. It is now possible to convert very desirable diploid parent stock to tetraploid stock by this process. The actual mechanics of meristem tissue culture of orchids varies a little from genus to genus and is not easy to describe. Briefly, the procedure is as follows in the case of the orchid genus *Cymbidium:*

1. Select a half-formed new shoot growth from a plant.
2. Strip off the outer leaves, thus exposing the growth "eyes" at the base of each leaf.
3. Sterilize in any well known sterilizing agent and transfer to a sterile, laminer flow unit.
4. Under low powered microscope the actual growth meristem is excised from each little growth-eye and this tissue is placed in a tube of sterile growth medium. Approximately six such meristems can be obtained from an average cymbidium growth.
5. After three weeks the meristems will have commenced to grow and they are returned to the sterile planting cabinet.
6. The "protocorms" are cut into three or four pieces each and placed in a tube of liquid medium which is placed on a rotating frame, or a vibrating platform.
7. Because of agitation and vibration, the protocorm pieces are restricted from forming leaves and roots but develop into large clumps of tissue.
8. The dividing process is repeated each three to four weeks until the required number of propagations is reached, at which time the pieces of tissue are transferred to a solid medium and allowed to differentiate and grow on to a complete plant in the usual manner.

During any of the preceding processes it is very simple to transfer the tissue to a liquid solution containing colchicine and a three week stay in such a solution guarantees that a fair percentage of protocorms will have their ploidy doubled. This procedure, which is somewhat costly as a number of protocorms will be killed in the process. is warranted in the case of certain diploid cultivars.

The determination of ploidy change is a rather difficult but interesting procedure. Of course, the only certain method is the microscopic observation of actual chromosome content in the cells. This, however, is a very time consuming and costly procedure as preparation of slides and necessary repetition is almost prohibitive.

The measurement of stomata guard cells of the leaves, especially in comparison with guard cell size of the unconverted plant, gives a fairly positive indication of a change. Careful techniques, with the further meristematic propagations gives a reasonably accurate production of converted clones.

REPORT OF I.P.P.S. TOUR OF ENGLAND AND EUROPE

PETER B. SMITH

Sunraysia Nurseries
Gol Gol, New South Wales

A tour of 4 weeks duration departed Australia for London in May 1977; 33 members of the Australian Region of I.P.P.S. participated. Countries visited include England, Germany, Denmark, Holland and France. The majority of tour members took the opportunity to take individual side tours before returning to Australia. We visited wholesale and retail nurseries, horticultural research institutions, colleges of horticulture, commercial horticultural laboratories, ornamental trial and foundation gardens, educational exhibition gardens and some truly magnificent examples of both formal and informal landscaping.

The two major highlights for me personally were Boskoop, Holland and Giesenheim, Germany, Boskoop being the birthplace of so many of our propagating techniques. This district has supported a nursery industry for more than 500 years, with some 400 open ground nurseries. The Viticultural Research Station in Giesenheim in the Rhine Valley is the Mecca of grapevine breeders and propagators, hence of immense personal interest.

Tissue Culture. Advances in tissue culture technique, as exhibited by the commercial operation of Twyford Laboratories are of great significance to the plant propagation world. Twyford Laboratories offer a service of plant reproduction from parent material supplied by their clients. We visited a number of specialist nurseries who grow-on the product of this form of plant multiplication.

Hydroponic Plant Culture. We were introduced to a new era of hydroponic plant culture at Rotchfords Nursery. They were the largest growers of indoor plants in England. Rotchfords rigid adherence to hygenic cultural practices is most impressive. Their hydroponic system utilizes a circulating solution on both propagating and acclimatization beds. After pottong-on to a L.E.C.A. (lightest expanded clay aggregate) medium, nutrients are supplied by an ionic exchange resin. Plants sold in this medium are guaranteed viable for 6 to 12 months.

Mechanization in the Nursery. Mobile benches in glasshouses were impressive in Holland. These are under experimentation as a means to increase space utilization. Myer, Jarvo and Planterex potting machines are in wide use.

Chelsea Flower Show. Chelsea flower show is a magnificent spectacle. It is breathtaking in its vastness and perfection of plantsmanship. This exhibition and our tour of England in general left me with a great respect for the Englishman's regard for the finished product. The propagation of a species seems to be less of a challenge to him than its culture through to maturity. Due to the destructive ice ages, England has very few indigenous plant species. Hence the Englishman is an avid plant collector and he derives a great deal of satisfaction in establishing introduced species in new environments.

Marketing. Aalsmeer Co-operative flower and plant market is a revelation in marketing technique. The system not only assures quality production from growers, for unsold plants are destroyed, but also circumvents the middleman commission agent. All plants are purchased by merchants on the day of sale. Plants are sold under auction on a diminishing value system which precludes buyers from "fence sitting". The mechanization and efficiency of the market is such that the Co-operative is financed by 4-1/2% of gross turn-over. Most Australian agents charge 10 to 15% for the service of selling, without accepting any risk.

As a group we are endebted to our tour organizers headed by Mary and Ed Bunker, Thomas Chang who was our host in France and, particularly, Ann and Richard Martyr of Pershore College, England, who spared no effort to make our tour the success it was. We gained greatly in knowledge and even more importantly in friendship.

A WORLD TOUR OF COMMERCIAL NURSERIES USING TISSUE CULTURE PROPAGATION

R.A. de FOSSARD

Department of Botany, University of New England
Armidale, New South Wales 2351

Tissue Culture Propagation Overseas is Expensive. One over-riding impression that I gained from visiting nurseries using tissue culture techniques was the large financial investments made in them and the apparent lack of thought and planning relative to cost-cutting methods. Investments of $50,000 were common and several nurseries had invested in excess of $100,000. The nurseries I had visited were, *ipso facto*, still in business and according to them business was not only good, it was very good. The majority of these nurseries tissue culture propagated for themselves, i.e. plants from culture were potted up in their nursery section and sold along with plants propagated by other means. One nursery that I visited propagated all of its plants by tissue culture; most nurseries propagated part only of their plants by tissue culture.

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The two most expensive parts of tissue culture propagation facilities were the inoculating and incubating areas. Whereas some had designed, or bought, relatively cheap laminar flow transfer chambers many had several expensive laminar flow chambers. I remain sceptical about the need for these chambers and believe that with good aseptic techniques and simple equipment, like glass tunnels, there should be only a low level of contamination due to microbes in the air. But there is no doubt that these laminar flow chambers are very efficient and allow risks which could not otherwise be taken; in addition, I was told that for work in humid sub-tropical regions, such as Florida, they are a necessity.

Personnel Employed in the Inoculating Area. I inquired at various nurseries about first the type of person employed to do the routine inoculation for multiplication and, second, the rate of transplanting that was achieved. It was fairly general for nurseries to train people themselves to do this work but the type of person being sought ranged from those who would do precisely what they had been told to do without any deviations, to one nursery that employed university women graduates only. The first type of personnel averaged less than two explants per minute (or about 600 to 800 explants in a working day) whereas the latter, employing women graduates, averaged seven explants per minute but kept them at the inoculating job for four hours only per day, the remainder of day being spent on other tissue culture tasks. The graduates employed were not necessarily science graduates, in fact I gained the impression that they were mainly arts graduates, and the reason for their dramatic increase in rate of inoculation lay in qualities associated with "critical" thinking. The job is essentially a "mindless" one: with a laminar flow cabinet, the contents of one flask are emptied into a sterile Petri dish, where they are divided into pieces and each piece is then either placed into an individual tube or flask with fresh medium or several to many pieces are placed in large flasks. It is quite easy to train a person to do this and after a short while such a person can do this all day without any great strain on the mind. In the case of graduates, this type of job soon gets very boring and, in my view, leads to one of two results: the graduate either leaves the job, or finds some way to make it more interesting, e.g. becomes more involved in finding quicker ways of doing it, learns more about each species, keeps an eye open for abnormalities. Even so, this work for graduates for eight hours a day, five or six days a week, would eventually become boring to most, but, to me, the single nursery that used graduates had reached a very satisfactory multiplication rate by at least in part realizing that an active critical mind was invaluable and by realizing that a four-hour period of inoculation alternated with a four-hour period of some other activity was a necessity for such graduates.

The Incubation Area. The majority of nurseries visited incubated their cultures indoors in rooms illuminated entirely by artificial light. Energy costs for illumination, heating and cooling, are high, and likely to get higher, and the cost of construction of "shelves" and light banks is also high. Many nurseries used round-bottomed tubes and overhead lights which in turn necessitated sloped tubes and supports for the tubes. Large Erlermeyer flasks (500 ml) were used by orchid and other tissueculturalists, and others used Mason jars and placed these on their sides thus obviating the need for supports and maximizing the amount of light reaching the cultures from overhead lights. One nursery used cheap pie dishes made of aluminum foil and fitted these with (clear) polystyrene lids; another used polystyrene sandwich boxes. One nursery did all of their incubation in Mason jars in a greenhouse, and claimed that although their multiplication rate was slower, their energy costs were much lower and that their cultured plants suffered fewer losses on transplanting to soil.

Preparation Area. I found less thought put into the preparation area than elsewhere in the tissue culture operation. Quite frequently very expensive autoclaves had been bought, but media was still being dispensed by hand or by funnels. Where relatively large volumes of medium per flask were used, e.g. 100-150 ml medium per 500 ml flask, the quickest way of dispensing that I saw was by means of a soupladle. Disappointingly, I saw no signs of a move towards semi-automative methods of vessel-washing, vessel-drying, vessel filling with medium, lid-fitting and autoclaving.

Costing of Tissue Culture Propagation. Details on cost-analysis were as difficult to obtain from tissueculturalists as they are from nurserymen in general. One orchid tissueculturalist said that his laboratory regularly inoculated 84 flasks per day with 50 plants per flask and, after a 7 month incubation period, sold each plant for US $1.50 (final prices varied depending on quantity and species). This laboratory employed three inoculators (who were also shareholders in his company) and there were two or three other people (including himself) helping in other tissue culture activities. Thus each day, US $6,300 (84 × 50 × $1.50) of business was created.

I inquired at several places of the proportion of their time spent on research to improve, for example, the multiplication rate for a species. Mostly, this proportion was very little, or nil, reliance being absolutely on research done under contract or available in scientific publications. One nursery was offering a service in research and development but with a Catch-22: They charged US $35 per hour during the research and development stage and at the end of this stage negotiated a multiplication contract from 18 to 25 cents per plant — but the investor was not told anything about the results of the research, which were the secret of the nursery concerned.

The derivation of a cost for a tissue cultured plant depends on a number of factors, which include the degree of difficulty in achieving its culture, its rate of multiplication, and the normal selling price of the species. One view is that the sale price of a tissue cultured plant should be in excess of that of a plant (of the same cultivar) propagated by other methods. This view is based, I think, on the frequent multi-crowned nature of a tissue cultured transplant which results in the formation of a bushy habit which "fills" the pot better than other propagated material. But another reason for this view is based on the potential of this technique to produce better plants because of its freedom from microbes and viruses — this presupposes that tissue cultured plants have this freedom, and this could not be assumed to hold for the majority of plants presently being propagated by tissue culture.

Conclusions. The value of this study tour lay in the detailed discussions held with many people with experience in commercial tissue culture operations. Ideas for cost-cutting possibilities had been developed prior to this tour (2), and many of these became points for discussion during the tour. More and more, I see the need for semi-automation in the preparative stages, and the need to use solar energy for incubation. Procedures, including constitution of the culture medium used for a particular species, might have to be modified when the decision is made to use greenhouse rather than indoor, controlled environment facilities.

Many of the discussions led to increased emphasis being placed on certain areas of research (1). These areas include: (1) embryogenesis and morphogenesis, (2) stability of genotypes, (3) organ culture, (4) juvenility, (5) constituents of culture medium, (6) incubation conditions, (7) genotype responses, (8) nature of the explant, (9) hardening-off, (10) "finger-printing" of clones, (11) germ plasm preservation, (12) mutation breeding with adventitious buds. These are not listed in order of priority. Increased knowledge in all of the above areas of research is likely to bring us closer to the day when we can tissue culture propagate all species.

Aknowledgements. Grateful acknowledgement is made to the N.S.W. Association of Nurserymen Ltd. who were the sole sponsors of this study tour.

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PROGRESS TOWARD CLONAL PROPAGATION OF EUCALYPTUS SPECIES BY TISSUE CULTURE TECHNIQUES

PAMELA K. BARKER, R.A. de FOSSARD and R.A. BOURNE

Department of Botany
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Abstract. Large numbers of clonal trees of eucalyptus species have been obtained by culturing nodes of seedling or coppice material. Adult nodes of two species have successfully produced multiple buds. Shoot systems have been established from such buds and research is being directed towards the establishment of healthy plants by inducing these shoots to form roots.

Culture media are discussed and the composition of the most successful media for the production of multiple buds and for rooting are given.

Problems concerning microbial contamination of field collected material are discussed and methods for reducing consequent losses are suggested.

A routine for the establishment of test tube plants in soil is described.

REVIEW OF LITERATURE

A number of attempts have been made to propagate *Eucalyptus* species by tissue culture techniques (4,7,8,9,10). Successful regeneration from lignotuber material has been reported for *E. citriodora* (1) and from seedling hypocotyl callus for *E. alba* (11). Two approaches have been used to propagate from nodal cultures; one is to produce multiple buds and shoots in aseptic cultures and then to induce these shoots to form roots (8,9,10). The other approach is the direct induction of roots and shoots on an initial nodal explant (2,3,7,10). Seedling nodes of *E. ficifolia* have been induced to form multiple buds and subsequently roots (8,9,10). Adult nodes of *E. ficifolia* and *E. polybractea* and seedling nodes of *E. regnans* have produced multiple buds (10). Suitable concentrations of chemical constituents of multiple bud media have been established by the broad spectrum approach (5,6). *E. grandis* plants have been successfully established from cultured nodes of seedlings, coppice and young trees (2,3,7,10). Microbial contamination has been a serious problem with field-collected material (8,9,10).

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MATERIALS AND METHODS

Culture Media. *Multiple Bud Medium.* A suitable medium for the production of multiple buds and the growth of shoots from *E. ficifolia* seedling nodes was derived from Broad Spectrum medium MHMH (5,6,8). This medium (Medium A, Table 1) differed from MHMH in having 100μM Fe instead of 50μM and in having IBA as the sole auxin at a concentration of 5μM instead of 10μM. Medium A is the same as Medium 1 reported in (10) except that the concentration of IBA has been changed from 10μM to 5μM.

Table 1. Medium A. General Multiple Bud Medium.

MINERALS		
Macronutrients	(mM)	NH_4NO_3 (10); KNO_3 (10); NaH_2PO_4 (1); $CaCl_2$ (2); $MgSO_4$ (1.5).
Micronutrients	(mM)	H_3BO_3 (50); $MnSO_4$ (50); $ZnSO_4$ (20); $CuSO_4$ (0.1); Na_2MoO_4 (0.1); $CoCl_2$ (0.5); $FeSO_4$ (100); Na_2EDTA (100); Na_2SO_4 (650).
AUXINS	(μM)	IBA (Indole butyric acid) (5).
CYTOKININS	(μM)	Kinetin (1); BAP (Benzylaminopurine) (1).
CARBON SOURCE	(μM)	Sucrose (120).
GROWTH FACTORS AND AMINO ACIDS		
	(μM)	Inositol (600); Nicotinic acid (40); Pyridoxine HCl (6); Thiamine HCl (40); Biotin (1); D-Ca-Pantothenate (5); Riboflavin (10); Ascorbic acid (10); Choline Chloride (10); L-Cysteine-HCl (120); Glycine (50).
AGAR (g/l)		Difco Bacto-Agar (8)

Rooting Medium: Medium B (Table 2) was selected by combining the medium of Cresswell and Nitsch (3) with Broad Spectrum medium MHZH to promote root and shoot growth in E. grandis nodes. Medium B is a simplified form of the combination medium reported in (10). As Medium B also induced excellent roots on *E. ficifolia* seedling shoots it was therefore used in experiments with four species.

Table 2. Medium B. Rooting Medium.

MINERALS		
Macronutrients	(mM)	$Ca(NO_3)_2$ (2.1); KNO_3 (2.2); KH_2PO_4 (0.92); NH_4NO_3 (1.0); $MgSO_4$ (0.66).
Micronutrients	(μM)	H_3BO_3 (160); $MnSO_4$ (110); $ZnSO_4$ (43); $CuSO_4$ (0.1); Na_2MoO_4 (1); $FeSO_4$ (100); Na_2EDTA (100).
AUXIN	(μM)	IBA (5).
CARBON SOURCE	(mM)	Sucrose (60).
GROWTH FACTORS AND AMINO ACIDS		
	(μM)	Inositol (620); Nicotinic acid (45); Pyridoxine HCl (3.0); Thiamine.HCl (5.5); Biotin (0.3); Folic Acid (1.1); D-Ca-Pantothenate (0.5); Riboflavin (1); Ascorbic Acid (1); Choline Chloride (1); L-Cysteine.HCl (12); Glycine (32).
AGAR (g/l)		Difco Bacto-Agar (8).

Culture Tubes. Aliquots (10 ml) of culture media were dispensed and autoclaved in transparent polycarbonate tubes with screw caps.

Plant Material. Seedling nodes were either prepared aseptically (8) or taken from young potted plants and disinfested in the usual manner (5,8,10). Adult nodes gave best response in culture when selected from healthy, well watered, well fertilized trees.

Species. Seedling nodes of *E. ficifolia*, *E. grandis* and *E. regnans* were planted under aseptic conditions on Medium A or Medium B. Field collected adult nodes of these three species and also *E. polybractea* were treated similarly.

Incubation. Explants were incubated in the dark for at least 24 hours, as this appeared to eliminate or reduce brown exudate formation in the culture medium (3). All cultures were then incubated in a room containing banks of fluorescent lights. Light intensity was about 300 microeinsteins/m^2/sec. The cultures received 12 hours light/12 hours dark at approximately 25°C.

Dissection and Subculture. The successful establishment of multiple buds and shoots required that most explants were dissected and subcultured a number of times on Medium A (Figure 1, Figure 2, Figure 4).

Establishment. Where complete regeneration was achieved, the plants were established in pots.

RESULTS

Progress with Individual Species:

E. ficifolia

Clonal propagation from seedlings. Aseptic seedling nodes produced multiple buds on Broad Spectrum Medium MHMH (8). These buds were subcultured onto Medium A where they proliferated with great vigour. After three passages on this medium the number of cultures had increased from 20 to over three hundred. The multiple buds developed from a mass of green basal tissue and formed a large cluster on the medium. When a cluster of buds was dissected and small pieces containing several buds transferred to fresh medium, further buds developed. Usually, one bud in the new cluster developed into a leading shoot with very small green leaves (Figure 2). Leading shoots were removed and placed on rooting medium (Medium B, Table 2) and the remaining buds were returned to fresh Medium A. In two to three weeks vigorous roots with abundant root hairs developed on most explants on Medium B. Sometimes poor roots and/or teratomas (callus-like projections) developed. When these occurred, the explants were removed

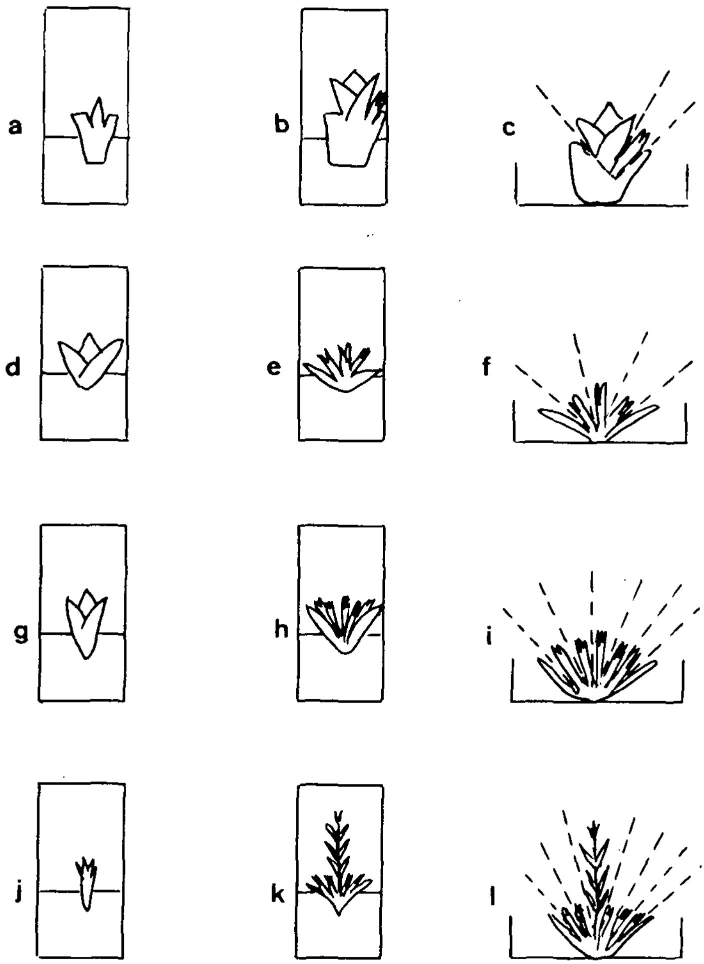

Figure 1. **(a-l)**. Stages in the development of multiple buds and shoots from nodes of adult *E. ficifolia*.
(a) Freshly excised node on medium A. **(b)** Main bud opened. Accessory bud developed. Any other buds which appeared at this stage were very small. Stem base made callus and became swollen. **(c)** Explant was removed to sterile Petri dish and buds dissected. Broken lines show where incisions were made. Most of the stem base was removed. **(d)** Each bud was planted on fresh medium A. **(e)** Two or three buds developed. **(f)** Buds were dissected. Outer leaves were discarded. **(g)** Each bud was planted on fresh medium A. **(h)** Several buds developed. **(i)** Buds were again dissected; outer leaves discarded. **(j)** Each bud was planted on fresh medium A. **(k)** A number of buds and a leading shoot with very small green leaves developed. **(l)** The leading shoot was removed and planted on medium B (rooting medium). The remaining buds were dissected and planted on fresh medium A.

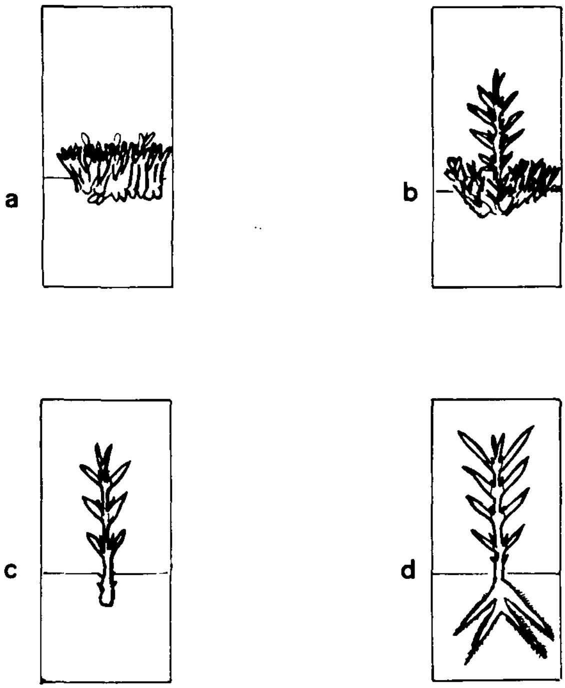

Figure 2. (a-d). Development of whole plant from shoots of seedling *E. ficifolia*.
(a) Multiple buds grown on medium A. **(b)** A leading shoot developed. **(c)** The leading shoot was excised and planted on medium B. Leaves at the base of the stem were trimmed away. ***(d)** Vigorous roots with abundant root hairs appeared in 2-3 weeks.

* Sometimes poor roots and/or teratomas developed. This condition was corrected by removing the explant, trimming the base of the stem with a scalpel and replanting on fresh medium B. Good roots generally appeared in about 10 days.

from culture, the stem bases surgically trimmed and the explants placed on fresh rooting medium. Vigorous roots then usually appeared in about ten days. If buds were placed on Medium B without forming good shoots, roots were generally obtained, but the shoots remained too small for the successful establishment of the plants. Many rooted plants with several leaves were successfully established in pots.

Clonal propagation from adults. Nodes taken from 25 year old Melbourne trees were successfully cultured on Broad Spectrum Medium MHMH. Growth was very slow. These nodes were transferred to Medium A where faster, more vigorous growth and multiple buds were observed. Newly cultured nodes were placed directly on Medium A, where they produced multiple buds. The production of shoots from adult nodes required the repeated dissection and subculturing of buds (Figure 1) until all traces of original adult tissue had been discarded. The small leaved shoots which then emerged were identical in appearance with the shoots produced by seedling cultures. The only shoot which has so far been placed on Medium B produced a root after two weeks. Adult nodes placed directly on Medium B without prior subculturing on Medium A failed to root.

E. grandis

Clonal propagation from seedlings, coppice and young trees. Nodes from glasshouse grown seedlings, coppice and young trees successfully formed plants when placed directly on Medium B. Buds started to open in one to two weeks and roots formed in the third and fourth weeks. *E. grandis* roots had fewer and smaller root hairs than *E. ficifolia* rooted on the same medium. *E. grandis* nodes cultured on Medium A developed leaf callus, and the shoots eventually abscissed.

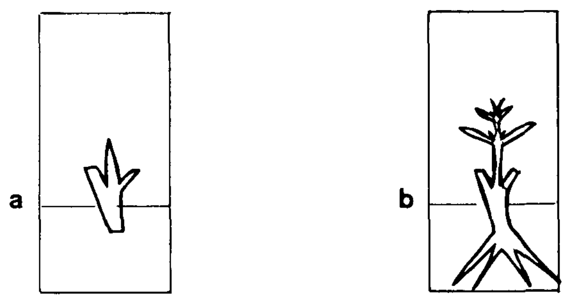

Figure 3. **(a-b).** Development of whole plant from node of seedling, coppice or young tree of *E. grandis*.
(a) Freshly planted node on medium B. **(b)** A single shoot developed in about 2 weeks and roots developed from 3-4 weeks.

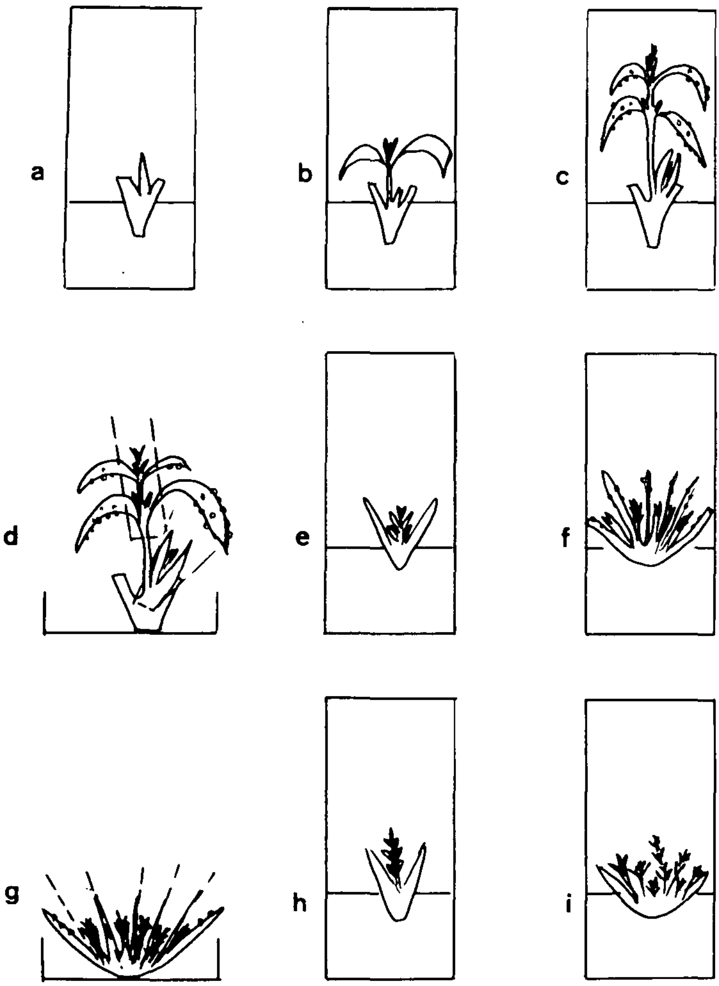

Figure 4. **(a-i).** Development of multiple buds from nodes of seedling or young tree of *E. regnans*.
(a) Freshly planted node on medium A. **(b)** Bud opened. Leaves were relatively large. Accessory bud appeared. **(c)** Shoot developed on long stalk. Accessory bud developed. Largest leaves developed a white sugary type of callus. **(d)** Callused leaves were removed and remaining apical shoot dissected. Accessory bud with some basal tissue was also removed. **(e)** Each shoot was transferred to fresh medium A. **(f)** Accessory bud gave rise to more new buds than the apical shoot. Some leaves continued to form callus. **(g)** Callused leaves were removed and developing buds were dissected. **(h)** Buds were placed on fresh medium A. **(i)** Multiple buds appeared without large callused leaves.

Clonal propagation from adult trees. No success has been achieved with adult material. Nodes were obtained from forest trees near Coffs Harbour, and invariably the cultures had to be discarded because of microbial contamination.

E. regnans

Clonal propagation from seedlings and young trees. Nodes from large seedlings (50-150 cm high) produced shoots on a number of media including Medium A and Medium B. Leaf callus was common on all cultures. However, by dissecting and subculturing on Medium A (Figure 4) multiple buds free from callus were obtained. In contrast with *E. grandis* no roots developed when nodes were placed directly on Medium B. In one nodal replicate out of ten a shoot with large leaves and a small root formed on broad spectrum Medium MHZH.

Clonal propagation from adult trees. Some nodes from adult forest trees produced shoots on a number of media including Medium A and Medium B but all cultures were eventually lost as a result of microbial contamination.

E. polybractea

Clonal propagation from adult trees. Nodes from adult trees have formed small shoots and multiple buds on Medium A.

Establishment of Cultured Plants in Soil. "Hardening off" was a critical period in the propagation of plants by tissue culture techniques and a considerable amount of intensive care was necessary. When the plants had developed vigorous shoots and roots and a total length of approximately 6-10 cm, the lids were removed from the culture tubes. The plants remained in the open tubes for several days. a few drops of water were added daily to each tube to prevent desiccation of the media and water stress to the plants. The possible introduction of microbial contaminants from the air at this stage was considered to be unimportant.

The plants were then removed from the tubes. Excess media was washed off the roots and the plants were placed in a sand/loam mixture (approximately 1 part sand and 1 part loam) in small pots and thoroughly wetted with a solution of commercial nutrients such as "THRIVE" or "ZEST". A covering of transparent glass or plastic was placed over the plants to maintain humidity and thus to prevent wilting. The covered plants remained for 24 hours in a shaded position and were then transferred to a shade house which screened 80% of light. The covers were removed after about two days but were replaced again for a further day or two if any plants were seen to wilt. New leaves which developed after potting were less prone to wilting than test tube leaves. When plants were established and making visible growth under sheltered conditions, they were gradually removed to positions of increasing light intensity. Leaf scorch was observed in cases where plants were removed from the shade house directly to positions of full, open sunlight.

DISCUSSION

The original objectives of our research with *E. ficifolia*. *E. grandis* and *E. regnans* was not only to clonally-propagate selected individuals by tissue culture (TC) but also to produce plants which would flower earlier than seed-propagated material. In the case of *E. ficifolia*, the hope was that TC-propagated plants for sale in nurseries could be seen to have red flowers or orange flowers or some other color of flower at the time of their purchase. In the cases of *E. grandis* and *E. regnans*, the reason for TC-propagation was to provide clonal material from superior trees for early seed production in isolated seed orchards. The fulfilment of these aspirations appeared to be dependent on the successful induction of root formation on material from adult trees, along with the maintenance of the adult physiological state in the rooted material. Our research in 1977 revealed that although seedling material could be used to select cultural conditions suitable for shoot and multiple bud development on nodes from adult trees, the result from experiments with seedling material relative to the induction of rooting could not be extrapolated to adult material. A culture medium that induced root formation on all seedling cultures and subcultures of *E. ficifolia* induced basal callus with adult nodal cultures. These findings led to research directed at two methods for the achievement of clonal propagation, both involving techniques to obtain juvenile material.

The first method involved the mutilation of adult trees at their base to induce the development of lignotuber or epicormic buds, that is to obtain shoots or coppice with juvenile characteristics. This seems to be a worthwhile approach with many species of Eucalyptus (including *E. ficifolia* and *E. polybractea*) but is less effective with non-lignotuberous species such as *E. grandis* and *E. regnans*. Shoots or coppice thus formed would then be used as sources of explants and, because of their juvenile character, might more easily be induced to form multiple buds or roots in culture by using media which induces these organs on seedling material.

The second method involves the culture and repeated subculture of nodes from adult trees on multiple bud inducing medium in the hope that this would lead to a change in their physiology, so that at some point in their subculture the buds would respond to rooting medium (developed for seedling cultures) by forming roots. If this happened it might be because the physiology of the buds had changed from their initial adult status to one similar to that in seedlings; if this were the case, then our original hope of achieving earlier flowering might be a forlorn one, but at least clonal propagation and multiplication would have been achieved.

Both of the above methods are showing signs of success but both are being hampered by the serious microbial contamination problem associated with numerous insect pests which attack Eucalyptus trees growing in the open in Australia. Microbial contamination is greatly reduced when nodes from greenhouse grown Eucalyptus trees are excised and cultured. A protocol for minimizing the field contamination problem is being tested which, in essence, involves putting a "greenhouse" around the material to be excised for culture. The "greenhouses" being tested are the glacine bags and sausage-skins used by plant hybridizers. The procedure is to cut the tree to induce new growth and to enclose this new growth in a bag; the parts of the tree treated are first sprayed with insecticides, such as Rogor, and fungicides, such as Captan. The new growth is later excised and cultured following a standard disinfestation treatment (see Methods) and all non-contaminated cultures will be put on to multiplication medium so as to obviate the need to return to the tree for further material. In other words, in Australia, because of the big insect and associated microbial problem, a lot of time and preparation has to be put into obtaining aseptic Eucalyptus cultures, but that once these have been obtained they become the nuclear stocks for particular genotypes, and can be maintained as such in culture tubes.

A great deal of work remains to be done to test and perfect these techniques, and special difficulties are associated with non-lignotuberous species of Eucalyptus such as *E. grandis* and even more so with *E. regnans*. The signs are that research on the four species described in this paper will be applicable to many species of Eucalyptus and, with some modifications, to many species of shrubs and trees.

One part of this research which might be put into practice immediately is the TC-propagation of seedling material. Seedling clones, even though their potentials are initially unknown, could be valuable in the following circumstances:

(a) Progeny from valuable controlled cross experiments and from elite seed orchards could be multiplied rapidly for commercial purposes or for further experimental work;

(b) Seeds of some species are rare, difficult to collect and/or expensive; unlimited numbers of plants can be obtained by TC-propagation of seedlings from very few seeds.

(c) Representatives of a number of seedling clones could be tested at a particular site and characters such a vigor, pest resistance, suitability to soil type and climate could be noted; further large numbers of well suited plants could later be obtained from the original TC "clone bank".

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BIOLOGICAL CONTROL OF GLASSHOUSE PESTS

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Sufficient information is now available about the biological control of glasshouse pests for it to be developed commercially as a management practice. Not only would such a scheme reduce the occupational hazards of the glasshouse worker to toxic chemical substances to which he is frequently exposed but it should also result in an increase in plant growth. It has also been the experience of European glasshouse growers that it results in more effective control because the dense planting makes adequate coverage of high volume sprays difficult.

The most persistent pests in glasshouses in southern Australia are the greenhouse white-fly (*Trialeurodes vaporariorum* Westwood), the long-tailed mealy bug (*Pseudococcus longispinus* Targ.), and two spotted spider mite (red spider) (*Tetranychus urticae* Koch). At times, aphids, usually the green peach aphid (*Myzus persicae* Sulzar), can also be a problem. Many and various insecticides are recommended and used regularly against one or more of these pests. However, all of these pests usually have associated with them a compliment of parasites and/or predators that, in the absence of insecticides, keep them under reasonable control. The use of an insecticide applied to control any one of these pests disturbs the natural balance of the others and they all become pests for which the grower is committed to regular insecticide applications. This remains economical while the insecticides are effective but eventually resistance develops and no control is possible.

The ever-increasing problems caused by the development of pesticide resistance in strains of two spotted spider mites and aphids has highlighted the need to reduce the selection pressure resulting from chemical control programs. The problem is particularly acute where the greater proportion of propagated plants are grown by a few large-scale producers who apply insecticides frequently in an effort to dispatch clean plants to their customers. Once pesticide tolerant strains of pests develop they are distributed to other nurseries, retail outlets and ultimately to the public at large. This method of production and distribution accounted for the rapidity with which organophosphorus resistance developed throughout the United Kingdom in 1964 (4). Even a partially successful biological control program may drastically reduce the number of pesticide applications which will, in turn, extend the life of the materials used. To date, most attention has been directed to insect natural enemies but the use of fungi, bacteria and viruses is also possible. The bacterial disease, *Bacillus thuringiensis*, is already available commercially in this country for the control of many kinds of caterpillars. The first attempt to develop biological control in commercial glasshouses was pioneered by Speyer (8) who used the parasite *Encarsia formosa* as a control for the whitefly, *Trialeurodes vaporariorum*. Within a few years this small wasp was being distributed to over 800 nurseries every year. There were two major reasons for the decision to discontinue this distribution scheme after the war. Firstly, the development of DDT afforded, for the first time, a really efficient and safe chemical control, and secondly, the rearing technique, based on large-scale glasshouse production, had fallen under some criticism as other pests such as spider mites and thrips were frequently, inadvertently, distributed to growers on the leaves carrying the parasitized whitefly scales. No further developments took place until Doutt (1) demonstrated that, on commercially grown gardenias, the mealy bug *Planoccoccus citri* could be successfully controlled by a combination of two encyrtid parasites *Leptomastix dactylopii* Howard, and *Leptomastidea abnormis* Girault, and the predatory ladybird *Cryptolaemus montrouzieri* Mulsant. Since that time a great deal has been discovered about the control of glasshouse pests. Today the management of these pests based upon the mass production and periodic colonization of various natural enemies is commercially practiced in England and the Netherlands (4). There is no reason why such practices could not be adopted in Australia. Natural enemies of our main glasshouse pests already exist in this country. The effective utilization of them in the glasshouse depends on creating favorable conditions for them to operate. In general, this means the establishment of the necessary balance early, and the judicious use of selective chemicals, especially fungicides, when necessary.

Control of Whitefly. Parr (5) obtained complete control of whitefly in 19 weeks by releasing the parasite *Encarsia formosa* Gahan at 1 per sq. ft. in a small scale experiment. In a large-scale trial on cucumbers Hussey in 1969 achieved control on 75% of the plants in 12 weeks. More recently, Gould, quoted in Hussey & Bravenboer (4), completed an exactly comparable experiment and achieved complete control on all plants. The effectiveness of the parasite is influenced by temperature. A minimum night temperature of 15°C is adequate as long as there is a reasonable number of sunny days to raise the mean temperature above 18°C. Given these conditions *Encarsia* can be safely used to control whitefly on all except the most highly pubescent hosts (3). *Encarsia* is well-established as a parasite of greenhouse whitefly in Australia.

Control of Mealy bug. The long-tailed mealy bug *Pseudococcus longispinus* in Australia has recently been studied by Furness (2) who found a number of native parasites and predators associated with it. The parasites include *Anagyrus fusciventris* (Girlt.), *Moranilia* sp., *Ophelosia crawfordi* (Riley) and *Hungariella pretiosa* (Timb.). The predators include *Chrysopa* sp, *Micromus tasmaniae* (Walk.), *Rhizobius ruficollus* (Lea) and *Stethorus* sp. In the absence of persistent broad spectrum insecticides the natural enemies reduce the numbers of mealy bugs to well below the economic threshold. If chemical treatment is required then aminocarb (Matacil (R)) should be used as it is very short-lived (1 day) and has a minimal effect on parasites & predators.

Control of Aphids. In Australia there are two very effective parasites of aphids, namely *Aphelinus* sp. and *Aphidius* sp., the former being very common and effective in glasshouses. Predators commonly associated with aphids are the ladybirds *Leis conformis* (Boisduval) and *Coccinella repanda* Thunberg, the green lace-wing *Chrysopa* sp. and the brown lace-wing *Micromus tasmaniae* (Walk). Richardson and Westdal (7) controlled the aphid *Myzus persicae* in glasshouses with *Aphelinus semiflavus* Howard. Wyatt (9) showed that even small numbers of *Aphidius* sp. can check an aphid's increase in 8 weeks and almost exterminate it within 15 weeks.

Control of Spider Mites. Mites are probably the most persistent and most difficult pests that have to be controlled in the glasshouse. Their control is made difficult by the necessity to completely cover the surface area of the plant. It is made more difficult by the fact that mites have become resistant to most of the chemicals that are available for control. In Europe these mites have been successfully controlled by introducing the predatory mite *Phytoseiulus persimilis* (Athias-Henriot). In Holland, biological control of mites was successfully achieved in about 50 nurseries during 1969 (4). A single grower reared the predator and sold it to others.

The predatory mite *Typhlodromus occidentalis* Nesbitt was introduced into Australia by the C.S.I.R.O. in 1972. It has been mass-reared and released into fruit gardens. It has been so successful in Victoria that the Department of Agriculture has a very ambitious mass-rearing program under way. It has been less spectacular in South Australia but has achieved satisfactory commercial control in many localities. However, in South Australia two spotted mite is not a pest in the absence of persistent broad spectrum insecticides. This is due principally to two native ladybird predators, *Stethorus loxtoni* Britton & Lee and *S. vagans* Blackburn. *S. loxtoni* is a very efficient predator and is capable of keeping mite populations well below the economic injury level. It can be easily reared and when tested in California under glasshouse conditions it was able to control a well-established mite population within 3 weeks (6). Unfortunately it is very susceptible to insecticides so its use to control mites depends on the judicious use of insecticides or the adoption of biological control practices for the other pests that occur in glasshouses. The undesirable side effects of chemical applications can be avoided by a strategy based on a separation of chemical and biological controls in time or space. For instance, "spot" chemical treatment of localized outbreaks of less serious pests. The most practical method to avoid the complications of the integration with chemicals would be to control the principal pests on a crop by the simultaneous use of several natural enemies. The success of the first attempts at biological control on a commercial scale in England and Holland suggests that the technique could be extended. However, the commercial future depends on the development of economic and reliable rearing techniques to provide the required number of natural enemies. The effective utilization of biological control will demand more skill on the part of the grower but the rewards can be substantial. Yield increases of glasshouse cucumbers of at least 20%, amounting to $7200 per acre, have been reported where biological control was used (4). These yield increases are attributed partly to superior red spider mite control by the predatory mites as compared to chemical control and partly to the lack of phytotoxicity under a biological control program. The alternative chemical method, frequent applications of petroleum oils and acaracides causes plant damage. Integrated control of glasshouse cucumber pests is now practiced commercially. Similar benefits could occur in other glasshouse crops.

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PROPAGATION OF DAPHNE ODORA

WILLIAM C. POYNTON

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Clayton, Victoria

The most important aspect of *Daphne* propagation is the use of clean healthy stock plants. Spraying regularly with systemic fungicides and insecticides is essential. Also a regular fertilizing program is necessary. The fertilizer must contain trace elements.

Cuttings are taken from the 1st week in September (spring) to the 1st week in April (mid-autumn), using a very sharp knife or razor blade. I recommend a throw-away Stanley knife.

Soft cuttings taken are 1 to 3 cm in length not including leaves. As each cutting is taken it is submerged in a bucket of warm Benlate solution of recommended strength for up to 10 minutes. Cuttings are transferred to 10" pot to drain where they may be left up to 24 hours.

The next step is to remove the bottom leaves carefully by pulling them off (*not* cutting off).

Cuttings are then placed in copper naphthenate-treated Victorian seedling boxes (flats) containing a mixture of 25% peat and 75% sand with 64 well-spaced cuttings to a box. They are watered in with 1/2 strength Benlate.

The boxes are placed under mist in an Igloo or poly house and are covered with a terylene net which has been previously dipped in copper naphthenate. The net is removed approximately 2 weeks later, depending on weather conditions. The net is removed on a cool day and replaced if the weather becomes too hot.

Mist is applied 10 seconds every 20 minutes and the Igloo temperature may reach 35°C.

Cuttings can be taken from young plants only 12 months old. This improves the plants and also gives a good source of extra cuttings. Of 12,000 cuttings taken, 10,500 were potted and 700 returned and potted later.

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The next step is to remove the bottom leaves carefully by pulling them off (*not* cutting off).

Cuttings are then placed in copper naphthenate-treated Victorian seedling boxes (flats) containing a mixture of 25% peat and 75% sand with 64 well-spaced cuttings to a box. They are watered in with 1/2 strength Benlate.

The boxes are placed under mist in an Igloo or poly house and are covered with a terylene net which has been previously dipped in copper naphthenate. The net is removed approximately 2 weeks later, depending on weather conditions. The net is removed on a cool day and replaced if the weather becomes too hot.

Mist is applied 10 seconds every 20 minutes and the Igloo temperature may reach 35°C.

Cuttings can be taken from young plants only 12 months old. This improves the plants and also gives a good source of extra cuttings. Of 12,000 cuttings taken, 10,500 were potted and 700 returned and potted later.

I believe that this method of propagation from very young micro seedlings helps to prevent spread of viruses, of which there are many.

NOTE: No hormone or bottom heat is used. Copper naphthenate (3%) mixed with 50% kerosene is used for treating the boxes and net. The boxes measure 71cm × 15cm × 5cm.

ROSE ROOTSTOCK, 'DR. HUEY', IN SOUTH AUSTRALIA

DEANE M. ROSS

A. Ross & Son
321 Sturt Rd., Bedford Park
South Australia 5042

South Australia is one of the main rose producing states of the Commonwealth, especially in proportion to its population. According to the latest statistical collection in 1974-75, almost 600,000 rose plants were grown; over half of these were sent interstate. The traditional rootstocks have been *Rosa indica major* (commonly but incorrectly called 'Boursalt') for dwarf budding and *R. canina* for stem or standard production. Both of these rootstocks suffer from certain disadvantages. *R. indica major* can give very erratic bud-take during autumn budding and will sucker under some conditions. *R. canina* also suckers badly and gives unreliable strike of cuttings.

For these reasons, several South Australian growers are turning to the rootstock 'Dr. Huey' for both dwarf and stem production.

'Dr. Huey' was originally bred as a garden rose in 1914 by G.C. Thomas in California, U.S.A. and it was not until 1940 that its potential as a rootstock was recognized but by the early 1950s it was being grown as the major stock in California. It tolerates alkaline soil and dry harsh summers very well — the same conditions experienced in Southern France, Spain, Italy, and, of course, South Australia, where it was first tested in small quantities about 1955. Nothing more was done with it until the early 1970's when a few nurserymen, including our company, decided to tests its potential as an alternative for growing two-year-old roses, in order to overcome the often disastrous bud take of *R. indica major* for late summer budding.

Since that time it has proved to be very suitable for South Australian conditions, both as a nursery plant and as the eventual garden plant. Its features may be summarized as follows:

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Since that time it has proved to be very suitable for South Australian conditions, both as a nursery plant and as the eventual garden plant. Its features may be summarized as follows:

Growth — annual cane up to 2m in length, fairly upright habit, maintaining a good thickness throughout its length, but sometimes tending to be rather thick at the base.

Bark is smooth and with only a few thorns. The bark separates and bends back easily for T-budding, and can be budded quite soon after the cuttings have been planted out — from about the half-dozen leaf stage onward.

Foliage is round and glossy, of orthodox form. Unfortunately, it is susceptible to powdery mildew and rose rust infection — its main disadvantage — but since the advent of some excellent systemic fungicides for these diseases, this is not the problem that it used to be.

Habit is apical dominant, so much so that stem roses need not to be de-eyed above ground level, as a couple of rubbings at the appropriate time will control side shoots adequately.

Roots radiate evenly from the callus and form quite a stout ring of roots with plenty of supporting fibre. However the roots on two year plants may be almost too large for easy packing!

Strike percentage of cuttings is usually well in excess of 90% provided the soil is warm and not excessively wet, such as during late summer and autumn planting.

De-eyeing is easy because of the fairly wide spacing of nodes, which are nicely prominent. However, the wood is tougher than usual and requires a little more effort to make each cut.

'Dr. Huey' makes far better growth in container culture than *R. indica major* and since there is a steady movement to containers in South Australia it appears to be the best proposition to date. Our company has planted cuttings of 'Dr. Huey' into containers most months of the year and found that they strike well in all but the wettest (and coldest) periods and, conversely, have given fair results when planted without shade or mist during a 35°C heat wave in late January.

For both field and container production 'Dr. Huey' can be headed two or three weeks after budding and be forced into a plant almost the same size as *R. indica major* (which is a notorious stock for forcing).

I appreciate that different climates and soils call for different rootstocks, but I am confident that 'Dr. Huey' rootstock will prove suitable for roses in the greater area of Australia.