Waste Management in Horticulture—The Global Perspective

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INTRODUCTION

Waste management could easily be the most significant issue confronting world horticulture by the year 2000. Some countries are already addressing the problems of pollution of waterways, leaching of nutrients, and recycling of packaging materials, but there will be increasing pressures for horticulturists to manage all the waste from production systems.

Society is demanding that the responsibility for disposing of waste must lie with those who create it and that waste products must not be dumped into the environment.

Words which are sometimes interchangeable with “waste” include “refuse”, “superfluous”, “rejected”, and “worn out”. Waste products can be defined as “materials produced or used in a process, that are discarded during or on the completion of that process.”

This paper reviews some of the horticultural waste problems around the world and indicates strategies in use or being developed to address the problems.

PHYSICAL WASTE

This category of waste includes packaging, polystyrene and plastic containers, rubber, chemical containers, polythene covers from greenhouses, fertiliser sacks, etc.

In Europe an EU directive on packaging waste has determined that:

- 90% by weight will be recovered
- 60% by weight will be recycled
- 10% by weight is the maximum to be allowed into landfills

Germany has taken a leading role based on a “polluter pays” principal. A “take-back obligation” is used with horticultural packaging being classified as either transport or sales. Protocols for transport packaging require exporters or German importers to make arrangements to have spent packaging collected and/or recycled by specialist companies.

In 1993, 50% of waste packaging collected in Germany was shipped overseas for re-processing. More than 4.5 million tonnes of used packaging was collected, of which nearly 4 million tonnes was fit for recycling, including 300,000 tonnes of plastic.

Cartons which are strengthened and waterproofed with wax coatings create difficulties with recycling but Australian and overseas manufacturers are developing improvements. There are additives which permit separation of wax from paper fibres and thus improve the re-pulpability of wax-coated corrugated fibreboard.

Australian carton manufacturers have been able to reduce the quantity of wax on containers while retaining strength and waterproofing.

German research with composting different types of waxed fibreboard has shown that the composted material can be used satisfactorily in medium quantities in plant growing media. Contamination with heavy metals, from printing ink, and boron can occur when large quantities of composted wax fibreboard are used.

Strict regulations in the UK restrict the disposal of plastic, used polythene covers from greenhouses, plastic fertiliser sacks, etc. so that burning and landfill dumping are being replaced by collection by specialist companies.

Pesticide manufacturers and suppliers in Canada operate a rinsing, collection, and recycling scheme for empty plastic containers.

Expanded polystyrene (EPS) presents severe waste management problems. The high volume : weight ratio makes it difficult to handle. Japan banned EPS packaging in 1994. Disposal of EPS waste creates problems at wholesale fruit and vegetable markets since it is being banned at landfill sites. Woolworths produce distribution centre at Homebush in Sydney has a polystyrene shredding facility and there are some opportunities for recycling EPS into growing media.

Re-usable polypropylene crates are being developed and used for fresh produce distribution. They are used in Europe, South and North America, Israel, Australia, and North Africa. The crates can be used to carry produce throughout the marketing chain, from farm to the retail outlet. Many re-usable crates fold flat to one-fifth the original volume for return.

Rubber tyres are being recycled into products which may be useful in horticulture. Pacific Dunlop in Australia is utilising technologies from the U.S.A. to convert shredded tyres into weeping irrigation hose and into non-slip pavers. A national collection network delivers used tyres to shredding plants where the rubber is separated and ground into granules of different sizes. These are then formulated into new products.

CHEMICAL WASTE

Contamination of water courses and ground water with irrigation run-off, nutrient leachates, or pesticide residues is a major issue for horticultural industries. There are R & D activities in Europe, North America, Japan, and Australasia to determine the extent of the problem and to develop strategies to minimise pollution.

A recent survey showed that approximately 10,000 ha of containerised woody nursery stock are grown in the U.S.A. Annual rates of nitrogen application range from 188 to 866 kg per ha with an estimated retention rate of 5% to 8% within the plants. Further estimates indicate that 18,500 tonnes of nitrogen are applied each year with 92% being a potential pollutant. More than 48% of the leached nitrogen is discharged to effluent.

The Dutch government is committed to reducing pollution from glasshouses and has developed memoranda based on growing all plants in closed, re-circulating systems separate from the soil. Targets for the year 2000 aim to:

- Reduce nitrate and phosphate leaching to surface water by more than 50%
- Reduce the use of chemical plant protection materials by 50%
- Reduce the use of soil disinfection products by 75%
- Increase energy efficiency by 50%
- Reduce carbon dioxide emissions by 5%

UK surveys have shown significant levels of nitrates and phosphates in water supplies and high levels of herbicides, including 2,4-D, MCPA, and MCPB, in surface and underground waters. More that 140,000,000 containerised hardy nursery stock plants are sold annually. Many are grown in conditions which favour the pollution of waterways through severe leaching.

Drinking water limits set by the EU are 10 mg litre^{-1} of nitrogen and 2.18 mg litre^{-1} of phosphorus. The Organisation for Economic Co-operation and Development (OECD) defines 0.09 kg litre^{-1} P as the level at which algae will flourish. Phosphorus is an essential nutrient for algae, contributing to the eutrophication of waterways.

Trials with containerised nursery stock in the UK captured leachates from plants grown with different levels of controlled release fertilisers in containers of open structured growing media standing on gravel beds and watered with overhead irrigation. Nitrate levels ranged from 100 to 200 mg litre^{-1} N while phosphate figures varied from 10 to 20 mg litre^{-1} P. High summer temperatures increased the nitrate release rate.

Several countries are utilising the pollution-treating properties of wetlands. The value of natural swamps and peat fens is being exploited and artificial wetlands are being constructed. Lockyer Seedlings in Australia are planting flaxes, reeds, and rushes as a living filter systems. UK authorities are using waste ash from power stations to construct reed beds which clean up polluted run-off water.

Researchers at the Institute for Horticultural Development, Knoxfield, Victoria, *are monitoring run-off water from 30 nurseries and cut flower farms to accumulate* base data for future studies. There are potential problems with high levels of leached salts, chemical residues, and pathogens. Initial results confirm the need to reduce the volume and fertiliser content of run-off.

The Environmental Protection Agency in the Republic of Ireland estimates that agricultural activities are responsible for 23% of serious river water pollution.

New EU directives for the Rural Environment Protection Scheme (REPS) enables farmers to receive up to Aus$360 per ha for farming in specified environmentally sensitive ways. REPS payments are only available for up to 16 ha on each property.

Developing countries who are moving from planned to market economies, such as China, with 48% of the rivers polluted, has introduced a system of fines for offenders with proceeds being used to develop methods of controlling pollutant discharges.

State Department of Ecology legislation will be introduced in Washington State in 1995 to control the chemical content of waste water from fruit packing sheds.

BIOLOGICAL WASTE

Un-saleable plant material, crop debris, pruning, liquid and solid food wastes, municipal and garden waste can be considered as biological waste.

Researchers from the School of Microbiology at La Tribe University in Melbourne have demonstrated that organic waste, such as citrus pulp, can be treated in a closed composting system to yield a useful material.

Local authorities in the United State are introducing municipal waste composting and there are now 50 to 60 schemes in operation. Composts are targeted for horticultural use and have been shown to be useful as a substitute for sphagnum peat, to improve soil physical properties and as a supply of essential plant *nutrients. Release rates are slow and the composts need supplementation espe-*

cially for nitrogen, phosphorus, and potassium.

Several local authorities in Australia are sorting municipal waste and composting the biological components into saleable products.

Victorian Department of Agriculture researchers are exploring the potential uses for potato waste from processing and packing plants. Disposal of waste on farms creates crop production and disease hazards. Cardboard manufacturers have shown interest in the project and are keen to develop a pilot plant where starch from potato waste is used instead of imported material. Potato production for industrial purposes already occurs in countries such as the Netherlands and the United States.

OTHER WASTE

Waste heat from power stations is used to supplement on-site heating with glasshouse units in Europe. Romania and UK glasshouse complexes have developed heat exchange units which enable the relatively low grade heat from power stations to have significant use in glasshouse heating.

Decomposing material in land fill sites generates noxious gases such as methane but there are several examples of the gas being used after the site has been sealed. A glasshouse complex near Leeds in the UK utilises the methane to fuel the heating boiler.

Prospect Electricity in Sydney taps methane from 700,000 tonnes of waste which was dumped in an old brick pit. Pipes are sunk 20 metres into the covered landfill to collect the gas which is then compressed and pumped to an electricity generator which powers 75 to 100 homes.

CONCLUSIONS

Disposal and management of waste is a growing problem for all societies. Governments are less inclined to meet the costs of industrial and household waste disposal. Waste policies are now based on prevention, recycling and re-use, and the safe disposal of non-recoverable residues. Horticultural industries will be forced to take full responsibility for management of their waste as traditional disposal methods are no longer available.

Research and development will provide technologies for:

- Reducing water use through more efficient irrigation
- Modifying growing media to reduce leaching losses
- Removing agrochemicals by innovative filtration
- The use of re-circulating, closed production systems which limit drainage from sites.

Nevertheless there is a growing pressure to improve recycling and re-use of materials. Wastes should not be viewed as un-wanted products but rather as raw materials which provide opportunities for the development of other products or systems.

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Efficient Water and Fertiliser Use

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INTRODUCTION

Water is the most important input in the production of plants in the nursery industry and, if we are honest, probably the most badly used. We have grown up in a time when water has been cheap and in most cases readily available when we need it. Water has not been the limiting factor in the development of most nurseries; it has been the capital needed to provide automatic irrigation systems which has been our major limitation.

We have taken for granted the readily available supply of cheap and good quality water but this cannot continue indefinitely. There is an ever increasing demand for water and this will gradually force up the cost of water for irrigation use. It is likely we will also have to face increasing pressures to avoid using high quality water supplies for nursery irrigation and to have greater reliance on the use of waste water such as sewage effluent.

The nursery industry in Australia has traditionally been an urban-based industry with most nursery producers having access to reticulated town water supplies at relatively low cost. During the last 20 years there have been pressures on the industry to move out of suburbia into more rural locations where often reticulated town water supplies do not exist. This has created the situation where nurseries have to become responsible for managing their water supplies more carefully to ensure that they do not run out of water, and to maintain the quality of that water at an acceptable level for the maintenance of plant quality.

IRRIGATION DISTRIBUTION SYSTEMS

Most nursery irrigation in Australia is via overhead sprinkler systems, usually controlled by microprocessor time controllers. The reason for the dependence on overhead sprinkler systems is largely a financial one: these are the simplest and cheapest systems to install.

However, overhead sprinkler systems have a number of limitations and many of the serious water management problems faced by the nursery industry would not be as severe if the industry did not rely so heavily on this type of distribution system. The drawbacks to the use of overhead sprinklers include:

Poor Water Efficiency. Overhead sprinkler irrigation of plants in containers has probably the lowest water efficiency of any system of irrigation. If the total amount of water used to irrigate a batch of plants is expressed as 100%, the actual amount of water reaching the target (i.e., landing in the pot and taken up by the potting media) is unlikely to be greater than 50% and may actually be as low as 20%.

The first step in reducing water waste must be to improve the efficiency of the irrigation system. Areas where considerable savings in water can be made include:

1) ***Application of water to growing beds which contain no plants.*** The irrigation system should be designed to ensure that individual sprinklers can be turned off when batches of plants are removed.

2) ***Group plants together according to pot size.*** On any one irrigation control station it is important to ensure that all plants being irrigated are in the same pot size. This prevents over-application of water to some small pots and under-application to larger plants.

3) ***Time the duration of an irrigation cycle to prevent waste.*** At the end of a cycle of irrigation all of the plants should be at container capacity.

4) ***Understand how water movement occurs in your potting mix during irrigation.*** With some highly porous mixes, especially those which are difficult to re-wet, the water being applied from overhead does not always move down through the mix in a uniform way. A large proportion of the water applied may actually run off the surface of the mix and move down the interface between pot and mix without wetting much of the potting mix volume. This problem can be greatest when the water is being applied from overhead very rapidly.

Nursery producers should seriously consider experimenting with pulse watering as a first step to the improvement of irrigation efficiency and the reduction in waste of water.

5) ***Ensure that the potting mixes being used have a satisfactory water-holding capacity.*** The emphasis on potting mix formulation is often placed on getting a high air-filled porosity to achieve rapid growth. A high air-filled porosity is achieved at the expense of water-holding capacity and it is important to aim for a balance in the air and water available in the pot. Fifteen to twenty percent air-filled porosity and 35% to 40% readily available water will provide an acceptable balance for satisfactory growth.

6) ***Adopt proper system maintenance.*** All fittings must be installed in a way that prevents leaks. Dripping taps, etc. should be repaired. Considerable wastage of water can occur through unrepaired leaks.

7) ***Keep accurate records of water use.*** Water meters should be installed in the supply line so that proper records can be kept of water use. Without accurate records it is not possible to monitor and reduce water use.

8) ***Evaluate alternative systems of water application.*** The efficiency of water use can be greatly improved by moving from overhead sprinkler application to other distribution systems such as drip irrigation and capillary irrigation. These systems of irrigation have a higher initial capital cost compared to overhead sprinkler systems and this acts as a deterrent to their use. However, very great savings in water can be achieved with their installation.

9) ***Investigate opportunities for recycling of water.*** Many nurseries have the potential to create storage dams to collect and store run-off water from irrigation and stormwater. Although costly in construction, recycling schemes will eventually provide the nursery producer with a degree of independence in the supply of water for irrigation.

Nutrient Loss Through Leaching. There is a very wide range of fertilisation strategies used in the nursery industry. Many fertilisers are highly soluble and they have the tendency to leach when heavy rainfall occurs or when irrigation is used to excess.

What is happening at present in agriculture and horticulture in general around Australia is an increased awareness of nutrient run-off and its impact on the environment. We as an industry need to address the questions:

- What nutrients are being leached from our nurseries?
- Where are they going?
- What environmental hazards do they pose?

A number of factors associated with nutrient leaching must be considered:

1) ***Selection of fertilisers to minimise leaching.*** The practice of fertigation (application of soluble fertilisers to containers via the irrigation system) is the most contentious fertiliser practice from the point of view of nutrient loss. The move towards greater use of controlled-release fertilisers in nursery production will reduce the nutrient loss through leaching.

2) ***Loss of fertiliser through leaching means reduced growth.*** Plant growth and quality must be adversely affected as a result of loss of fertiliser through leaching. Plants will not grow as quickly, the quality of the growth may be impaired, and extra fertiliser may be required to keep the plants growing.

3) ***Design potting mixes with a high cation-exchange capacity (CEC).*** Where soluble liquid fertilisers are used it is important to have potting mixes with a high CEC. In the past most potting mixes contained a high proportion of peat, the naturally high CEC of peat resulted in good retention of most nutrients. With the trend away from the use of peat in recent years in favour of the use of low-cost organic substitutes, the CEC of many modern potting mixes is quite low and a greater amount of fertiliser is being lost.

4) ***Monitoring of nutrient leaching in nursery run-off water.*** At present there is little activity in the routine monitoring of nursery waste water to determine its nutrient content. I believe that the time is not far off when we will all be required, as a matter of course, to carry out regular testing of run-off water.

The challenge which we all have to face is to ensure that the final quality of our run-off water at the back of the nursery is as close as possible to the quality that we started with. It will require substantial changes to present day irrigation and fertiliser practices but it can be achieved.

The nursery industry likes to project itself as an environmentally "green" industry which is helping to solve the nations' environmental problems. If we do not get our act together and implement improvements to our water and fertiliser-use practices, we may be seen as a part of the pollution problem, rather than the answer to it.

Nursery Management—The Production of a Textbook for Australian Conditions

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The I.P.P.S. is an organization concerned with seeking and sharing information regarding plant propagation. This paper is about the business of propagation. Without good management, much of the time and effort we devote to propagation, and many of the techniques we continually seek to improve, both lose their purpose.

This paper aims to do two things:

1) To encourage more of you to record and write down the knowledge you have, and to provide a glimpse of what is involved in getting your ideas published.

2) To raise some issues about nursery management which frequently warrant more attention than they get.

WRITING THE BOOK

Nursery Management is a 142-page hardback book published in April 1994 by Kangaroo Press. I wrote this book with assistance from staff of the Australian Horticultural Correspondence School and a number of friends in the nursery industry.

Producing this publication, like any other non-fiction book involved the following steps:

- Deciding what to write
- Getting the information together
- Structuring/organising it in a sensible, and easy-to-refer-to fashion.
- Wordsmithing
- Finding and dealing with a suitable publisher.

DECIDING WHAT TO WRITE

Deciding why to write a book on nursery management was obvious. Demand for, and a lack of accessible information on nursery management has been apparent for many years. Despite the availability of several Australian books on propagation techniques, and soils; there has been little written, and made readily available in this country, on nursery management.

By early 1993, we had been gathering information for some years; through the activity of our business both in writing and conducting courses, as well as working as a consultant to various nurseries for over a decade or more.

The information was largely there, so there wasn't an excessive amount of work involved in research. This made the prospect of writing the book potentially more profitable.

FINDING A PUBLISHER

Some books find their publisher before the book is written, when it is little more than an idea. Others find their publisher after the writing is completed. Either way, the secret to finding a publisher is the same as selling anything; you must give the customer what they want. You must convince the publisher that you are doing that, that there is a demand, and that you can supply something relatively unique which won't have too much competition.

A book starts with an idea. We all have ideas, some good and some not so good. A successful book needs a very good idea!

To succeed there must be demand for the book from a large number of people. Without good sales, a publisher will not invest in the book; and without sales, the author will never recover the cost of writing it. Most authors don't make good money, because they don't choose appropriate subjects to write on, and secondly that, it is first impressions that sell a book: the title, the index, the photos and diagrams....not so much the body of the text, no matter how good it is.

The question of how many people might buy a nursery management book was uncertain, but the success of a previous book I had written gave some indication of the potential (i.e., *Starting a Nursery or Herb Farm*, Night Owl Publishers, 1983).

Timing is important. It is generally not a good idea to bring out something on a topic when there is lots of competition in the same subject area. If there is very little material available in print on that topic, then it may be a worthwhile proposition.

STRUCTURING/ORGANISING IT IN A SENSIBLE, AND EASY-TO-REFER-TO FASHION

Once you have the information, it must be put together in a logical and balanced way. Our way of doing this is to work as a team out of two offices, one in Melbourne, one on the Gold Coast. This probably isn't viable for everyone, but our business, by retaining a number of professionals as tutors in the school, can do this. As team leader I developed an outline first which is then commented on and modified by staff at both offices. We then insert information from our computer data base (developed over 12 years). This information is then reworked, expanded, and developed chapter by chapter in one office before being sent to the other office for further reworking and balancing. The aim is to produce writing which is both easy to read, rich in facts, concise, and relevant in a wide range of climates and situations.

WORDSMITHING

If writing is clear, concise, and grammatically correct it is much easier for a publisher to edit. If editing is easier, the publishers costs are less, profits are higher, the book is therefore more likely to remain in print longer, and make more money for the author. The book will also be much easier and enjoyable for readers to use. This will encourage word-of-mouth sales.

DEALING WITH PUBLISHERS

It is essential to use the right publisher for a particular type of book. Different publishers have access to different types of markets. Also, some publishers are more aggressive with selling particular types of books. You can get an idea of what publisher to use by looking at the types of books he publishes, the types of titles he/she acts as agent for, where his/her books sell, etc. Also consider:

- Do his/her titles remain in print for a long time, are they reprinted, are they remaindered?

- Does he/she pay well—advances, frequency of royalties, on time, etc?

Talk to some of his/her other authors.

WHAT WAS WRITTEN

We applied one acid test to choose what to include in this book. This was to ask ourselves:

"Does this information make a difference to productivity and in turn profitability of a nursery" If our answer was "yes", or even "sometimes", then it was valid to include it.

Using this test, We developed the following chapters: "Scope & Nature of the Nursery Industry", "The Nursery Site", "Production Systems", "Managing Plants in the Nursery", "Nursery Materials", "Tools and Equipment", "Buildings and Structures", "Management", "Marketing", and "Developing a Nursery Stocklist"

I want to highlight four concerns extracted from the book, which I believe are spoken about and practiced too infrequently:

1) Managing people
2) Developing a business plan
3) Sensitivity analysis
4) Marketing

Managing People. Work in a nursery can be divided into several different types of activities (e.g., office work, propagation, potting up, and plant maintenance). It is important to allocate adequate man-hours to each area of work each week. If there are several people working in a nursery, each can be given specific responsibilities—one marketing, one doing general plant maintenance, one doing propagation, etc.

Some nurseries only employ the services of one or two people, and in such cases, work roles are less defined.

Employee Responsibilities. Responsibilities should be clearly defined and preferably in writing, for anyone working in a nursery. A copy of an employee's responsibilities should be given to each employee when they commence work.

Developing a Business Plan. A business plan is essential for any commercial nursery. They are important as they forecast the nursery's viability and can help assist with obtaining bank loans. A business plan should take into account what the desired productivity should be and set out systematically what is intended to be done for that productivity to be achieved. A plan is best if developed for a number of years, such as 5 years.

The following cost items (excluding labour and training) are provided as a guide to how you might develop estimates of costs, income, and profit:

- Capital costs—property purchase, grading site & preparing garden bed, drainage pipes, vehicles, trailers, propagation houses, polyhouses, irrigation equipment, surfacing material, hot beds, shadehouses, stock plants, nursery barrows/trolleys, computer/printer, potting and work benches, office equipment, office furniture;

- Operating costs—consumables, fertilizers, pesticides, hormones, disinfectant, spray equipment, trays, pots, soils/media, petrol, office stationery, plant labels;
- Other operating costs—rates, insurance, phone, power, water, advertising/marketing.

Sensitivity Analysis. A nursery is a business based on living materials, not inert materials which can be put in a store room to hold. Plants need constant attention. Due to this there is a need for sensitivity analysis. Sensitivity analysis is involved in monitoring items within production systems which could effect production and the end results of achievable sales.

There are several danger areas which could cause problems in a nursery's development.

These should be given particular attention, and continually monitored.

The sensitive areas of concern are as follows:

- Productivity levels
- Pest and disease
- Plant care
- Obtaining appropriate propagation material
- Inappropriate supervision
- Staff management
- Customer relations
- Financial management
- Marketing
- Production planning
- Record keeping
- Insurance

Marketing. Marketing can make or break a nursery. There are many different ways of marketing nursery products.

Marketing involves:

- The products available (range, quality, diversity)
- Packaging and presenting the goods or services
- Making contact with the person to whom you are selling
- Communication—ensuring they understand about the goods or services
- Convincing—presenting the "product" in a way which favours you achieving the result you are aiming to achieve.
- Follow up—ensuring the "buyer" is satisfied with what they get (in the long term)

SUMMARY

Running a nursery involves a wide range of skills and knowledge, apart from plant propagation and propagation systems and equipment, and the commitment to plan and allocate time to apply such skills and knowledge.

The Potential for the Use of VA Mycorrhizae in Nursery Crop Production

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This paper reviews experimental work on the benefits of VA-mycorrhizae in nursery crop production.

INTRODUCTION

About a century ago, several biologists noticed that some plant roots that were extensively invaded by fungi, were not diseased. The name mycorrhiza (fungus root) was thus coined in 1885 (Kendrick, 1992). Mycorrhizas are the association between plant roots and the hyphae of various naturally occurring, soil inhabiting fungi which operate together in a symbiotic partnership. The nature of this partnership is such that the plant provides the fungal component with nutrients (sugars, amino acids, vitamins etc.), while the fungal component assists the plant with the uptake of water and nutrients such as phosphorus (P) and zinc (Zn) (Brown, 1992) which are often limiting for plant growth. It is estimated that over 90% of all higher plants species are normally mycorrhizal (Kendrick, 1992) making this the "normal situation." Although naturally occurring in soil, mycorrhizae do not spontaneously form in the soilless media used for container grown plants. Their incorporation into such systems could potentially improve growth and survival rates by restoring a missing component which is the norm in natural communities.

There are two major categories of mycorrhizae; ectomycorrhizae and endomycorrhizae. Ectomycorrhizae are fungi which can be grown in artificial culture (like mushroom spawn) and occur largely on woody plants in families such as Pinaceae, Fagaceae, and Betulaceae (pines, oaks and birches; Linderman, 1981) and *Eucalyptus* (Kendrick, 1992).

The group of mycorrhizae most relevant to nursery and horticultural crops, however, are the endomycorrhizae. These fungi produce loose networks of hyphal strands which are often associated with the plant's feeder roots making their presence undetectable without the use of a microscope. Often known as Vesicular Arbuscular Mycorrhizae (VA mycorrhizae or VAM) these fungi produce a range of microscopic structures within and outside of the plant root (Fig. 1). The arbuscule is a branched feeding organ which penetrates the root's epidermal and cortical cells and allows the two-way exchange of nutrients between the fungus and the plant. The vesicle (which does not occur in all instances) contains oil droplets and is thought to be a storage organ. VA mycorrhizal fungi are obligate symbionts, they can only exist in the presence of living plants, and as such, they cannot be grown in artificial culture. In general, VA mycorrhizal fungi are capable of colonising a wide range of plants (St. John and Evans, 1990), thus a single isolate may be used to colonise a wide range of plant species.

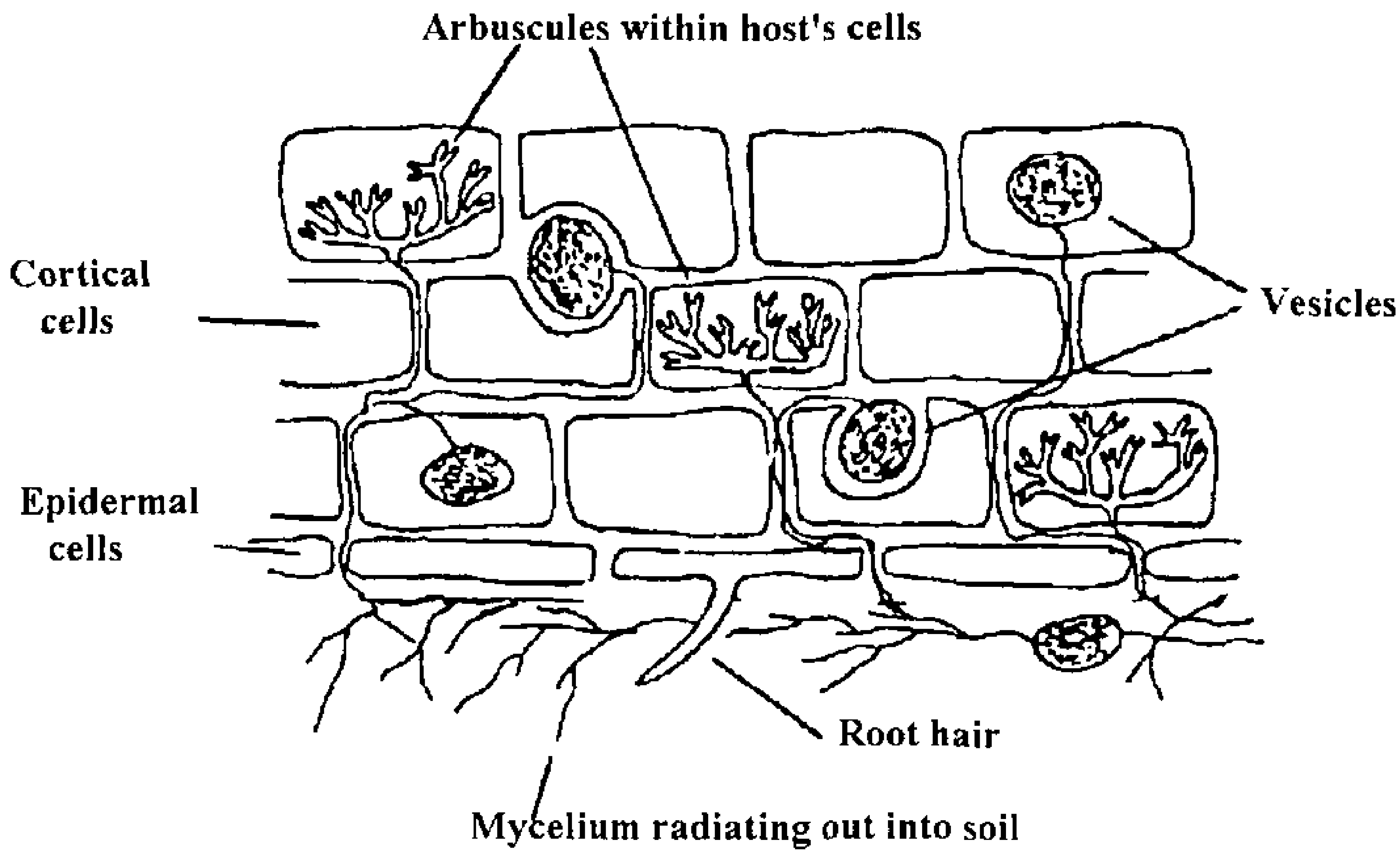

Figure 1. Diagram of a root section showing the features of VA mycorrhizas (Brown, 1992)

PLANT NUTRITION AND VA MYCORRHIZAE

Countless experimental trials have shown that plants colonised by mycorrhizal fungi are generally larger and have higher concentrations of phosphorous in their tissues (Krikun, 1991). The improvement in plant nutrition is due to the production of an extensive network of hyphae into the soil (or media) around the plant. Normally, the plant root removes phosphorous (P) rapidly from the region immediately surrounding the root. The hyphal network grows beyond this depletion zone and supplies phosphorous that is not normally available to the plant's roots alone (Brown, 1992; St. John and Evans, 1990). This effect can often be reduced by the addition of high levels of P as mycorrhizae are most active in P-deficient situations. Johnson (1982) showed that the addition of *Glomus fasciculatum* and *G. mosseae* to container-grown plants (woody ornamentals) could reduce the use of P fertilisers by 70% and reduce the levels of nitrogen (N), potassium (K), and micronutrient fertilisers by 30 to 40%. Maronek and Hendrix (1978) inoculated southern magnolia *(Magnolia grandiflora)* seedlings with *G. fasiculatus* in a pot experiment. Their results indicated that mycorrhizal plants grown at ¼ the normal fertiliser rate (1.1 kg m^{-3} Osmocote, 18-6-12) were twice as large as non-mycorrhizal plants grown at the full rate (4.5 kg m^{-3}). Ponton et al. (1990b) demonstrated that inoculation of Boston fern (*Nephrolepis exaltata*) with *G. vesiculiferum* resulted in growth levels similar to that achieved with a low rate of P addition. This lead the authors to suggest that mycorrhizal ferns were more efficient at P utilisation, which will have greater implications when fertiliser supplies become limiting at the end of the next century. Abbott and Robson (1985) advocate the comparison of mycorrhizal with non-mycorrhizal plants grown over a range of nutrient (P) levels. Comparisons can thus be made at a particular plant yield (horizontal comparison) rather than at a particular nutrient rate (vertical comparison). This allows the nutrient savings (due to mycorrhizal colonisation) to be determined when growing plants to a particular size (Abbott and Robson, 1985; Bolan et. al., 1983)(Fig. 2).

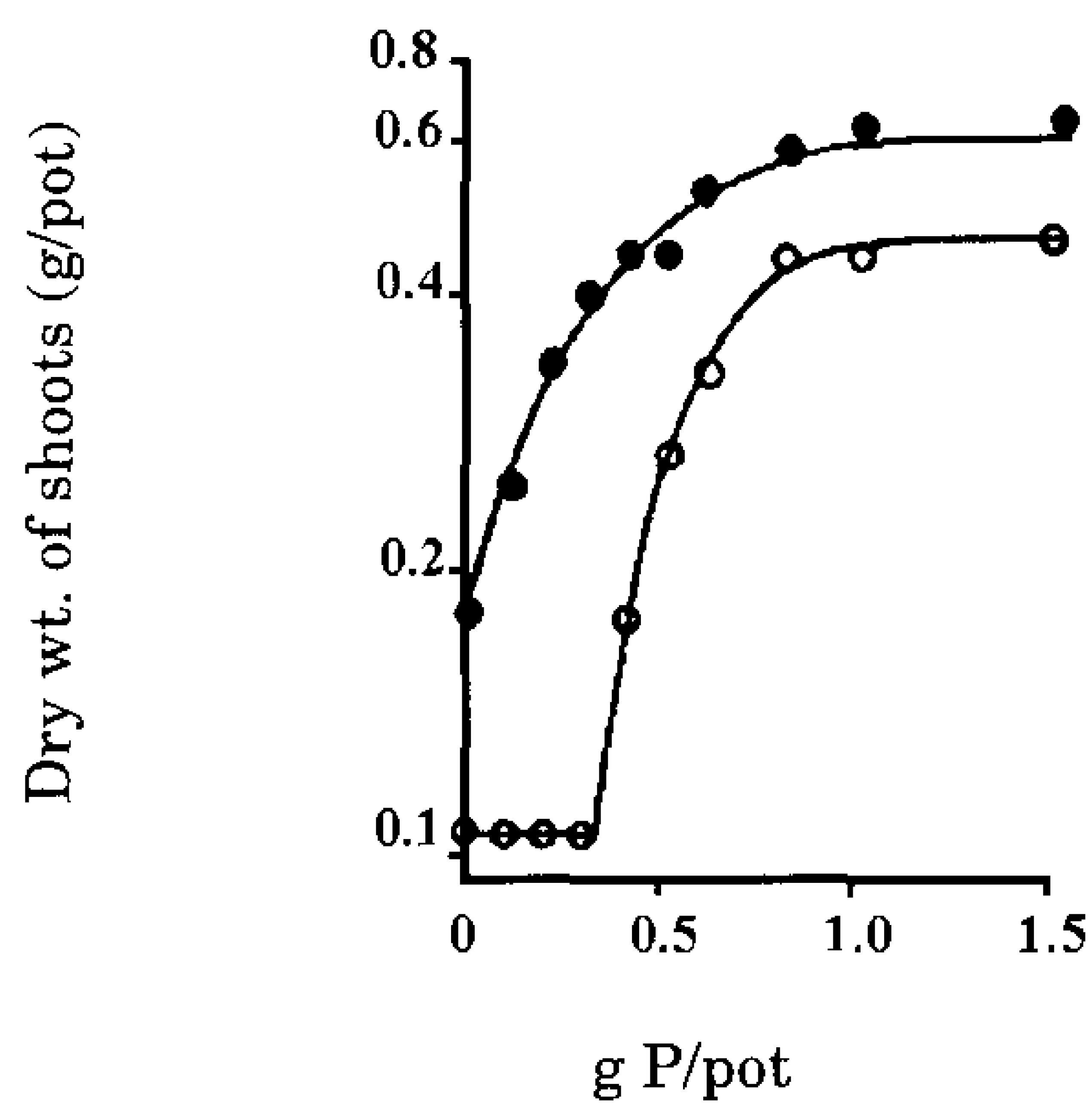

Figure 2. The effect of phosphate application and mycorrhizal inoculation on the dry weight of shoots of subterranean clover (Bolan *et. al.*, 1983). (• = inoculated plants, ○ = un-inoculated plants)

PROPAGATION SUCCESS AND VA MYCORRHIZAE

The benefits of VA mycorrhizae in propagation of arrow wood (*Viburnum dentatum*) was demonstrated by Verkade (1986), who found that root initiation and root weight were both increased in plants (cuttings) inoculated with *G. fasciculatum*. Improved rooting of cuttings in woody plants has been recorded elsewhere (Maronek et al., 1981). There is considerable discussion in the literature about the role that mycorrhizae play in the hormonal balance of the plant. It has been shown that plants colonised by these fungi produce altered amounts of hormones such as gibberellin, abscisic acid, cytokinin and zeatin (Krikun, 1991). Although it is difficult to prove that the source of hormones is the fungal partner (Maronek et al., 1981), the evidence suggests that mycorrhizal fungi influence the hormonal balance of the plants that they colonise.

Transplant survival of micropropagated strawberry plants was significantly increased by inoculation with the VA mycorrhizal fungi *G. etunicatum, G. fasciculatum,* and *G. mosseae* (Chang, 1990). These fungi also increased the numbers of runners produced, flowering activity, and fruit yield over the non-inoculated control group. Chávez and Ferrera-Cerrato (1990) also working with micropropagated strawberries, evaluated three VA mycorrhizal fungi *G. macrocarpum, G. versiforme* and an unidentified *Glomus* species against four cultivars. In some cases, inoculated plants yielded better than the un-inoculated controls, while the reverse was true in other cases. Vestberg (1992) evaluated nine isolates of *Glomus* for their ability to increase production in micropropagated strawberries. Some isolates increased plant growth several fold over the un-inoculated plants with the differences persisting into the second year of the field planted trial. Micropropagated avocado plantlets showed improved survival rates when inoculated with isolates of *Glomus* spp. (Azcón-Aguilar et al., 1992). Micropropagated pineapples (Guilemin et al., 1992; Lovato et al., 1992) and grapevines (Lovato et al., 1992) have also been shown to have superior growth when compared to plants which are not inoculated with VA mycorrhizal fungi.

Survival of micropropagated Boston fern (*Nephrolepis exaltata*) rooted plantlets was increased when transferred into pots containing media inoculated with the VA mycorrhizae *G. intraradices* and *G. vesiculiferum* compared to un-inoculated controls (Ponton et al., 1990a). The potential benefits to plants generated by cuttings and micropropagation, of inoculation with VA mycorrhizae, are increased survival and plant vigour, which leads to a more uniform product and possibly a shortening of the production time required.

WATER UTILISATION AND VA MYCORRHIZAE

A much neglected area of mycorrhizal research has been the influence of this symbiosis on the water utilisation of plants. It has been clearly demonstrated in many species that a significant contribution to the plant's water supply is provided by the mycorrhizal fungus (Read, 1985) and that this is particularly important in arid-zone plants.

Through particularly elegant experiments, Hardie (1985) demonstrated that the removal of VA mycorrhizal hyphae (*G. mosseae*) from the roots of red clover affected their ability to maintain or increase transpiration levels. The importance of VA mycorrhizae (*G. intraradices* and *G. deserticola*) has also been demonstrated to increase drought tolerance in *Rosa* hybrid (Augé and Duan 1991; Henderson and Davies, 1990) and in capsicum (Davies et al., 1992). These results indicate the potential for using VA mycorrhizae to increase the drought hardiness of container-grown plants. In theory, such plants would be more tolerant of desiccation between watering periods. This would allow extended periods between irrigations and potential reductions in water use and waste water disposal problems in the commercial nursery.

PLANT DISEASE AND VA MYCORRHIZAE

There has been little work done on the interactions between VA mycorrhizae, nursery crops, and their pathogens. Evidence for the beneficial role of VA mycorrhizae in reducing disease levels comes mainly from other cropping systems. Iqbal and Nasim (1988) showed that cauliflower seedlings pre-inoculated with an unnamed VA mycorrhizal fungus had greater resistance to attack by *Rhizoctonia solani*. Champawat (1991) found that inoculation of cumin with *Gigaspora calospora*, *G. fasciculatum*, *G. mosseae*, or *Acaulospora laevis* reduced the severity of disease caused by *Fusarium oxysporum* f. sp. *cumini*. *Glomus fasciculatum* was also found to promote healthier roots in sweet orange challenged with the pathogen *Phytophthora parasitica* in low-P conditions (<15 mg P per g soil). Similar plants provided with higher levels of P (56 or 600 mg P per g soil) were not protected by the VA mycorrhizal fungus (Davis and Menge, 1980). Kendrick (1992) proposed three mechanisms by which plant disease severity is reduced by VA mycorrhizal fungi; (1) increased nutrition producing a plant more capable of resisting attack; (2) chitinolytic enzymes produced by mycorrhizal plants to digest senescent arbuscules in their tissues, may assist in destroying pathogenic fungal structures; (3) the presence of VA mycorrhizal fungi on the root system reduces the number of sites available for pathogen invasion. Although there are several reports of VA mycorrhizal fungi reducing the severity of pathogen attack, there are also some reports indicating that they can also increase the level of disease (Dehne, 1982).

POST-POINT-OF-SALE PERFORMANCE AND VA MYCORRHIZAE

Johnson (1982) referred to some earlier work where he observed improved establishment and survival of mycorrhizal plants over non-mycorrhizal plants in landscape soils. Western red cedar plants (*Thuja plicata*) grown in fumigated beds in a bare-root nursery were found to be stunted and deficient in VA mycorrhizae when compared to plants grown in non-fumigated beds. The mycorrhizal plants maintained their growth advantage up to 13 months after transplanting into the field (Berch et al., 1991). Stunted and chlorotic citrus seedlings growing in fumigated soils were found to be lacking VA mycorrhizae. Inoculation of these plants with *Endogone mosseae* resulted in normal growth being restored. After transplanting into a fumigated (methyl bromide) field site, the colonised plants were found to perform significantly better than the non-VA mycorrhizal plants (Kleinschmidt and Gerdemann, 1972). Davies (1982) has even suggested that the superior performance of VA mycorrhizal plants may even be translated into their commanding a premium price in the market place.

INOCULUM PRODUCTION

VA mycorrhizal inoculum can only be produced on the roots of live plants due to the obligate dependency of the fungal component on the plant. Generally such inoculum is produced by growing a host plant in media under glasshouse conditions. A small amount of VA mycorrhizal culture is introduced into the system and is multiplied accordingly. Fast growing tropical grasses such as Sudan grass and sorghum are ideal hosts (Morton et al., 1993). The container medium used should be relatively low in nutrients to encourage the spread of the fungus, rather than rapid plant growth (St. John and Evans, 1990). A major concern with this process is the contamination of the inoculum with unwanted pathogens such as *Fusarium, Rhizoctonia*, etc. High levels of hygiene must be maintained to reduce the possibility of this occurring as many fungicides, particularly the systemic compounds benomyl (Boatman et al., 1978; Smith, 1978) and thiophanate-methyl (Boatman et al., 1978) , are known to be toxic to VA mycorrhizae.

Commercially produced inoculum is rapidly becoming available in several countries. NPI in Salt Lake City (Utah) produced a product called Nutri-Link (St. John and Evans, 1990) containing plant roots, hyphae, and spores of various VA mycorrhizal fungi. A similar product known as Dr. Kinko is produced in Japan. The Agricultural Genetics Company in the UK (Vam Inoc®) and Phytotec in Belgium also produce commercial inocula (Lovato et al., 1992). Typically the production cycle for such inocula is 2 to 4 months. The successful use of mycorrhizal fungi in nursery production will require identification and isolation of superior fungi, production of pathogen-free inoculum, development of inoculation techniques, and adjustments of cultural practices to ensure that the plant-fungal association is maintained (Maronek et al., 1981).

Experimental production of VA mycorrhizal inoculum has been achieved through the use of aeroponic systems (Jarstfer and Sylvia, 1992) and it is potentially possible through the use of other hydroponic systems. It is conceivable that through such systems, pathogen-free inoculum could be produced easily and processed in the form of colonised root material.

CONCLUSION

The benefits of VA mycorrhizae to plant growth have been clearly demonstrated by many workers. VA mycorrhizae have the potential to increase propagation success, produce healthier and more robust plants while reducing fertiliser inputs. Such plants are more resistant to disease attack, have greater drought tolerance, and potentially have better after-sales performance (and retail value). Initially, research must be conducted to examine the benefits of VA mycorrhizae to a range of commercially produced species, particularly as little work has been done in this area with Australian natives and many exotics. For example, a survey of 80 species of Australian Asteraceae (native daisies) found most of these to be capable (and some highly dependent upon) forming VA mycorrhizae (Warcup and McGee, 1983). A range of commercial inocula suited to the needs of the industry are being developed, and some of these are already commercially available. Innoculation with VA mycorrhizae will eventually become an integral part of nursery production systems.

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Junipers in the Subtropics

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INTRODUCTION

Junipers provide a wide range of colour all year round. In a variety of shapes and sizes, there is a species of juniper to provide feature plants, screen and wind breaks, ground covers, and tub specimens. Junipers are extremely hardy, tolerating temperatures ranging from -10 to 50C. They will tolerate long periods of drought and very wet conditions, provided drainage is good. Best of all, junipers are easy to propagate.

METHODS

Cuttings are taken practically all year round depending upon availability of material. Size ranges from 5 to 14 cm. These are placed in a steam-sterilised mix of 9 perlite : 1 peatmoss (v/v) in flat trays. Horizontal forms are multi-planted into 6.5-cm tubes. All cuttings are placed out in the full sun under constant mist. The mist runs for 15 sec at 10-min intervals during summer and 12 sec at 15-min intervals during winter. The mist is left on continuously from 7 AM to 4:30 PM in summer and from 8 AM to 4 PM during winter.

No hormonal powders are used. Percentage strike rate is generally from 70% to 90%, and quite frequently 100%. It takes approximately 12 weeks for the first roots to appear. A further 6 to 8 weeks gives a solid mass of roots and the cuttings are then ready to be removed from the mist. They are then hardened off for a few weeks prior to tubing.

CLIMATIC COMPARISON

We are situated at D'Aguilar, approximately 20 km inland from Caboolture, 50 km from the coast and 150 m above sea level. Winter temperatures range from 5C to 18C, occasional frosts are experienced. Summer temperatures are usually 18C to 35C or higher.

Bromine and Chlorine Disinfestation of Nursery Water Supplies

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INTRODUCTION

A wide range of plant pathogens are waterborne, and recycled irrigation water is recognised as a major source of inoculum. *Phytophthora, Alternaria, Aschochyta, Fusarium, Pythium,* and *Helminthosporum* are some of the nursery crop pathogens capable of entering water storages (Gill, 1970; Thomson and Allen, 1974).

Chlorination of nursery irrigation water from surface sources is currently the main method of disinfestation in Australia. Microfiltration, ultraviolet irradiation, bromination, ozonation, and the use of chlorine dioxide are lesser used methods.

A prior (unpublished) survey conducted by the authors indicated that chlorination was not being used successfully by nursery operators in most situations. A major reason for this was a general lack of appreciation by the survey participants of the need to routinely monitor chlorine demand and thus enable themselves to constantly maintain biocidal concentrations of residual free chlorine. The majority of operators included in the survey were calculating chlorine doses based on demand-free water and were not monitoring chlorine concentrations. That is, they were not catering to the changing chlorine demand needs resulting from seasonal water quality fluctuations.

Most microorganisms in water are inactivated at free available residual chlorine levels of 1 to 3 mg/litre (Clark and Smajstrla, 1992; Ewart and Chrimes, 1980; von Broembsen, 1990). In order to achieve these concentrations it is often necessary to add 5 to 10 mg of chlorine per litre of irrigant to ensure that 1 to 3 mg/litre is available as a biocide. This is because a large percentage of the added chlorine is lost in reacting with substances such as ferrous ions (0.6 mg/litre of chlorine will react with 1.0 mg/litre of ferrous ion), ammonium ions, and other inorganic and organic contaminants (Clark and Smajstrla, 1992). Field experience in Australia indicates that where water is high in organic substances, the chlorine demand can often be in the order of 25 to 30 mg/litre.

Bromine and chlorine are members of the same chemical family known as halogens and hence have similar actions in disinfesting water supplies. They rely on the formation in water of hypohalous acids for biocidal activity: for bromine it is hypobromous acid ($HOBr$) and for chlorine hypochlorous acid ($HOCl$). Both hypohalous acids are powerful oxidising agents which enter the cells and chemically react with proteins causing interruptions in the metabolic processes. This means they are toxic to all living organisms and that organisms can not become tolerant of their action.

Dissociation of these acids to their respective ions causes a marked drop in their ability to perform as disinfestation agents, possibly because they do not permeate the cell walls of organisms as readily (White, 1986). This dissociation is dependent on the pH of the water and as seen in Fig. 1, the active acid of bromine ($HOBr$) occurs in greater amounts over a much wider pH range, making the quality of water being treated less important.

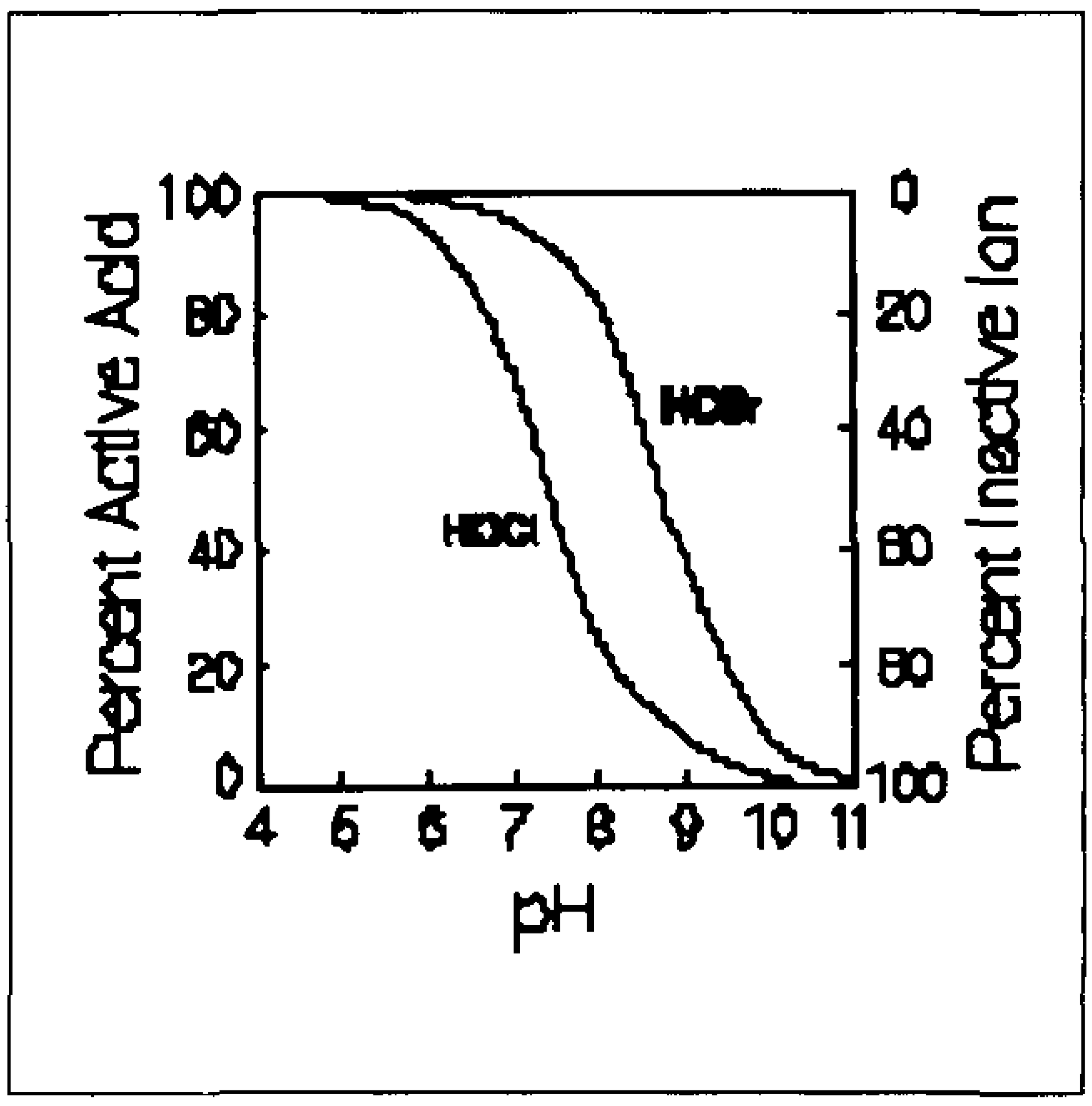

Figure 1. Dissociation curves of hypohalous acids (Adapted from Conley et al., 1987, with permission).

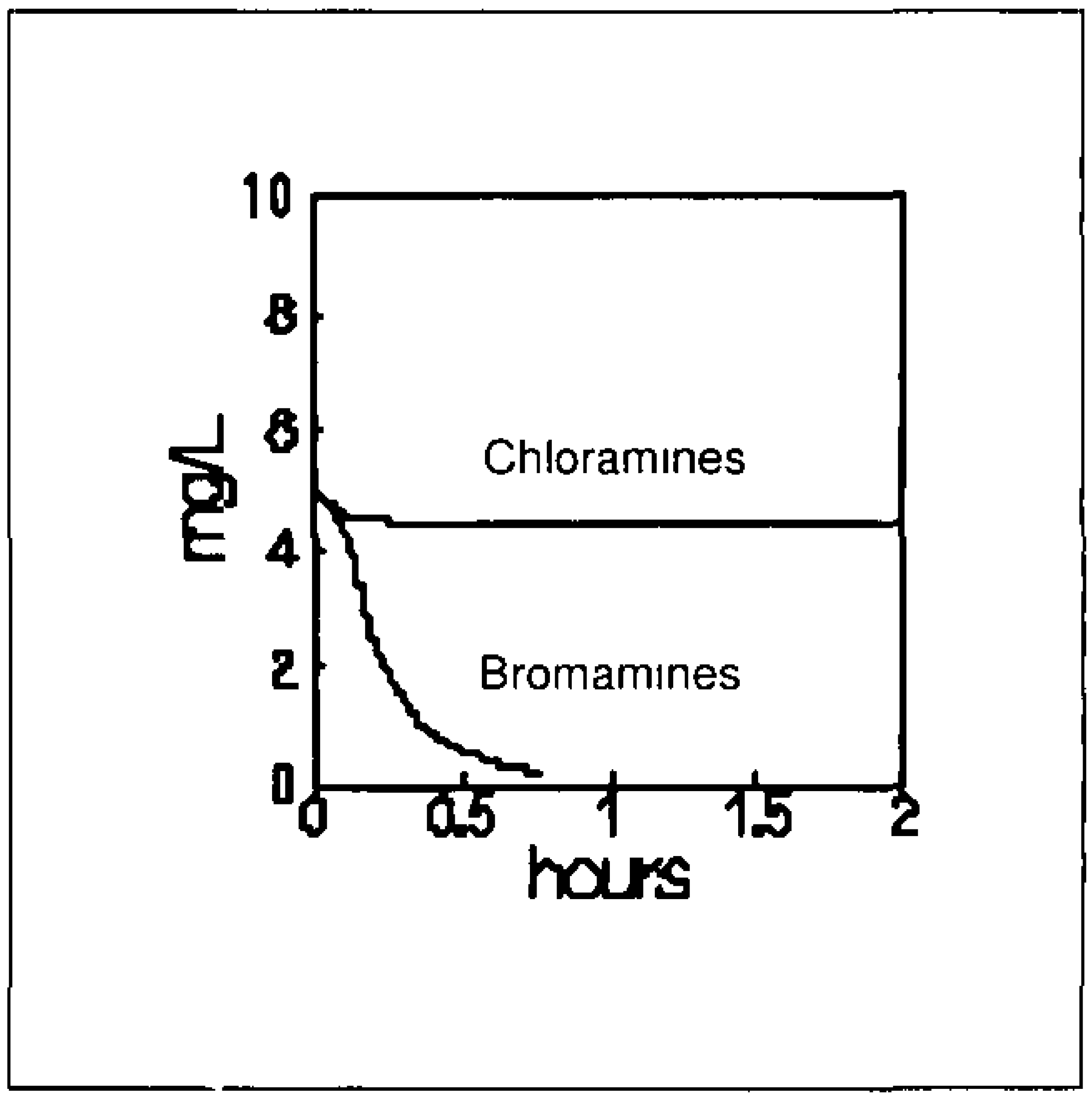

Figure 2. Relative decay of haloamines (Adapted from Conley et al., 1987, with permission).

Most surface waters, and in particular, recycled waters commonly used in nurseries, contain various and fluctuating levels of ammonium and/or other nitrogen-based compounds. Both bromine and chlorine react with these compounds readily to form haloamines. The chloramines formed are relatively poor biocides with the activity of monochloramine being eighty times less than that of free chlorine (White, 1986), while bromamines show disinfection properties comparable to free bromine (Johnson and Overby, 1971). Typically, breakpoint chlorination requires 10 mg/litre of chlorine for every 1 mg/litre of ammonia (Conley and Puzig, 1987; Conley et al., 1987; Degremont, 1991), but because bromamines are very effective biocides, breakpoint bromination is not relevant.

In the application of chlorine or bromine to water it is necessary to ensure that a sufficient amount has been added to achieve the desired result in terms of pathogen control. In practice, this control consists of frequent determinations of residual active agent in the water after a given contact time. The amount of chemical used up by reaction with living organisms, organic contaminants, and nitrogen compounds depends upon the actual dose applied and the time of contact (dwell time in a tank or length of pipe from injection point to spray head) with the chemical. Situations where the water will be in contact with the chemical agent for a short period of time will require a larger initial dose to bring about the required disinfestation (White, 1986; Smith, 1977).

Given the problems experienced with chlorination, bromination appears to offer a number of advantages. The great majority of Australian nursery operators who sanitise water are already using chlorine and therefore have experience relevant to bromine use. The methods of applying and monitoring it are very similar to the techniques used for chlorine, and capital costs in changing over to bromine are therefore minor.

In most situations where 10 to 25 mg of chlorine per litre of irrigation water is needed to produce an excess of 1 to 2 mg/litre of free available residual chlorine, the use of bromine would appear to offer distinct economic advantages.

As byproducts of chlorine and bromine (particularly chloramines and halomethanes) have been implicated as environmental and human health hazards (Office of Water Regulations and Standards, 1986; Division of Environment, 1992; Anon, 1992, 1993, D'Onofrio, 1988) the use of bromine, which produces less long-lived halogenated residuals than chlorine, (Fig. 2) has additional benefits in terms of reduced environmental impact.

Bromine reacts more quickly than chlorine and this may provide some benefits in reducing the required contact periods between the biocide and the pathogen (Great Lakes Chemical Corporation, 1989). Because of the good biocidal properties of bromamines and the consequent reduced need to achieve the breakpoint concentrations and free residual halogen requirements of chlorine, halogen phytotoxicity problems may be reduced with bromine use. This could have important implications with regard to the continuous disinfestation of hydroponic solutions, where chlorine toxicity may be the major limitation to an otherwise significant reduction in some pathogens (Runia, 1988). Runia (1988) found that 1 to 5 mg $litre^{-1}$ of chlorine reduced the activity of *Fusarium oxysporum*, however 3 to 10 mg of chlorine per litre of nutrient solution was phytotoxic to plants in hydroponics. Containerised stock, even in propagation areas would appear to be tolerant of levels of hypohalous acid of 5 to 10 mg $litre^{-1}$ (Hammen, 1989; Powell and Ashley Smith, 1989). These levels reduced algal growth and some foliage and flower pathogens such as *Colletotrichum* and *Botrytis*. Chase (1990) and Chase (1992) using Agribrom under continuous mist reduced the effect of pathogens such as *Alternaria panax* and *Rhizoctonia solani* using hypohalous acid concentrations up to approximately four times greater than the above, but with phytotoxicity problems at the highest rates.

Therefore it appeared to be of value to investigate the use of bromine as a substitute or replacement for chlorine, in situations where there are water quality and other constraints to the effective use of the latter. The first phase of the study was to install and monitor bromination systems and compare them with chlorinators in term of halogen delivery (particularly the constancy of biocidal doses). Methods of quantifying free available residual halogen and combined available residual halogen in the field were also tested. The effect of several different water qualities was also considered when comparing chlorination with bromination.

MATERIALS & METHODS

Application Methods. There are many methods for applying both chlorine and bromine to water supplies. For chlorine the most common is the in-line feeding of sodium hypochlorite solution. Other methods such as chlorine gas injection, calcium hypochlorite, or sodium dichloro isocyanurate (swimming pool dry chlorine) are not commonly used because of safety and injection difficulties (Degremont, 1991) and are not studied in this paper.

The three most practical methods of delivering bromine are bromine chloride (BrCl), activated bromide (Br^-), and bromochlorodimethylhydantoin (BCDMH) (Conley and Puzig, 1987; Conley et al., 1987). The feed systems for using BrCl and BCDMH are quite complicated and somewhat expensive. The activated bromide method relies on the reaction of the bromide ion with hypochlorous acid in the pH range of 7-9, to form hypobromous acid (White, 1986). This is done by adding a sodium bromide (NaBr) solution to bulk sodium hypochlorite (NaOCl) solution at a stoichiometric ratio of 1:1 or slightly higher (Conley et al., 1987). The added advantage of this system is that present chlorine-based feeders can easily be modified to bromine feeders.

Six nurseries utilising either chlorine or bromine disinfestation techniques were observed over a longer than 12 month period:

Nurseries A & B. Both nurseries used activated bromine systems. The combined chemicals were injected into the passing dam water supply (sand filtered) which was stored in holding tanks, before going out onto the nursery. Nursery B had a water quality which fluctuated considerably more than A, both in terms of organic matter and pH. This was because excess water from the nursery was immediately drained back into the storage dam. The metered pumps of both nurseries were switched on and off with the main irrigation pump from the dam, with Nursery A having added regulation from a flow meter. Both nurseries carried a wide range of outdoor and greenhouse crops.

Nursery C. This nursery had an in-line chlorine feeder using sodium hypochlorite solution. The chlorine was injected at the pump station from the dam, some distance from the sprinkler heads. This distance ensures an approximate 20 min contact time before the water is used on the nursery. The nursery grew both outdoor and greenhouse crops.

Nursery D. This nursery employed a modern, sophisticated, self-regulating chlorine feeder. Before entering the irrigation system a sodium hypochlorite solution was injected into a recirculating water flow (from a holding tank) to a pre-determined residual level for a precise period of time. This nursery recycles this water. The nursery produced both outdoor and greenhouse crops.

Nursery E. Sodium hypochlorite was fed into the water supply and held in tanks. This nursery had several water sources from good quality bores to a recycling dam high in nitrogenous compounds, tannins, and organic matter. The nursery produced both open-grown and greenhouse crops.

Nursery F. Water was treated with a flocculating agent in a storage tank and pH adjusted and chlorinated by injection of sodium hypochlorite and then it passed into a second treatment tank. The water quality on this site fluctuated considerably. The nursery produced only greenhouse crops.

Analytical Methods

Chemical Analysis. Residual bromine and chlorine levels were monitored using a modified DPD titrometric method (Anon 1980; APHA, WPCF, AWWA, 1985; White, 1986). Hach® "free chlorine reagent pillows" were selected as a source of DPD and buffer for field analysis because of ease of transport and reagent stability. The DPD method was chosen because of ease of use in the field, as well as simulating commercially available test kits which would normally be used to monitor levels in the nursery.

Water quality analyses for pH, electrical conductivity, major cations and anions, and iron were carried out broadly following the standard methods of water analysis (APHA, WPCF, AWWA, 1985).

Phytotoxicity Determinations. Control plants could not be maintained under the same conditions as treated stock, and this limited the validity of assessments of plant damage due to the treatments. Situations existed where plants were irrigated with untreated bore or town water, however, these were in propagating or holding areas only.

However, comparisons were made between crops which were not irrigated with treated water, prior to the installation of treatment facilities, and later crops.

Any loss of foliage and flower quality not later found to be due to other causes was noted. Overall crop performance was also considered.

Disease Control Determinations. Surveys of soil-borne and water-borne pathogens were made on all nursery sites. The methods used in sampling and for the laboratory determinations are described by Bodman and Forsberg (1994).

RESULTS

Chemical Analysis. The quality of the water used for irrigation on the various nurseries differed considerably in such things as mineral content, clarity, and pH. During the period of investigation the quality of the individual supplies also fluctuated greatly. As an example of this the pH values recorded at one nursery can be seen in Fig. 3. In general during drier periods the mineral content increased and after rain periods biological activity increased in surface supplies.

Residual levels of chlorine/bromine were also observed to change greatly and at times the required amount greatly exceeded the doses being applied. The test kits used by the nurseries showed good agreement with results we obtained and therefore would be quite acceptable for routine monitoring of residual levels. Some supplies contained potentially troublesome levels of iron which were eliminated by both chlorine and bromine. Neither chlorination nor bromination caused any adverse increase in mineral salt levels, even at the highest application rates.

Phytotoxicity Determinations. There were no, or no easily detectable, problems with flower and foliage quality in the majority of crops treated with brominated water. *Cyathea cooperi* at one site suffered from a marginal and tip necrosis of the lower fronds, but similar age plants on the other brominated water site did not. No other possible cause for the problem was determined. Two *Calathea* species at one brominated water site experienced similar symptoms. A number of other causes were possible but the problem was not ultimately resolved.

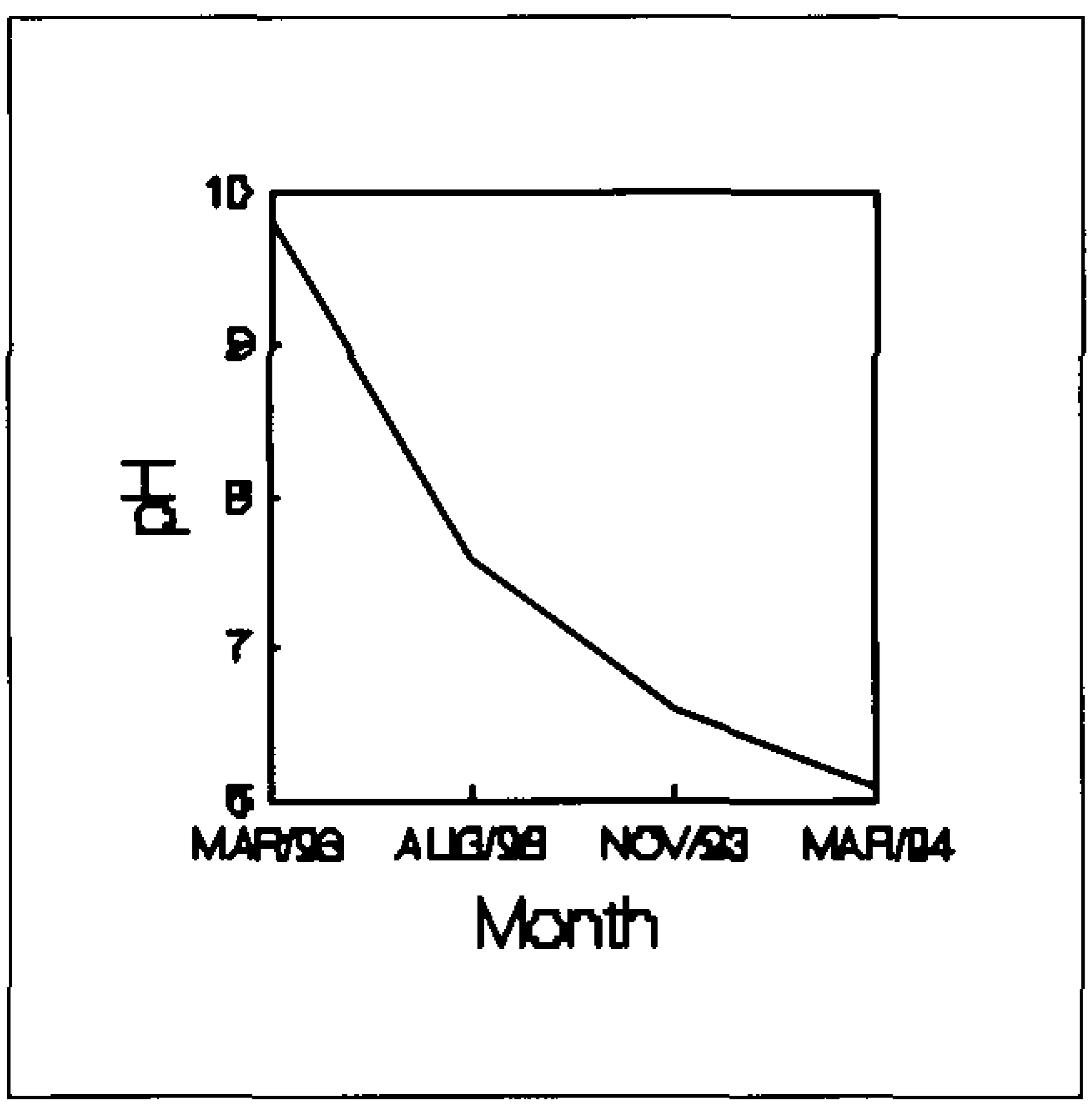

Figure 3. pH values of water supply at nursery B.

Two *Anthurium andraeanum* cultivars experienced an irregular etching of new leaves during the period when the highest bromine rates were used. An unidentified thrips was associated with the plants but damage appeared to persist after this was controlled. Another three *A. andraeanum* cultivars in the same production area remained asymptomatic.

Disease Control Determinations. *Phytophthora cryptogea* was baited from two dams on two sites. It was not isolated from crops on these sites during the observation period.

Operator error allowed a disruption to chlorination on one site, but there was no evidence of a subsequent change to the status of *Phytophthora* as determined by lupin baiting 1 and 3 weeks after the disruption.

DISCUSSION

The repeated fluctuations in water quality emphasised the need to carefully and regularly monitor the systems being operated to maintain proper levels for disinfestation. To this end, bromination may have a slight advantage as it performs better over a wider range of water qualities. In situations where water quality is suboptimal in terms of pH and organic and inorganic contaminants, the advantages of using bromine become greater.

From our observations treatment should take place after filtration. This can considerably lower the chemical demand of the water by taking out a lot of the microorganisms and organic matter which would use up the chlorine or bromine. Adding nutrients to the water supply for fertigation purposes is best done after a sufficient dwell time to allow disinfestation to take place, as some nutrients (e.g., ammonium) react with the treatment chemicals.

Possible phytotoxicities to two cultivars of *Anthurium andraeanum* and two species of *Calathea* occurred at one nursery using brominated water. If resources are available this will be evaluated later, under controlled conditions. At the doses used, there was no evidence that bromination was less or more effective than chlorination in preventing waterborne disease at the sites tested, however this needs to be determined by further work.

Acknowledgements: Thanks go to Greg Woodley of International Sales and Marketing Pty Ltd and Peter Conn of ProMinent and Fluid Controls Pty Ltd for their help and advice.

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How Much Potassium do Flowering Plants Growing in Soilless Media Really Need?

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The minimum potassium/nitrogen (K/N) ratio of fertilisers that produce optimum quality in *Petunia* 'Celebrity Salmon' growing in soilless media depends on the composition of the medium. For peat/perlite medium the minimum K/N (mg/mg) is about 0.8. For media containing materials such as bark, which have a store of native K, the ratio can be as low as 0.4 for short-term crops. For media whose components are being decomposed by microbial activity, and therefore in which there is much "drawdown" of soluble N, the ratio need not be higher than about 0.4. Fertilizers with K/N ratios above these minima, applied in amounts that produce maximum growth, do not increase flower numbers in *Petunia*. Broadly similar results have been obtained for *Fuchsia coccinea*.

INTRODUCTION

A glance at manufacturers' product lists shows that fertilisers sold for use on containerised plants have a wide range of nitrogen/phosphorus/potassium (NPK) compositions. In particular, the ratios of P and K to N vary considerably. Fertilisers stated to have been designed for foliage and woody ornamental plants often have K/N ratios (%/%) in the range 0.4 to 0.5, but they can be much higher. Those that claim to boost flowering typically have K/N ratios of well over 1, and sometimes over 2. Yet the optimum K/N ratio for at least one flowering plant—African violets—has been found to be in the range 0.52 to 0.83 (Poole et al., 1990), with the variation apparently caused by differing composition of the potting medium used.

A search of the literature on K requirements of plants in potting media and hydroponics solutions suggested one reason for differences in optimum K/N ratios found in different experiments might be the amount of nitrogen drawdown (immobilisation) taking place in the growing medium. This paper summarises the results of several experiments which have been conducted to test this hypothesis.

OVERVIEW OF THE EXPERIMENTS

In one experiment, *Petunia* 'Celebrity Salmon' seedlings were grown in three soilless media and fertilised with nutrient solutions containing 200, 300, or 600 mg litre^{-1} N and K to give 10 K/N ratios in the range 0.08 to 1.6 (mg/mg). The media were 5 peat : 1 perlite (v/v), 2 peat : 3 composted *Pinus radiata* bark (v/v) and 11 peat : 12 composted eucalypt sawdust (v/v), all of pH 6. Micronutrients, P, Ca, Mg, and S were incorporated into the media to give optimum initial amounts, as determined by extraction with dilute DTPA (Standards Australia, 1993). There were five, 125-mm plastic pots of each medium for each K/N treatment, each planted with one *Petunia* seedling.

Nutrient solutions were applied weekly at 200 ml per pot. Symptoms of K deficiency and general quality were noted from time to time and the shoots harvested at 42 days (peat and perlite, and peat and bark) and 71 days (peat and sawdust). The shoots were analysed for total N and K.

In a second experiment, *Petunia* 'Stereo Red' seedlings were grown in media composed of peat and composted eucalypt sawdust mixtures containing 0 to 60% sawdust. They were fertilised with nutrient solutions containing 300 or 600 mg litre^{-1} N and K to give five K/N ratios in the range 0.33 to 1.1 (mg/mg). The nitrogen drawdown index values (NDI_{75}) (Handreck, 1992a,b) of the mixtures ranged from 1 to zero. General cultural conditions were similar to those of the first experiment. At harvest 72 days after planting the shoots were dissected into old leaves, mid-stem leaves, shoot tips, stems, and flowers, which were analysed separately for total K and N.

RESULTS AND DISCUSSION

First Experiment. K deficiency symptoms appeared first in plants growing in peat and perlite medium, at 28 days after transplanting and at the lowest fertiliser K/N ratio. By harvest, plants in peat and perlite showed deficiency symptoms at K/N ratios up to 0.67, but not at 0.83 (Table 1).

Table 1. K/N ratios for whole shoots of *Petunia* 'Celebrity Salmon' as affected by potting medium composition and the K/N ratio and N concentration of the liquid fertiliser solution applied weekly.

	Shoot K/N ratio						
	Peat/pine bark		Peat/perlite		Peat/sawdust		
Fertiliser K/N ratio	200 mg/l N	300 mg/l N	200 mg/l N	300 mg/l N	200 mg/l N	300 mg/l N	600 mg/l N
0.08	0.51*	0.42*	-	-	-	-	-
0.17	0.56*	0.49*	0.24*	0.26*	0.32*	0.33*	0.43*
0.33	0.76	0.82	0.38*	0.43*	0.96	0.74	0.71
0.50	1.02	0.84	0 50*	0.61*	1.30	1.21	0.84
0.67	1.04	1.11	0.58*	0.80	1.44	1.62	1.19
0.83	1.21	1.19	0.77	1.08	1.84	1.87	1.53
1	1.41	1.48	0.92	1.40	2.13	2.44	1 90

* = K deficiency symptoms.

In contrast, in peat and bark as well as in peat and sawdust media, deficiency symptoms were less severe and were restricted to plants receiving fertiliser with K/N ratios up to 0.17, but not 0.3 (Table 1). Examination of data for the K/N ratios of the shoots (Table 1) gives a clue to the reasons for these differences in response to the same fertiliser solutions by plants growing in different media. These data show that the K/N ratios of the shoots were similar to those of the fertiliser solution for plants growing in peat and perlite, but they were much higher in plants growing in the other two media. A cause for plants growing in the peat and bark medium lies in the amount of K in medium components. The peat and perlite contained a total of 40 mg K per pot, while the peat and bark contained 204 mg per pot. Much of this extra K in the bark was available to and taken up by the plants, so they were protected from the deficiency that would normally accompany use of a fertiliser with a very low K/N ratio.

There was a different cause for high shoot K/N ratios in plants growing in the peat and sawdust medium, which contained a similar amount of K (46 mg per pot) to that in the peat and perlite medium. The data of Table 1 show that the effective K/N ratio of the fertiliser was about doubled for plants in peat and sawdust. In this medium, microbial decomposition of the sawdust was using soluble N at a very high rate. Its nitrogen drawdown index (NDI_{75}) was only 0.1 (Handreck, 1992a, b). This means that each week about 20 mg N per pot was being consumed during microbial decomposition of the sawdust (Handreck, 1993). This is half the 40 mg N per week applied in the fertiliser. An assumption that K is not used during microbial decomposition, or if it is, it is quickly recycled, leads directly to a conclusion that the effective K/N ratio of the fertiliser would be doubled in a medium such as this.

Table 2. Effect of nitrogen drawdown and fertiliser on K and K/N ratio of *Petunia* 'Stereo Red' shoots.

	Fertiliser K/N ratio					
NDI_{75} of the medium	0.33 Shoot K % dm	0.33 Shoot K mg/pot	0.33 Shoot K/N ratio	0.50 Shoot K % dm	0.50 Shoot K mg/pot	0.50 Shoot K/N ratio
			300 mg/litre N in fertiliser			
1.0	1.31	139	0.46	1.96	247	0.68
0.76	1.67	173	0.59	2.02	254	0.63
0.69	1.83	159	0.66	2.05	219	0.57
0.46	2.22	154	0.84	2.07	221	0.64
0.28	2.53	159	0.73	4.35	231	1.13
0.05	3.23	140	0.87	5.18	214	1.25
0	4.18	118	1.11	6.06	194	1.52
			600 mg/litre N in fertiliser			
1.0	1.99	324	0.49	2.97	443	0.66
0.76	2.28	298	0.52	2.79	519	0.69
0.69	2.51	309	0.60	2.46	457	0.66
0.46	2.23	319	0.53	3.55	399	0.73
0.28	2.25	293	0.65	3.61	414	0.75
0.05	3.02	271	0.78	4.97	352	1.34
0	2.88	257	0.67	4.00	334	0.95

Second Experiment. The second experiment confirmed and extended this link between nitrogen drawdown and effective fertiliser K/N ratio. Some of the results, shown in Table 2, show a progressive increase in effective K/N ratio with lowering of the NDI_{75} of the medium. The effect is somewhat swamped through application of the large amounts of K in more concentrated fertiliser solutions, but is still in evidence (Table 2).

EFFECT OF K/N RATIO ON FLOWERING

The second experiment provided interesting information on the effect of K deficiency on flowering and on the partitioning of K amongst the various parts of *Petunia* plants. Potassium deficiency symptoms in the leaves did not impair flowering (Table 3). This can be understood by considering the data of Table 4. These show that the plants were able to maintain a fairly constant K concentration in the flowers, at the expense of greatly reduced concentrations in the leaves and stems. The flowers (and shoot tips) were protected. Raising the amount of K applied to a very high level (Table 4) produced only modest increases in the K concentration in the flowers.

Table 3. Effect of the K/N ratio of the fertiliser solution on the number of flowers per *Petunia* 'Stereo Red' plant (averaged over all mixes).

Fertiliser K/N ratio				
0.33	0.5	0.67	0.83	1.1
		300 mg $litre^{-1}$ N		
20	25	23	20	21
		600 mg $litre^{-1}$ N		
35	36	40	41	38

These data do not support the notion that flowering is improved by providing plants with large amounts of K. There is an optimum, which varies with type of medium, above which there is little increase in flower K content, or in flower numbers.

Table 4. Examples of the effect on K (% dm) in various parts of *Petunia* 'Stereo Red' shoots of fertiliser composition and of the NDI_{75} of the medium in which they had been grown.

NDI_{75} of medium	Oldest leaves	Middle leaves	Shoot tips	Stems	Flowers
		K/N = 0.33: 300 mg/litre N			
1.0	0.66	0.57	1.83	1.03	1.8
0.76	0.89	1.13	2.21	1.37	2.11
0.69	1.70	1.62	2.31	1.45	1.88
0.46	1.89	2.09	2.62	1.91	2.14
0.28	3.17	2.96	2.80	2.09	2.15
0.05	4.75	3.41	3.33	2.53	2.59
0	3.87	4.33	4.21	4.11	no fl.
		K/N = 0.83: 600 mg $litre^{-1}$ N			
1.0	5.87	4.90	4.68	4.21	2.70
0.76	5.31	4.92	4.69	3.59	2.76
0.69	6.10	5.46	4.72	4.33	2.61
0.46	7.26	6.38	4.87	3.95	2.82
0.28	7.71	5.20	5.58	5.07	3.02
0.05	7.84	8.54	7.18	8.70	4.48
0	8.36	8.87	6.88	5.90	3.87

EPILOGUE

An experiment with *Fuchsia coccinea*, of similar design to the second experiment described here, has given broadly similar results, suggesting wide applicability of the results to flowering plants in potting media.

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Propagation of *Persoonia* Species by Seeds and Cuttings

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INTRODUCTION

Several species from the genus *Persoonia* have been noted for their horticultural potential (Wrigley and Fagg, 1989), either as a floricultural or an ornamental crop. The genus belongs to the Proteaceae family. There are approximately 72 species of *Persoonia*, all endemic to Australia except *P. toru*, which is found in New Zealand (Closs and Orchard, 1985).

The flowers and foliage of *P. virgata*, a species in south-east Queensland, are currently bush-picked and sold on the domestic market. Being an evergreen shrub that flowers year round, this filler has the potential to supply both the domestic and export markets continuously. However, as the propagation of this species has not been resolved, it cannot be cultivated. This limits the export potential of this product due to the fact that there is no guarantee of continuity of supply, uniformity, or quality of the product.

MATERIALS AND METHODS

Seed Experiment. Drupes of *P. sericea* were collected from Murphy's Creek, southeast Queensland in June 1992. The mesocarp was removed by either fermentation, following the method as described by MacDonald (1986), or acid extraction, using 32% hydrochloric acid (HCl), following the method as described by Crossley et al. (1993). The seed were then stored in plastic bags at ambient temperature.

The following treatments were then applied in February 1993:

Chemical Scarification. This treatment was used to soften the woody endocarp, and thus aid the mechanical scarification process. Treatments used were: sulphuric acid (H_2SO_4) at 98% for 15 min or caustic soda (NaOH) at 5% for 15 min.

Mechanical Scarification. The degree of endocarp removed, using a sharp scalpel, was either:

- Moist fruit—pierced; ends removed; half removed longitudinally; or majority removed;
- Dry fruit—half removed longitudinally; or
- Moist fruit—none removed (control).

The experiment was a 2 × 2 × 6 factorial, with three replications and four fruit per replication. A completely randomised layout was used. The fruits were cultured aseptically, following a disinfestation process. This involved the scarified seeds being soaked in an airtight vessel containing an aqueous solution of sodium hypochlorite (2000 ppm chlorine) for 20 min, with regular shaking. The culture medium used was de Fossard's (1981) Holding Medium at half strength, with 10

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ml placed in glass jars. The cultures were placed in a growth chamber with a 16 h photoperiod, and at a constant temperature of 25C. Visible protrusion of the radicle or cotyledons was used as the parameter to determine germination. Fruit were assessed three times weekly for up to 100 days after culturing.

Cutting Experiment. Young, vegetative, tip growth of *P. virgata*, which had slightly firmed, was collected in the morning from State Forest 959, Gympie district in southeast Queensland in June 1993. The plant material was trimmed to tip cuttings approximately 10 cm in length, and rinsed for 10 min in sodium hypochlorite (600 ppm chlorine), followed by a final rinse in tap water. The treatments tested were:

Hormone Treatments. These were applied as 5-sec, basal quick dips, using combinations of the auxin, IBA, and the cytokinin, benzylaminopurine (BAP), dissolved in 80% ethanol. The cuttings were trimmed at the base and the basal third of the leaves removed prior to dipping, with excess solution allowed to evaporate before planting. Hormone concentrations and combinations used were:

1) Control (80% ethanol)
2) 2 ppm BAP
3) 4 ppm BAP
4) 2000 ppm IBA
5) 2000 ppm IBA / 2 ppm BAP
6) 2000 ppm IBA / 4 ppm BAP
7) 4000 ppm IBA
8) 4000 ppm IBA / 2 ppm BAP
9) 4000 ppm IBA / 4 ppm BAP
10) 8000 ppm IBA
11) 8000 ppm IBA / 2 ppm BAP
12) 8000 ppm IBA / 4 ppm BAP

Propagation Media.

1) Oasis® Wedge® growing medium;
2) Growool® blocks; or
3) 1 peat : 1 perlite : 1 vermiculite (by volume) in jiffy peat pots.

Oasis® growing media are rigid, open-celled, water-absorbing foams that are recommended to be always kept moist (Smithers-Oasis, sales brochure). Growool® is a rockwool product, that provides a fairly wet medium with low air porosity (Peate, 1989). However, Peate further explains that when used in fogging propagation systems, the media will not be as wet as when used in a misting system.

The experiment was a 12 x 3 factorial, with five replications and eight cuttings per replication. A completely randomised layout was used. The cuttings were placed in a propagation house, with bench heating at 25C, and humidity maintained at 86% by a fogging system. The cuttings were manually irrigated daily.

During the twelfth week of the experiment, the cuttings were assessed for callus or root development. Any unrooted, live cuttings were recut and retreated with the hormone being tested before being placed back into the propagation environment with fresh medium. These were finally assessed after a further 12 weeks. Callus production was rated on a scale from : 1—no callus, to 4—large callus.

RESULTS AND DISCUSSION

Seed Experiment. The seed experiment described in this paper shows that fermenting the fruit of *P. sericea* and then removing half of the endocarp longitudinally from moist fruit will maximise seed germination in an aseptic environment.

The method of fruit removal had a significant effect ($P<0.01$) on germination, with no germination resulting from fruit removal using 32% HCl, while some fruit which had been fermented germinated. The reason for this result is unknown and requires further investigation.

Minimal or no mechanical scarification inhibited germination, possibly due to the hard woody barrier restricting embryo development or limiting oxygen availability to the embryo. However, germination was significantly increased (P<0.01) when the endocarp was half removed longitudinally from moist fruit. Germination of seed which had almost all of the endocarp removed was significantly lower (P<0.01) than when the endocarp was half removed from moist fruit. The lack of germination from these seed may be a result of the embryo being damaged during the removal procedure, or the endocarp may have a role in the regulation of seed imbibition.

Neither chemical used for scarification had a significant effect (P>0.05) on the germination of the fermented fruit. As illustrated in Fig. 1, with the three endocarp treatments having a germination response, each chemical contributed to approximately half of the total germination percentage. Even though the chemical scarification treatment appears to have no direct effect on the germination response of this species, it did make the endocarp easier to remove, as did the moist fruit compared to the dried fruit.

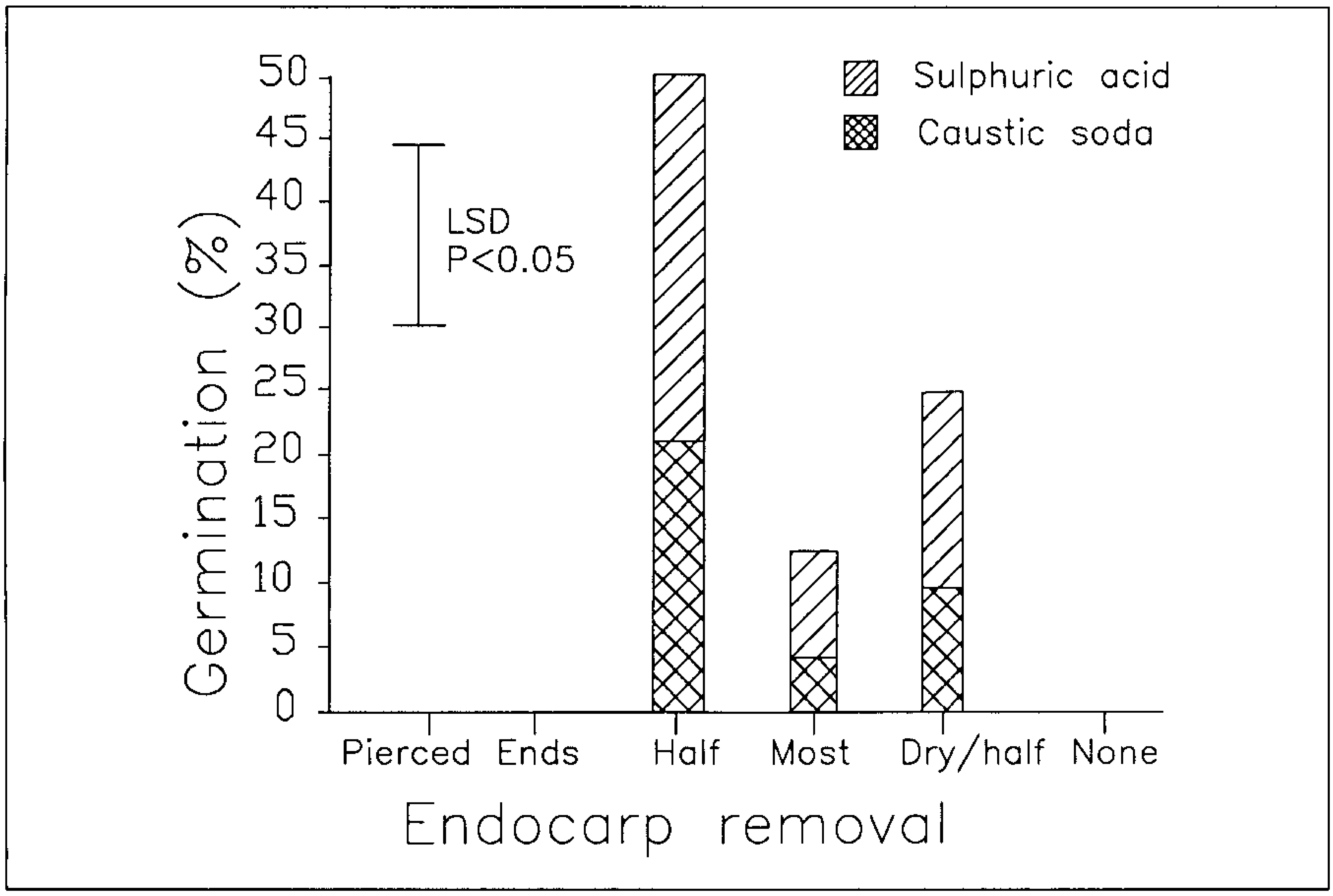

Figure 1. Effect of scarification treatment and endocarp removal on the germination percentage of fermented *Persoonia sericea* seed.

Cutting Experiment. Hormone treatment influenced cutting survival. A significantly greater (P<0.01) number of cuttings died when treated with a hormone containing 8000 ppm IBA, when compared to the control (Table 1). This result was consistent with both harvests, suggesting that a toxicity effect was occurring from such a high concentration of IBA.

The effect of the hormone treatments on callus production was not significantly different (P>0.05) at either harvest periods, when compared to the control (Table 1). Further investigations are required with the hormone treatment, allowing for comparisons of higher concentrations of BAP.

The Growool® medium was demonstrated to be the superior medium in this experiment. It produced a significantly lower ($P<0.01$) number of dead cuttings, and a significantly higher ($P<0.01$) callus rate, than the other two media, as indicated in Table 2. This result was consistent for both harvest periods. The use of a fogging propagation system allowed the Growool® medium to be less moist than the peat mixture, with the Oasis® blocks being too dry for an optimum rooting response. The physical properties had a direct effect on the callus production and death of the cuttings, suggesting that for a fogging propagation system, Growool® should be used for *P. virgata*.

Table 1. Comparison between number of dead cuttings and between callus rate of a control and each of the hormone treatments of *P. virgata* cuttings at 12 and 24 weeks.

	Harvest (weeks)		Harvest (weeks)	
	12	24	12	24
Hormone treatment	Number of dead cuttings		Callus rate	
Control	0.27	0.47	1.79	2.32
2 ppm BAP	0.33	0.87	1.73	2.07
4 ppm BAP	0.53	0.93	1.71	2.13
2000 ppm IBA	0.33	0.80	2.14	2.41
2000 ppm IBA/2 ppm BAP	0.47	1.13	2.02	2.37
2000 ppm IBA/4 ppm BAP	1.00	1.80	1.77	2.22
4000 ppm IBA	1.40	2.00	1.60	2.10
4000 ppm IBA/2 ppm BAP	0.40	0.67	2.12	2.59
4000 ppm IBA/4 ppm BAP	0.53	0.73	2.07	2.44
8000 ppm IBA	2.73	3.60	1.59	2.17
8000 ppm IBA/2 ppm BAP	2.27	3.07	1.60	2.48
8000 ppm IBA/4 ppm BAP	1.73	2.20	1.83	2.21
$LSD_{0.05}$	0.99	1.26	NS	NS
$LSD_{0.01}$	1.30	1.65		

Little rooting occurred in this experiment. However, of the rooted cuttings, the majority were treated with the hormone 4000 ppm IBA/4 ppm BAP and were planted in the Growool® medium.

Table 2. Comparison between number of dead cuttings and between callus rate of the media treatments of *P. virgata* cuttings at 12 and 24 weeks.

	Harvest (weeks)		Harvest (weeks)	
	12	24	12	24
Media treatment	Number of dead cuttings		Callus rate	
Oasis®	1.40	1.98	1.70	2.19
Growool®	0.22	0.43	2.05	2.66
Peat/perlite/vermiculite	1.38	2.15	1.75	2.02
$LSD_{0.05}$	0.53	0.65	0.19	0.20
$LSD_{0.01}$	0.69	0.85	0.25	0.27

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Formulation of a Production Program for Container-Grown Plants—A Nursery Manager's Approach

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One of the most rewarding experiences for a nursery person is observing the successful release of new and improved product lines into a discerning market. However, many fail to appreciate the challenging and sometimes frustrating stages necessary in developing a product from "grow" to "woah". While often it may be tempting to take a chance in the rush to introduce new lines to the market, a methodical approach is more likely to be successful.

A suggested plan for the formulation of a production program includes:

- Identify any special production requirements of the plant species/ cultivar for a new or existing stock line. Background information can be obtained from past production experience with related species and published literature. Concisely summarise these findings, highlighting the important agronomic traits.
- Conduct trials using existing nursery production programs. Grow trial batches throughout the nursery for at least a 1-year production cycle. This will give an indication of how the plant performs through each season. Microclimates which exist throughout production areas may also have a significant effect on plant performance.

Detailed records should be kept of the trial progress, this includes weather information, pest and disease details, written descriptions and photographic records of plant health and vigour.

The information gained from the literature, together with the trial results, forms a useful basis to determine whether production of a particular line is feasible.

Some further points which may influence production viability include:

- Market climate, e.g., consumer demand and expectation, competition from other producers.
- Potential production problems, e.g., need for specialised growing facilities, specific nutritional programs.

Pending consideration of the above factors future trial work can be directed towards the refinement of production techniques. Patience is the key to successful product development, sufficient time must be allowed to fully overcome production problems and explore new marketing ideas.

Propagation of Xerophytic Plants

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INTRODUCTION

The nursery and landscaping industries are always looking for new and exciting plant species. There is great economic potential in relatively unknown Australian plants from which these industries could benefit. In my opinion native Australian plants have not been explored to their full potential.

I am in charge of the permanent pot collection at the Australian National Botanic Gardens. It comprises Australian native plants that are either difficult to grow in cultivation or have a conservation status. While these plants have proven difficult to grow in Canberra's heavy clay soils, they perform very well when containerised. The plants in the collection represent different ecological areas from within Australia, which include plants from temperate to arid environments. The plants in this collection are genetically identical to wild or naturally occurring plant populations.

In total the collection holds 378 different taxa. Included in the collection are small trees, shrubs, groundcovers, herbaceous perennials, tufted perennials, perennial herbs, bulbs, grasses, and semi-parasitic plants.

PLANTS WITH HORTICULTURAL POTENTIAL

Many of the plants grown have spectacular characteristics which ensure their horticultural potential. The work program at the nursery allows for experimentation and trials to be conducted by the staff. The results of these activities may be of benefit to the horticultural industry, including the cut flower sector. Arid plants make up approximately one third of the collection which I maintain. I believe these plants in particular have enormous potential as they adapt to a variety of conditions and would make good feature specimens for low maintenance and rock gardens.

For example, *Haemodorum coccineum* or blood root is found growing in Queensland, the Northern Territory, and Western Australia, it is easily propagated by division of the rootstock or from seed. This plant requires a low level of maintenance, but would make a spectacular cut specimen because of its intense scarlet flowers on a 70-cm stem.

XEROPHYTIC PLANT USE

With the current concern for water conservation, it is necessary to reconsider the type of plants grown and the type of landscape to use. In many areas of Australia dry periods can last for several months. In these areas local species or species of an arid or semi-arid origin are severely under-utilised. Plants that can tolerate low water conditions must also be able to adapt to changes in climate, root environment, and soil pH as well as many other factors affecting growth. For the Australian National Botanic Gardens this becomes relevant with the planned arid

[1] 1994 Rod Tallis Award Winner.

plant display. Termed xeriscaping, this is an exciting and new form of horticulture that will play a large role in the gardens of the future.

PROPAGATION TECHNIQUES

The single most important factor in maintaining a healthy and aesthetic collection of containerised plants is propagation. Regular propagation, every 3 to 5 years depending on the species, maintains healthy and vigorous plants which have greater pest and disease resistance, better flower production, and improved strike rate when propagated.

When such a diverse collection of plants is to be maintained a wide range of propagation methods and techniques must be used.

CUTTINGS

The most common method of propagation used on the collection is cuttings. The type of cuttings, hardwood, semi-hardwood, or softwood, vary between different species and the time of year that cuttings are taken. The preferred cutting type is softwood, though many species will respond better with semi-hardwood cuttings.

The cuttings are usually no more than 150 mm in length according to the species and amount of material available. Sterile conditions are maintained in all working areas and propagation instruments are treated with a chlorine-based sterilising agent prior to the commencement of propagation.

Hormonal Treatments. Various hormone treatments are used and these are discussed in a paper previously given by Carmen (1993).

Other Treatments. Other treatments or variable treatments exist for propagation. These include the use of fogging, mist, no or low humidity, and plastic-bag treatments. The use of these varies with plant species, e.g., plastic-bag treatments for difficult-to-propagate plants with tomentose foliage.

Propagation Mix. The propagation media is sterile and is comprised of 5 perlite : 1 peat (v/v). The high air-filled porosity of 35% and its good water holding capacity prove to be a suitable combination for the fog conditions.

DIVISION

Division is an essential form of propagation used on the collection. Special considerations including time of year, type of plant, bottom heat, and pruning techniques all play important roles in the success of this method. The collection is highly diverse, many plants are easy to divide, e.g., *Mimulus prostratus*, while others like *Boyra nitida* require special attention to all the above factors and more, including careful monitoring and application of water.

GRAFTING

Grafting is a useful technique for those plants that are difficult to propagate, e.g., *Grevillea plurijera*, or plants which are susceptible to root diseases, e.g., *Prostanthera* sp. An example where grafting has been used successfully on a difficult species is with *Eremophila* sp. using *Myoporum insulare* as the root stock. The success of this is largely due to the nature of the stock, which produces copious amounts of callus tissue in a short period of time. Another reason for grafting plants in this situation is size control or dwarfing. Many plants are too vigorous to be maintained in a pot for a long period of time, they either become pot bound or regularly blow over in the wind due to being top-heavy.

CLONAL MATERIAL

All of the above methods of propagation produce plants with an identical genetic make-up to the stock plant. This is desirable as it ensures the continuation and purity of the species from the wild population.

CONCLUSION

The large number of different taxa from all over Australia make the collection very interesting and challenging to work with. I enjoy the responsibility of being in charge of such a collection as it gives the opportunity to use a wide variety of propagation techniques and to develop protocols for particular plant species.

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Overcoming Poor Germination in Australian Daisies

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INTRODUCTION

The evaluation and commercialisation of many Australian daisies has been limited by poor germination (Schaumann et al., 1987). Achenes of the Asteraceae consist of an embryo encased in a membranous coat (testa) which is surrounded by a fibrous outer coat (pericarp) which often has pappus hairs to aid dispersal. Both the testa and the pericarp have been identified as barriers to germination with exotic members of the Asteraceae. Removal of these layers, puncturing them, or soaking seeds in various solutions such as gibberellic acid are all reported to improve germination although the result is generally species specific (Atwater, 1980; Taylorson and Hendricks, 1977). Investigations were conducted to test the effects of scarification of the testa and pericarp, gibberellic acid, and light, on germination and dormancy of selected Australian daisies.

MATERIALS AND METHODS

Achenes from 27 species of Australian daisies were collected from wild populations throughout Western Australia and Queensland during the Summer of 1990 and 1991 (Table 1).

Achenes were stored at room temperature and germination trials conducted in petri dishes, within 36 weeks of collection. Germination trials were completely randomised designs of three germination treatments—intact achenes moistened with water (control), scarified achenes moistened with water, and intact achenes moistened with 500 mg $liter^{-1}$ GA_3—with two light levels (light and dark). There were five replicate petri dishes of 15 achenes for each species evaluated. Moistening solutions also contained 0.2% Thiram® fungicide (Rhone-Poulenc) and were applied at 5 ml per dish. Achenes were scarified by exposing a portion of the embryo with a dissecting needle. Petri dishes were placed on laboratory benches in ambient conditions. Mean daily minimum and maximum temperatures were 13±2C and 24±1C, respectively. Dark treatments were covered with aluminium foil while light treatments were exposed to 45±6 $\mu M\ m^{-2}\ s^{-1}$ from a combination of fluorescent and natural light, for 10 to 12 h daily.

Germinated achenes were counted at Day 15 in dark treatments and every 3 days for 30 days in light treatments. At the end of the assessment period, achenes were dissected and those which contained undeveloped or no embryos were scored as nonviable. Germination was then recorded as percent viable achenes. Time (days) to 50% maximum germination (T_{50}) of intact achenes, following imbibition with water and exposure to light, was derived from plotted curves of mean percent germination against time for each species.

RESULTS AND DISCUSSION

Species responded differently to the treatments applied and germination following one or more treatments occurred in 17 of the 27 species evaluated (Table 1). The testa and pericarp were influential in suppressing germination of *Leucochrysum stipitatum*, *Rhodanthe chlorocephala* ssp. *chlorocephala*, *R. manglesii*, and *R. stricta*, while an embryo dormancy which could be overcome by GA_3 limited germination of *Brachyscome iberidifolia, Chrysocephalum apiculatum, L. fitzgibbonii, L. molle, Myriocephalus stuartii, R. polygalifolia*, and *R. moschata* (Table 1).

Light stimulated germination of *Brachyscome iberidifolia, C. apiculatum, Hyalosperma glutinosum* ssp. *venustum, L. fitzgibbonii, L. stipitatum, R. humboldtiana, R. stricta,* and *Waitzia acuminata* (Table 2).

On the other hand, germination of *R. chlorocephala* ssp. *chlorocephala* was inhibited by light in control treatments (Table 2.).

Recommendations for seed propagation of seventeen species are given in Table 3.

CONCLUSIONS

This study has documented the germination characteristics of seventeen Asteraceae native to Australia. The pericarp and testa were influential in suppressing germination in some species, while an embryo dormancy which could be broken by GA_3 and/or light, occurred in others. It is suggested that a pre-germination treatment of GA_3 would be beneficial when germinating native daisy achenes about which little is known.

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Table 1. Effect of scarification and GA_3 on mean percentage germination at thirty days from imbibition, of seventeen species of Australian daisies (Asteraceae) in light conditions.

Species[1]	Seed age[2] (wks)	T_{50}[3] (days)	Germination (%) Intact (control)	Scarified	GA_3	Signifcance of treatment effect[4]
Brachyscome iberidifolia Benth.	32	3.0	82.4a	78.7a	99.5b	**
B. latisquaemea F.Muell.	32	13.4	51.1ab	43.0a	64.4b	*
Chrysocephalum apiculatum (Labill.) Steez. (syn. *Helichrysum apiculatum*)	28	9.8	65.9b	N[5]	26.5a	*
Hyalosperma glutinosum ssp. *venustum* (Moore) Wilson (syn. *Helipterum venustum*)	28	3.4	31.7a	31.4a	37.0a	NS
Leucochrysum fitzgibbonnii (F. Muell.) Wilson (syn. *Helipterum fitzgibbonnii*)	36	5.5	18.4a	18.5a	69.6b	**
L. molle (Cunn. ex DC) Wilson (syn. *Helipterum molle*)	36	-	0	1.7a	17.4b+	*
L. stipitatum (F. Muell.) Wilson (syn. *Helipterum stipitatum*)	28	9.6	24.2a	56.3b	65.7b	**
Myriocephalus stuartii (F. Muell. & Sond.) Benth.	28	-	0	0	6.2	-
Rhodanthe chlorocephala ssp. *chlorocephala* (Turcz.) Wilson (syn. *Helipterum chlorocephalum*)	24	9.4	4.0a	17.9b	8.3[a]	*
R. chlorocephala ssp. *rosea* (Hook.) Wilson(syn. *Helipterum roseum*)	24	2.0	72.4a	68.2a	78.1a	NS
R. humboldtiana Wilson (syn. *Helipterum humbodtianum*)	24	1.5	99.9a	99.9a	99.9a	NS
R. manglesii Lindley (syn. *Helipterum manglesii*)	24	2.6	38.5a	63.9b	53.1a	*
R. moschata (Cunn.ex DC.) Wilson (syn. *Helipterum moschatum*)	36	16.5	16.0a	22.4a	75.6b	**
R. polygalifolia (Cunn.ex DC.) Wilson (syn. *Helipterum polygalifolium*)	28	-	0	0	17.3	-
R. stricta (Lindley) Wilson (syn. *Helipterum stricta*)	28	13.4	0.5a	15.9b	31.5b	**
Schoenia filifolia ssp. *subulifolia* (Turcz.) Wilson (syn. *Helichrysum subulifolium*)	32	4.0	94.9a	91.3a	93.9a	NS
Waitzia acuminata Steetz	36	4.0	86.3a	66.2a	69.0a	NS

[1] *Chrysocephalum podolepidium* (syn. *Helichrysum podolepidium*), *Erymophyllum*

ramosum ssp.*involucratum* (syn.*Helipterum involucratum*),*Lawrencella davenportii* (syn.*Helichrysum davenportii*),*Lawrencella rosea* (syn.*Helichrysum lindeyi*),*Minuria denticulata, Podolepis auriculata, Podolepis gracilis, Podolepis jaceoides, Waitzia aurea* and *Waitzia citrina* failed to germinate during the course of the experiment.

2 Seed age (weeks from collection) at beginning of germination trial.

3 T_{50} (time to 50% germination) of intact seeds treated with water.

4 *, **, NS; Significant at $P < 0.01$, $P < 0.05$ and non-significant, respectively. Treatment means within rows followed by different letters, are significantly different at $P < 0.05$.

5 N = not scarified.

Table 2. Effect of GA_3, scarification and light on mean percentage germination at fifteen days from imbibition of seventeen species of Australian native daisies (Asteraceae).

	Germination (%)						Significant effects[1]		
	Intact		Scarified		GA_3				
Species	light	dark	light	dark	light	dark	light (l)	treatment (t)	t x 1
Brachyscome iberidifolia	82.4b	80.7b	78.7b	58 8a	99.5c	90 3b	*	**	NS
B latisquaemea	28.0abc	26 2ab	13.6a	31 9bc	47.3cd	52.0d	NS	**	NS
Chrysocephalum apiculatum	56 9c	0.05a	N[2]	N[2]	24 7b	17.1b	**	NS	**
Hyalosperma glutinosum ssp. *venustum*	31 7b	0 05a	30.0b	0.6a	31.0b	34.4b	**	**	**
Leucochrysum fitgibbonnii	18.4b	1.7a	16.2b	1 7a	62 3d	40 9c	**	**	NS
L. molle	0	0	1 7a	6 3ab+	15 3b+	6.1a+	NS	*	*
L. stipitatum	15.4b	1 4a	25 7bc	0.05a	48 5d	41.4cd	**	**	*
Myriocephalus stuartii	0	0	0	0	4.4a+	9.4a+	-	NS	-
*Rhodanthe chlorocephala*ssp. *chlorocephala*	1 4a	27 3c	11.7bc	6.5ab	8.3ab	3 7a	NS	NS	**
R. chlorocephala ssp *rosea*	72.4a	62.6a	66.9a	62.8a	76.9a	97 7b	NS	**	*
R. humboldtiana	99.9b	99.9b	99.9b	99.9b	99.9b	97.1a	**	**	**
R. manglesii	37 1a	37.5a	68 4cd	77.7d	48 6ab	58.0bc	NS	**	NS
R. moschata	5 3a	18 5ab	11 2a	37.9bc	66.0d	59.1cd	NS	**	NS
R polygalifolia	0	0	0	0	4.3a+	12.0a+	-	NS	-
R stricta	0.5a+	0 05a	14.6b+	4.2ab+	12.4b+	1.4a	**	**	NS
Schoenia filfolia ssp. *subulifolia*	94.9a	89 8a	86.2a	86 7a	93.9a	91.6a	NS	NS	NS
Waitzia acuminata	34 5b	7.4a	24.8b	3.1a	69 0c	54 8c	**	**	NS

[1] *, **, NS; Significant at $P < 0.01$, $P < 0.05$ and nonsignificant respectively; +, significantly different from zero. Treatment means in the same row followed by different letters are significantly different at $P < 0.05$.
[2] N = not scarified.

Table 3. Recommendations for seed propagation of seventeen species of Australian daisies.

Species	Pre-sowing treatment	Light response	Sowing
Brachyscome iberidifolia	GA_3	positive	surface
B. latisqaemea	no	neutral	surface/shallow
Chrysocephalum apiculatum	no	positive	surface
Hyalosperma glutinosum ssp. *venustum*	no	positive	surface
Leucochrysum fitzgibbonii	GA_3	positive	surface
L. molle	GA_3	neutral	surface/shallow
L. stipitatum	scarify or GA_3	positive	surface
Myriocephalus stuartii	GA_3	neutral	surface/shallow
Rhodanthe chlorocephala ssp. *chlorocephala*	scarify	negative	covered
R. chlorocephala ssp. *rosea*	no	neutral	surface/shallow
R. humboldtiana	no	positive	surface
R. manglesii	scarify	neutral	surface/shallow
R. moschata	GA_3	neutral	surface/shallow
R. polygalifolia	GA_3	neutral	surface/shallow
R. stricta	scarify or GA_3	positive	surface
Schoenia filifolia ssp. *subulifolia*	no	neutral	surface/shallow
Waitzia acuminata	no	positive	surface

Commercial Marcotting of Fruit Trees

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INTRODUCTION

Marcotting is the internationally recognised horticultural term for aerial layering, originating from the French word "marcotte"; that is "to aerial layer". This method of vegetative propagation is widely used throughout the world to clonally propagate fruit trees which are difficult to reproduce by any other means, e.g., lychee and longan. It is also an easy way to propagate most types of plants without the need for specialised equipment, growing houses, or skills.

Marcotting uses large amounts of propagation material and is labour intensive. Both these factors limit the commercial use of this propagation technique when compared to the more cost-effective methods used in the highly competitive nursery industry. It can also produce a weak-rooted plant that is prone to lodging if the root system is not properly trained when the marcot is removed from the parent tree and grown on.

PRINCIPLES OF MARCOTTING

The basic principle is to cincture the branch by completely removing a section of bark around the branch to a width of 1-4 cm, depending on branch diameter. A suitable rooting medium is placed over the cinctured area and enclosed in an impervious material that will retain the desired moisture level in the rooting medium and keep excess moisture out. Usually sterile peatmoss is used as the rooting medium and clear plastic is used as the impervious material. The plastic is held firmly in place by binding with strong twine or by using plastic covered wire, such as twist-ties.

The marcot root ball needs to be held firmly in place during the rooting period as any twisting of the rooting medium around the branch will damage roots.

BOTANY

Cincturing the branch removes the bark and hence the phloem or food conducting tissue down to the active cambium layer. Care must be taken not to excessively damage the water-conducting tissue or xylem inside the cortex (the hard woody section of the branch). The stronger the cortex, the easier it is to cincture a branch without damaging the xylem. This is important as the branch, stem, and leaves above the cincture rely on this water supply for survival.

Sugars manufactured by the leaves above the cincture can no longer transfer down the branch to the lower stem and roots, and therefore accumulate in the cinctured branch. This accumulation of sugars is as important as root development, for this supports the marcotted branch once removed from the tree until an independent root system develops.

It is important that no active cambium cells or any bark remnants remain within the cinctured area. Re-callusing of the cincture will result in the sugars going to the main parent plant, and even if adequate roots develop in the marcot root ball, the marcot can die soon after removal from parent tree due to lack of food reserves.

Starches and carbohydrates begin to accumulate at the top of the cincture. This encourages the development of a ring of callous at that point and, provided moisture conditions and rooting medium are correct, roots develop from this callous into the rooting medium.

The first roots that appear are generally thick, corky, adventitious roots that are few in number and very fragile. In time, fibrous secondary roots develop from the primary roots. It is important that marcots are allowed to remain on the parent tree until secondary roots are well developed. This time will vary depending on plant genus, species, variety, and temperature. Usually a minimum of 10 weeks to a maximum 20 weeks is required for proper root development and sufficient food reserve accumulation.

MARCOTTING PROCEDURE

Cincturing. The width of the cincture is generally 3 to 4 times wider than the branch diameter. A pair of adjustable pliers or multi grips are ideal for bark removal.

Some species with very active cambium that tends to re-callous during the rooting period need to be left for 1 to 2 weeks prior to wrapping with rooting medium. Alternatively the cambium can be removed by scraping or by using abrasive emery paper.

Angular stems can be a problem as bark with associated cambium may remain in grooves. Remove bark using a pointed instrument.

Cincturing is best done when there is good sap flow as bark is easier to remove.

Rooting Media Type/Placement. Many different media may be used such as peatmoss, vermiculite, perlite, bagasse, leaf mould, clay, straw, well drained soil, coconut dust, rice hulls, and raw sphagnum moss. Any medium that is well aerated but holds moisture is suitable.

Generally, peatmoss or raw sphagnum moss mixed with varying amounts of vermiculite or peatmoss are used to obtain the correct physical properties for each particular plant species. Sterile, disease-free materials give best results. A rooting medium that holds together is easier to use, as less is lost during the plastic wrapping procedure.

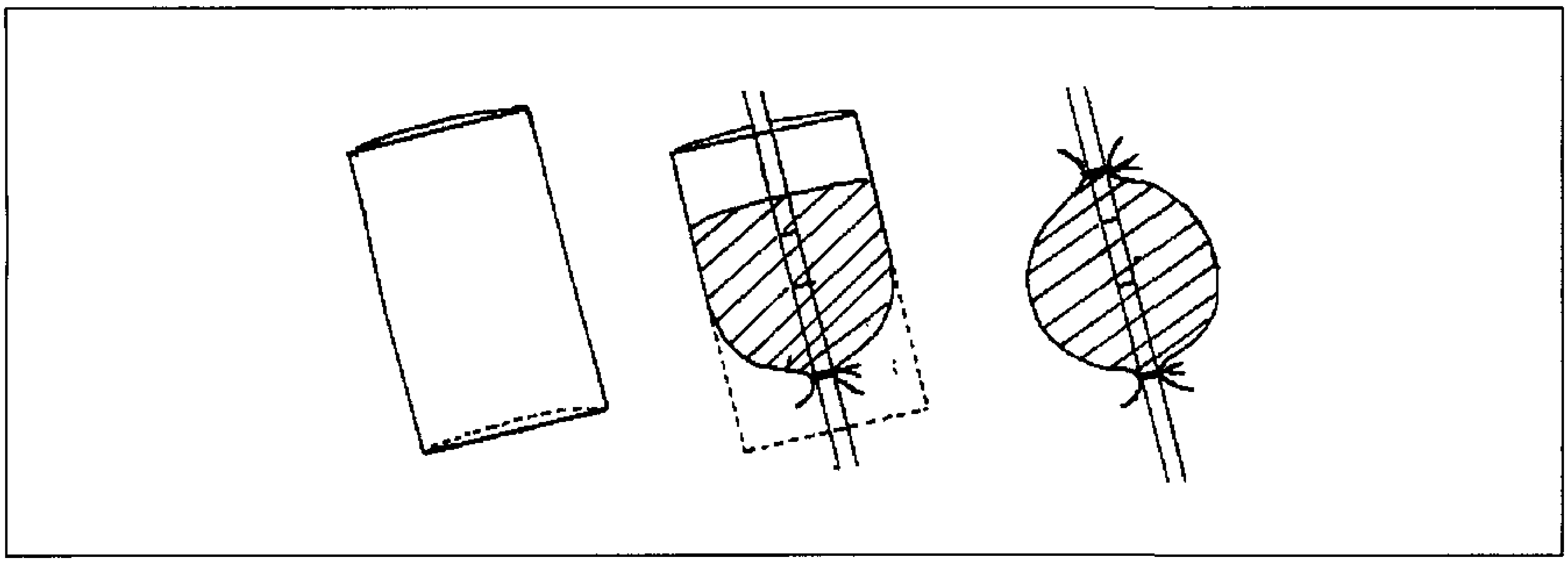
Root ball size should be as small as possible relative to branch size to achieve success, e.g., a completed root ball of 12 cm by 8 cm is ideal when marcotting lychee and longan branches, 1-2 cm in diameter with a total marcot branch length of 50-60 cm. Too large a root ball will hold excess moisture that will inhibit root development and increase the weight on the parent tree which can cause limb breakage.

The placement of the rooting medium is important. Aim to have the top of the cinctured area in the top one-third of the rooting medium. This allows for some flexibility when wrapping rooting medium onto the branch. Too low and the roots will not develop as the top tie will prevent root development. Too high and the roots will not have sufficient room to grow.

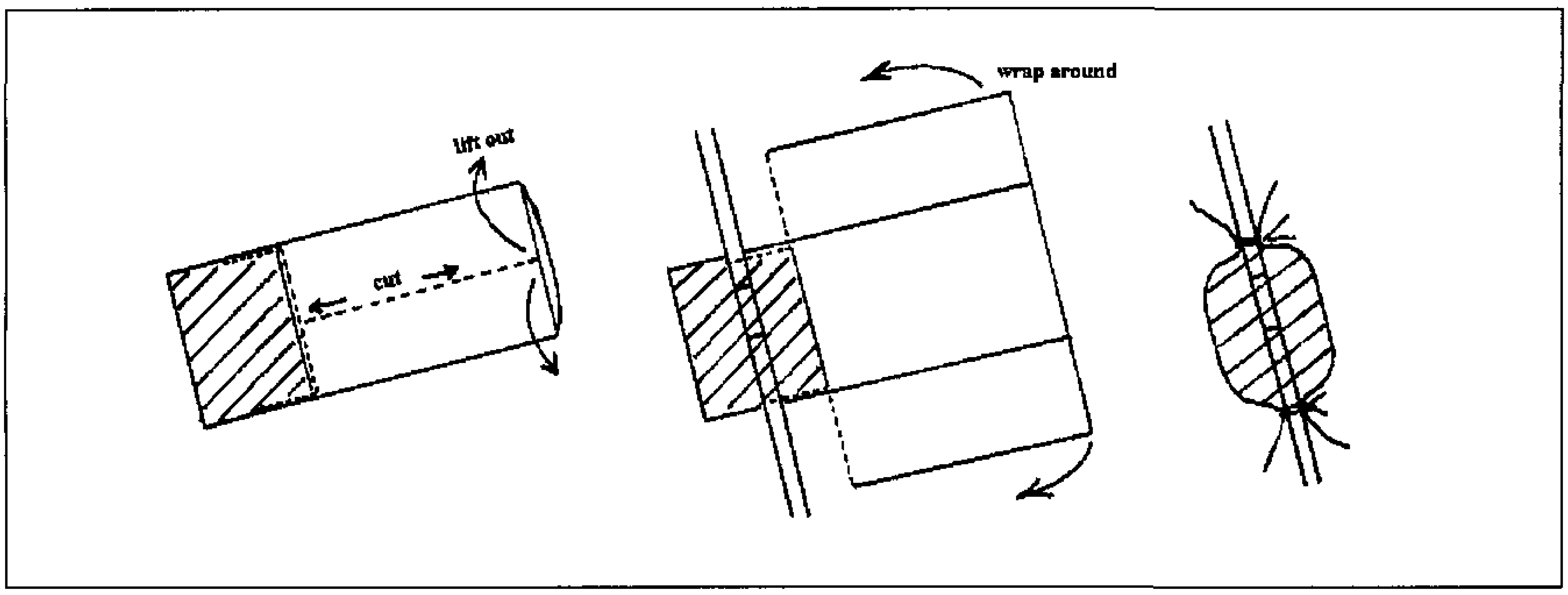
Wrapping Methods. The methods of applying the rooting medium, plastic wrapping, and securing vary greatly depending on personal preference and speed of operation required.

1) Plastic sleeve suitable for small numbers as this method is slow (approximately 25 per hour). The required size plastic sleeve is pulled down over top of branch, tied

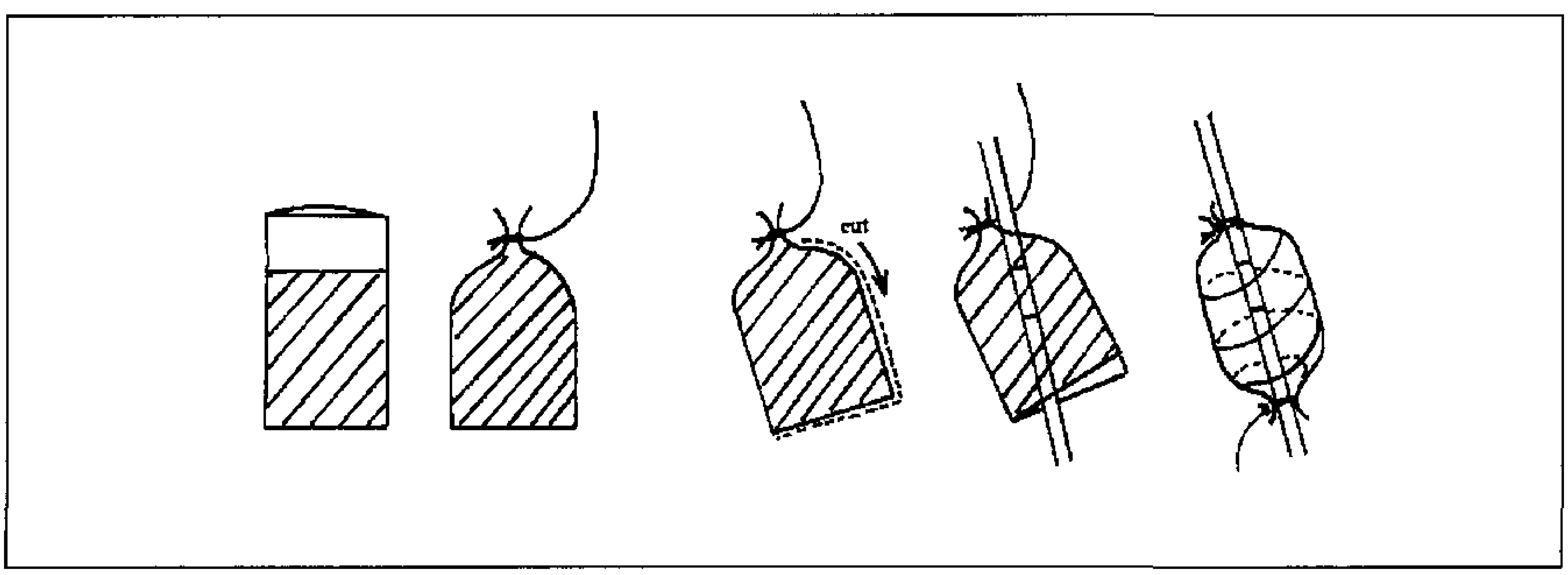
off below cincture, rooting medium is placed into sleeve, plastic sleeve is pulled up, medium is squeezed tight, and plastic sleeves are tied off above cincture.



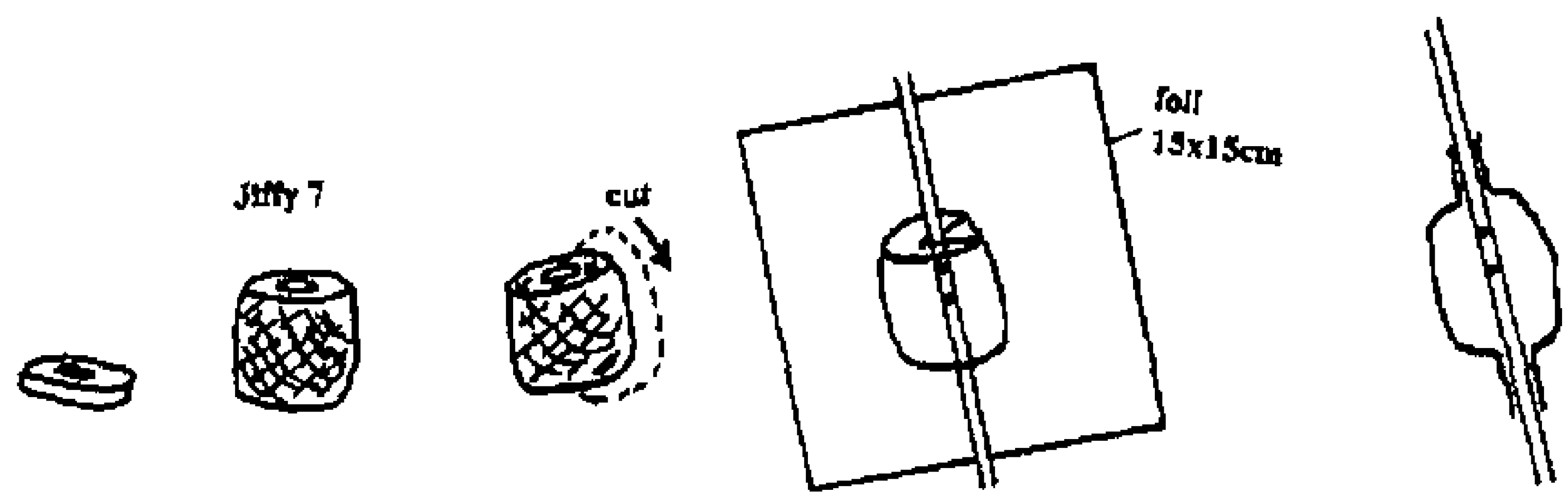
2) Split pre-filled plastic pouch and flap—lower pouch is filled with rooting medium, pouch is placed around cincture, and rooting medium is pushed up and around branch. Remaining plastic flap is wrapped around branch and the top and bottom are fixed using twist-ties. Approximately 45 per h can be completed.



3) Pre-filled plastic bags tied off with 30 to 60 cm twine—plastic bags 20 × 10 cm are pre-filled and the open end is tied off with 60 cm of strong twine. The plastic bag is cut from twine knot, along one side and down to the bottom. The rooting medium is pushed up around branch, plastic is pulled up either side of branch, over and around rooting medium. The plastic is then tied up using attached twine. Approximately 50/h can be completed.



4) Jiffy 7 peat pot/aluminum foil wrap for mini marcots—Jiffy 7 peat pots are expanded in water and allowed to free drain. The attached net is cut lengthways along one side of Jiffy 7. Peatmoss is pushed around branch and wrapped with pre-cut aluminum foil sheet—suitable for very small branches around 0.5 cm only. This has limited use, generally when propagation material is scarce.



TIMING

Marcotting can be carried out at any time of year so long as the bark is easily removed during the cincturing operation. Late spring to early summer is usually the best, provided mother plants are well grown and under irrigation if dry weather conditions are experienced at that time of year. Best root development occurs under the diurnal temperature range 15 to 28C depending on plant species.

Ideally if marcots can be removed and grown on during the warmer summer months, root establishment is easier and plants are stabilised before the onset of cool winter temperatures. If dry springs and early summers are likely, or if parent trees are not irrigated, it may be best to delay marcotting until mid summer or when rainfall is likely. Excessive rain with extended periods of cloudy weather and low temperatures generally gives a poor result. The physical properties of the rooting medium and thickness of plastic used may need to be varied according to weather conditions.

AFTER CARE

When removing mature marcots with very dry rooting medium, place in water within 5 to 10 min of removal to avoid stress and possible root damage. Trim leaves on marcot branch according to the extent of root system development. Trim any twisted roots and roots growing around and upwards before potting on. Keep the newly potted plant in a high humidity atmosphere of at least 75% to 80% RH.

Avoid excessive watering of newly planted marcot but do not let potting medium and/or marcot root ball dry out. Care must be taken with fertilisers and any applied nutrients during the initial establishment period. Weak nutrient solutions or small amounts of longer-term slow-release fertilisers are safest for 3 to 4 months. Roots take 3 to 6 months to establish depending on plant species and temperature.

The Development of a Program of Commercial Production of Staghorns from Plant Tissue Culture

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INTRODUCTION

Staghorns (*Platycerium superbum*) are naturally found in subtropical to tropical areas of Australia, Singapore, and the Philippines. They are a magnificent epiphyte and are sought after to such an extent that they are becoming rare due to the removal of their natural habitat through logging, clearing, and bush harvesting operations. This species has a single growing point and therefore cannot be propagated using off shoots as is the case with the elkhorn (*P. bifurcatum*). Spores are produced annually by mature specimens. Production from spores in a greenhouse requires a time frame of 2 to 4 years and is considered to be an unreliable method of propagation.

No references can be found for in vitro production of staghorns. Previous work with *P. stemaria* (Beauvois) Desu by Hennen and Sheehan (1978) produced 300 explants in a 16-month period using the shoot tip from a mature plant. By comparison there are numerous references to in vitro production of (*P. bifurcatum*) where 150 new shoots from one explant were obtained in 3 months using young excised leaves as the initial explant with no growth regulators in the culture media (Camloh and Gogala, 1991).

A program has been developed in our laboratory where commercial numbers have been produced, deflasked, and re-established which should ease the pressure of bush harvesting on this species.

MATERIALS AND METHODS

Spores were collected in autumn from a mature domesticated plant and were surface sterilised using the centrifuging techniques of Taji (1993). The spores are shaken in a centrifuge tube using sterile water with a drop of Tween 80 detergent and centrifuged at 2800 RPM for 5 min to settle the spores to the bottom of the tube. The supernatant is decanted and replaced with sterile water; this is then shaken and left at room temperature for 24 h. The tube is then re-centrifuged, the supernatant is again discarded, and 10 ml of 1% sodium hypochlorite solution is added and the tube allowed to stand for 5 min. The tube is centrifuged again, the supernatant discarded, and the spores planted aseptically onto a modified de Fossards (1976) medium level, broad-spectrum media (Table 1). The spores are planted without final washing with sterile water.

Spores were cultured in a 200-ml-capacity, glass screw-capped jar with an opaque polypropylene lid containing 25 ml of media, then sealed in a small plastic bag. This helped prevent desiccation and reduce microbial contamination from spores in the air or small insects such as mites in the incubation area.

Cultures were incubated using 36 W fluorescent tubes with an average light intensity of 1000 lux with a 16-h light 8-h dark photoperiod. A constant temperature of 25C±3C was maintained.

Table 1. Modified deFossard's medium (1976).

Macronutrients (mM)	NH_4NO_3	10
	KNO_3	10
	NaH_2PO_4	1
	$CaCl_2$	1.5
	$MgSO_4$	1.5
Micronutrients (µM)	H_3BO_3	75
	$MnSO_4$	50
	$ZnSO_4$	20
	$CuSO_4$	0.05
	Na_2MoO_4	0.5
	$CoCl_2$	0.05
	KI	2.5
	FeEDTA	50
Sucrose (mM)		90
Growth factors (µM)	Inositol	300
	Nicotinic Acid	20
	Pyridoxine HCl	3
	Thiamine HCl	20
Agar		8g per litre
Activated charcoal		150 mg per litre

Within a period of 3 months aseptic spores had germinated producing prothallus which could be subcultured at intervals of 2 to 3 months providing a source of gametophytic tissue. Large numbers of small sporophytic plants were spontaneously produced from these cultures without the need for flooding the surface with water to aid germination.

Shoot multiplication occurs either directly from the prothallus tissue or from adventitious buds formed in large numbers on the lower surface of larger leaves in close proximity to the media surface.

These small explants are subcultured to fresh media and incubated for a further 2 to 3 months where rapid growth occurs; typically these plants are 2 to 3 cm in diameter and are large enough to be deflasked.

Initially large numbers of plants were lost at this stage. The problems of re-establishing plantlets from in vitro conditions to greenhouse conditions are well known. The plantlets are very small and have been shown to have little crystalline wax on their leaves, they are not photosynthesising and usually have a poorly developed root system not adapted for handling the stresses of the outdoor environment.

The following conditions need attention if successful acclimatisation is to be achieved:

Humidity. Plants take 6 to 8 weeks to become fully acclimatised. High relative humidity for the first few weeks is essential and can be provided by either mist or a fogging system. Fog systems conserve plant moisture and cool the atmosphere with only small volumes of water being used.

Light. Plants are provided with up to 90% shade, especially during the hot summer months. Once roots have developed and leaves are fully functional the plants can be weaned through a series of structures designed to reduce the dependence on reduced light. A 70% shadecloth-covered structure offers excellent light and wind protection.

Temperature. Laboratory incubation rooms maintain a constant temperature of 25C year long. Plants transferred to a greenhouse are subjected to much greater temperature fluctuations ranging from 10 to 50C. Being sub tropical to tropical plants, a temperature range of 25 to 35C would be expected to be ideal.

Diseases and Pests. Sanitation and disease prevention is essential for transplanting success. Plantlets have come from the laboratory in an aseptic state and are therefore vulnerable to disease-causing microbes. Every effort is made to ensure that standard nursery hygiene procedures are adhered to. The two most commonly encountered groups of pests include root- and stem-rot fungi which can be controlled with Mancozeb™, mites which can be controlled with Rogor™, and fungus gnats which can be controlled with Mesurol™ or diazinon.

Bio-systems Environmental Growth Rooms. As an alternative to a conventional greenhouse with inherent problems associated with the management of

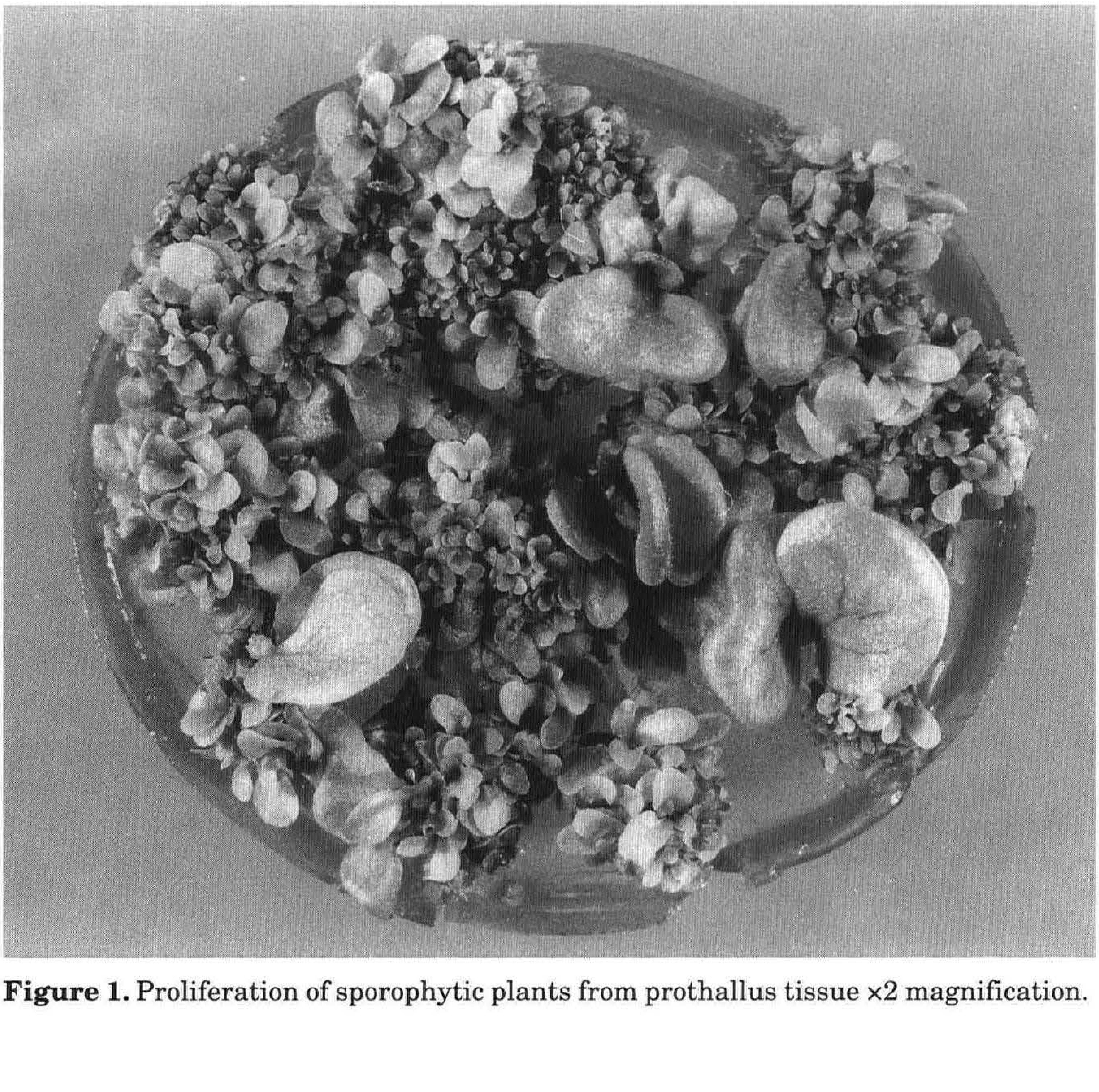

Figure 1. Proliferation of sporophytic plants from prothallus tissue ×2 magnification.

temperature, lighting, and humidity, we have deflasked large numbers of staghorns in the Biosystems Growth Rooms. The room is based on a shipping container with ten shelves and a central walkway down the entire length of the room. Each room has a shelf surface area of 50 m^2 and is lit with cool-white florescent tubes. Production is possible 12 months of the year since the controlled environment operates independently of ambient season and weather influences.

Minimal watering is required since the relative humidity is accurately controlled without the need for mist resulting in a lesser opportunity for either fungus or pest development. The computer-controlled cabinet offers precise control of temperature, lighting, humidity, and carbon dioxide enrichment of atmosphere. A 6- to 8-week turnaround of plants is possible throughout the year.

Potting Media. With loses of large batches of plants we realised that a plug was required that was sterile, free-draining, and would allow the staghorn to rotate from a horizontal position to a vertical position. It is thought that if the growing point is in this position it will shed excess water and help prevent rotting problems from occurring.

Using larger plants than initially tried, a high plant-out success rate using Oasis Wedge (Smithers - Oasis Aust. Pty. Ltd.) has been achieved. A small elastic band is used to secure the staghorn to the top of the wedge. Plants are place either under fog or in our environmental growth room (Gaincover-Biosystems) under a Maurix cover until the plants are sufficiently hardened off to be transferred to a 70% shadecloth-covered structure—a period of 6 to 8 weeks is normal.

Once plants have been hardened off they can be placed vertically on the side of a 50 mm-plastic tube with a 10 mm wedge cut from the top of the tube. A coarse free-draining potting mix of perlite and slashed pine is preferred. The next stage of production involves mounting the staghorn. Although none have yet reached full size it is believed that they will be of a marketable stage within a period of 2 years.

CONCLUSION

Platycerium superbum has displayed a high multiplication potential using a single hormone-free agar based media for all stages of production. Initiation from spores has two advantages, the mother plant remains intact, i.e., the single growing point is not destroyed, and surface sterilisation of spores does not present a major microbial contamination problem. Commercial numbers of plants have been produced and marketed through the College Nursery and tissue culture laboratory. This program should reduce the need to bush harvest this species.

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New and Novel Temperate Legumes for Ornamental and Landscape Horticulture

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INTRODUCTION

The Leguminosae is one of the largest plant families, and the source of many valuable food, fodder, grazing, and ornamental plants. Most of us when we think of legumes, focus quickly on food, that is peas and beans, or on fodder, that is lucerne or clover, and those of us who are also gardeners, certainly know of lupins and sweet peas.

However, there are a number of little-known, or completely new, leguminous species which possess attributes that lend them to broader horticultural application. There are also wider benefits in growing legumes. Not only do the majority have attractive flowers and foliage, but they are also soil enrichers via their symbiotic relationship with nitrogen-forming bacteria, known as rhizobia. This symbiosis is particularly valuable when we use annual plants as green manure, a fertility-building system that works equally as well in the ornamental garden as in the vegetable garden. This ability to fix nitrogen is particularly useful when legumes are used to restore fertility back into virtually sterile sites, for example, new road embankments, mine spoil sites, or to the patient and forward-thinking home gardener, when cover is needed in a new home site. The principal genera and species are:

Dorycnium. A small genus of three species from the western Mediterranean, two have high potential as ornamentals and as landscape repairers. *Dorycnium hirsutum*, often known as, hairy canary clover, is a particularly attractive small shrub grown to 1 metre high and across. It has a very long flowering period with the pink-white flowers evident over the grey foliage for more than 6 months. It does particularly well on dry, acid soils. *Dorycnium pentaphyllum* is of a similar size but with finer foliage, small white flowers, and a preference for soils with high lime levels. Both are excellent bee-attracting plants.

Lathyrus. A large genus with species occurring naturally on every continent except Australia. One of the most familiar species is *L. latifolius*, the perennial pea, in its many forms. It is an excellent plant for covering an unsightly fence, or as a spill-over on an embankment. It has a short but spectacular flowering period of approximately 3 weeks in mid-summer. A more appealing plant which fills the same niche, but flowering for at least 6 weeks is *L. longifolius*. Coming from the drier parts of the Balkans, it is cold hardy enough to be grown throughout temperate Australia, and has no specific soil requirements. The highly ornamental flowers are in dense heads, magenta pink in colour, and held high above the foliage.

Originating also from southeast Europe, *L. digitatus* is particularly useful for well-drained, limestone-based soils. A herbaceous, long-lived perennial, with a long flowering period over late spring and early summer, the two-toned purple and white flowers are well displayed. Judging from its origin, it would be cold hardy throughout Australia and it can stand quite long periods of summer dryness. It has potential both as a garden plant and a pot or tub specimen.

In the mountains of central Asia *L. mulkak*, a herbaceous perennial, is found on dry, rocky limestone-derived soils. It is a rare plant in its native habitat owing to its palatability to livestock. Seed has only become available in the last few years. The striking features of this somewhat sprawling plant are the very large two-toned red flowers and the long flowering period over the summer months.

The newly discovered annual *L. belininsis* is the closest relative of the well known sweet pea. It was found in a remote mountainous region of southern Turkey where it occurs, like most members of the genus, on limestone-derived soils. The bright yellow and red flowers are unusual in that they are highly scented, a characteristic shared only with the sweet pea from the genus *Lathyrus*. It is quick growing, tolerating very cold winters and flowering in the late spring. This species is attractive in its present form but clearly a combination of both perfume, and yellow flowers would surely encourage the plant breeders to produce even more exciting characteristics.

Lupinus. A very large genus with virtually all the species having ornamental potential coming from the Americas. Many are dwarf, caespitose perennials, adapted to very well-drained soils and an alpine dry atmosphere, and as such have little to offer the general gardener. However, a small number are particularly showy and have already proven themselves in cultivation.

Lupinus rivularis is a small shrub growing to just under 1 m high. It is evergreen in Tasmania and maintains a neat appearance throughout the year. The showy purple-blue and white flowers are produced throughout the summer months with an occasional second blooming in the late autumn. This lupin is not specific in its soil requirements and is surprisingly drought tolerant. It would fit comfortably into a mixed garden bed.

Lupinus sp. aff *caudatus* is a small shrubby species growing up to 60 cm, but with flower spikes attaining a metre in height. It flowers profusely in early spring, when there is little colour around and the mauve blooms are spectacular. Coming from northern California it is quite hardy in temperate Australia, a period of heavy frosts assists the species reaching its full flowering potential. Seemingly indifferent to soils, it has grown and tolerates dry conditions.

Another as yet unnamed species is *L.* sp. aff *mutabilis* collected in the Andes mountains of Ecuador. It is a fast-growing annual or short-lived perennial growing to a height of approximately 1.5 m on a single stem. The flowers appear in mid-spring and continue on until mid-autumn, although in warmer areas it may flower continuously. The blooms are large and showy—blue, white and yellow in colour—and produce an agreeable perfume. Its main use is likely to be where there is a need for a quick-growing shrub that can also double as a fertility builder. It is suprisingly frost tolerant considering its origin.

Lupinus littoralis is another tidy evergreen shrub, growing to 1.5 m. It is native to the coastal areas of California and Oregon where it grows profusely on exposed sand dunes. Attractive in bloom, with numerous small flowers (for a lupin), the blue colour stands out against the deep green foliage. Whilst it may well find a place in gardens, especially those with sandy soils that dry out rapidly, its greatest use is likely to be in stabilising coastal dunes where it will be used as a fertility restorer.

Lupinus varıicolor is well named; a mixture of red, pink, and yellow flowers all produced on the same plant. The growth is semi-decumbent to prostrate spreading to approximately 1 m. Originating in the near coastal areas of California it will probably prove to be hardy throughout temperate Australia.

Lupinus leucophyllus could be grown for its downy grey foliage alone, but with its long spikes of light purple flowers it makes a most attractive addition to the spring garden. It does require a dry position in the garden, well drained, and with no hint of waterlogging, no doubt reflecting its origins from the semi-arid region of northern California. It has proved to be very cold tolerant in Tasmania.

Parochetus. *Parochetus communis,* shamrock pea, is probably a native of the high mountains of east Africa. It has been known in cultivation for a long time, but like many such plants is tender in the major gardening areas of Europe and North America. Unlike many other legumes it thrives in damp, shady situations and provides quite an adequate ground cover, spreading quickly by surface stolons. It is quite spectacular as a hanging basket subject or even as a potted house plant, with a combination of trailing stems and deep blue flowers over a long period. It is surprisingly cold tolerant in Australia withstanding temperatures as low as -8C. It has the further advantage of being easily propagated vegetatively.

Trifolium. A genus better known for its contribution to feeding livestock rather than its ability to provide ornamental horticultural plants. Nevertheless many of the species are known for their attractive flowers produced over a long period of time. *Trifolium burchellıanum* is found in many forms, from the sub-alpine zone of the East African mountains to the warm temperate woodlands of South Africa. The flowers have been described as miniature pom-pom dahlias, and the two-tone purple and white blossoms are produced in abundance during both the spring and the autumn. The plant is naturally a dense ground cover, but its greatest use is likely to be in pots to which it is very well adapted. Easily propagated from both seeds and runners it has clearly demonstrated horticultural potential.

Trifolium alpestre is well known as an alpine garden plant in Europe. It is a herbaceous perennial, spreading from rhizomes to eventually form a dense mat. It is probably suited to only the coldest areas in Australia, and prefers a high level of summer moisture. The bright red flowers appear very early in the spring and continue to appear well into the summer. Ideally suited to both pot culture and garden it can be readily propagated vegetatively.

Trifolium decorum is found naturally on the highest mountains of Ethiopia, where it grows on some very infertile soils. A short-lived perennial, it is ideally suited to pot culture in cold areas but would probably adapt quite well to areas that suffer only light frosts. The flowering period starts in the spring and finishes in autumn, with the red and pink flowers held well above the foliage. Unfortunately it is a poor seed producer and probably requires a high bee population in order to ensure seed set.

There are many species of legumes that remain to be brought into general horticulture, some still await discovery, others only needing recognition from within the industry. As their many valuable characteristics become known, the potential exists for a much greater use of leguminous plants in ornamental and landscape horticulture.

The Propagation of *Metrosideros thomasii* in Queensland

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INTRODUCTION

Metrosideros thomasii is a native of New Zealand. In its native habitat a height of 25 m can be reached, but in cultivation they seldom exceed 6 m. The tree is attractive and neat in appearance, leaves are green with a silver felted appearance. The flower is dark red and of a bottle brush type. The plant flowers at Christmas time and is often referred to as the New Zealand Christmas tree. In Australia, particularly Queensland, the tree will also flower in autumn and winter.

These trees are salt and wind tolerant on the coast, and make tidy trouble-free street trees which can tolerate polluted city air. *Metrosideros thomasii* is also suitable as a hedging plant. The species can grow in a variety of soil types.

Selection of Cutting Stock. The following attributes are necessary in the selection of material for cutting propagation: vigorously growing stock plant, good tree shape, flowers well, and free from disease.

PROPAGATION

Media. The propagation media used consists of 1 peat : 1 perlite (v/v). No fertiliser is added.

Propagation Method. Semi-hardwood cuttings are taken in the morning. Cutting material is kept moist until prepared. Multiple node cuttings produce superior plants to single node cuttings. Three to five nodes are preferred. Basal leaves are removed. The cutting is dipped in a hormone powder containing 8 g/kg IBA. The tray of cuttings should be placed on a mesh-covered bench. This is important as the protruding vigorous roots are very brittle.

Facilities. Propagation is carried out from April to September. The most successful period is when the night temperature is about 15 to 18C. During this period the humidity in Queensland is lower and infection by fungal diseases is less likely. Experimentation with chilling the cuttings to enable propagation during the summer months has been trialled, however, the humidity appears to be the major controlling factor of strike rate. Mist and bottom heat are also detrimental to the cuttings. Cuttings are placed in a house with 30% shade cover.

Maintenance. The cuttings must be kept moist, but not wet, to reduce the incidence of fungal attack. However, they are not drought tolerant and the media must not be allowed to dry out. A protective program of fungicide is used. Cuttings will develop roots after 6 to 8 weeks; once the roots appear a liquid fertiliser program is implemented. Cuttings are fertilised every 10 days, this promotes shoot growth from the nodes.

Hardening Off. The plants are removed from the shade house once roots appear through the base of the tube. The trays are placed on a bench in full sun and are potted on in the 11th or 12th week from cutting. Care must be taken in removing the plant from the tube as roots are well developed at this stage.

The Availability of Minerals in Plant Tissue Culture Media

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This paper examines some of the factors affecting the availability of minerals to plants in vitro. The growth of *Ptilotus exaltatus* explants decreased when minerals were supplied in the gel at some distance from the explants rather than in direct contact, suggesting that transport of minerals through the gel may be limiting mineral uptake. Explant growth in dry weight was proportional to the relative matric potential of the medium. Since water was lost from the culture vessels during the culture period, relative matric potential would also decrease. It is argued that mineral uptake in vitro, and hence plant growth, is limited by the declining water availability which in turn affects the rate of diffusion of minerals through the medium.

INTRODUCTION

The basic technique of plant tissue culture is now a well established commercial practice. Many plant species are routinely propagated through micropropagation. An essential part of the micropropagation process is formulation of the medium. Minerals are an important component of such media. The earlier pioneer tissue culturists (White, 1943; Heller, 1965; Murashige and Skoog, 1962; Gamborg et al., 1968) recognised the essential requirement for the supply of minerals for plant growth in vitro and developed the formulations on which most current media are based.

Increasing or decreasing the supply of minerals in the medium causes varying responses. Lee (1978) found that omission of individual elements such as N, K, P, Mg, or Fe from the culture medium significantly reduced plant growth. Barbas et al. (1993) reported growth of walnut shoot cultures dramatically decreased to almost nil after 28 days due to mineral deficiency. Increasing the supply of minerals in the medium increased the net uptake of minerals and the growth of *Ptilotus exaltatus* explants (Winney, 1988); and *Hemercallis* (George et al., 1987). However, other reports indicate that increasing mineral concentration in the medium does not always increase growth. Lumsden et al. (1990) reported that there was no significant effect of doubling the concentration of PO_4^{-3} on *Iris* growth in vitro. Inhibition of plant growth preceded the exhaustion of minerals in plant tissue. Likewise Williams et al. (1991) found that none of the essential minerals had been exhausted from the medium after growth of *Ptilotus* has ceased. Thus growth in vitro is not simply dependant on the supply of minerals provided in the medium, some other factor limits the utilisation of these minerals by the plant.

For many years little attention has been paid to the control of mineral availability and uptake in vitro until the topic was reviewed by Williams (1992, 1993). Mineral availability depends on a number of factors including the concentration of minerals in the medium, solubility of the ions, and transport of ions through the medium, as well as uptake by the plant. In this paper we are examining mineral transport through the gel.

There are two main mechanisms of mineral ion transport, diffusion and mass flow. Mass flow is where the ions are carried in solution as water moves through the system. Given the high humidity in tissue culture vessels, transpiration by the plant, and hence water flow through the plant, is low. Thus water flow through the medium to the plant would also be minimal. Therefore, it is assumed that transport through the gel must be predominantly by diffusion.

There is evidence to suggest that localised depletion of minerals occurs around plants in vitro (Lumsden et al., 1990). In fact, localised depletion has also been reported in stationary liquid cultures (Asher et al., 1965). This could occur if diffusion through the medium was slower than uptake by the plants. Romberger and Tabor (1971) argued that diffusion of macromolecules could be limited by the pore size of gelled medium. We have tested the importance of diffusion by supplying minerals either adjacent to or remote from the explants in vitro. Our hypothesis was *that mineral uptake (and hence growth) of plants in vitro will be less if the minerals are supplied at a distance from the plant rather than adjacent.*

Whether mineral transport is by diffusion or mass flow, the supply of water in the medium will be important. Diffusion requires "free" water in the pore spaces of the gel. The availability of water can be measured in terms of matric potential. The total water content and hence the matric potential of the medium would be expected to decrease over time as water is lost by evaporation from the culture vessel. It would also be expected that diffusion of minerals through gelled media would depend on mineral concentration, gel brand (Scherer et al., 1988), gel concentration (Romberger and Tabor, 1971), and water availability. The effects of gel concentration and water loss have also been investigated.

MATERIALS AND METHODS

Experiment 1. To test the hypothesis on mineral proximity, *P. exaltatus* shoot explants were cultured on a double-layered gel system. For the treatments, minerals were supplied in either the top or bottom layer only (Fig. 1). The control had minerals in both layers. Each layer was composed of 30 ml of modified MS-basal medium with 3% sucrose and 0.8% Difco Bitek^{TM} agar with or without minerals as required. Medium pH was adjusted to 5.5 before agar addition. Then medium was autoclaved at 101 KPs, 120C for 15 min.

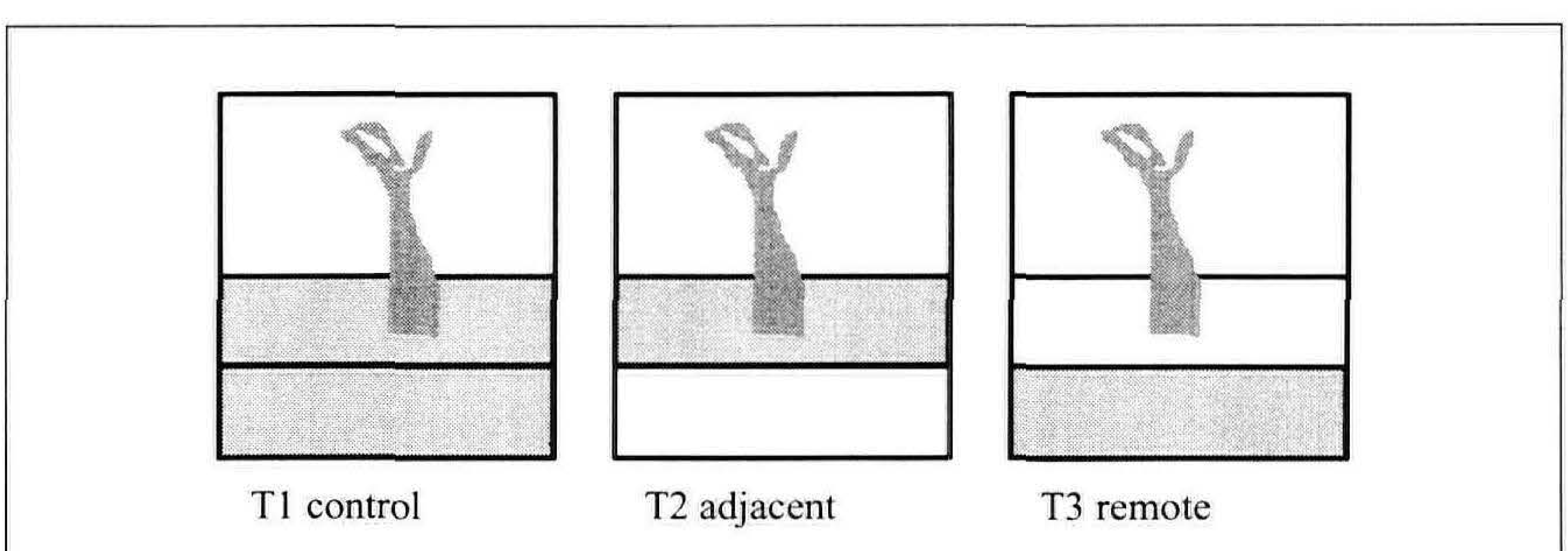

Figure 1. Layout of the two-layer media with minerals either adjacent to or remote from the plants.

Experiment 2. In a separate experiment different concentrations of gelling agents were used to modify the water potential of the medium. The relative matric potential (RMP) was determined using the technique of Owens et al. (1991) in which the rate of water absorption by air-dry filter paper discs is measured. Discs of Whatman No. 3 filter paper 5.5 mm diameter were weighted and moistened to about 90% of saturation by adding liquid medium equal to 2.60 times the initial weight of dry filter paper. The moistened paper disc was placed on the surface of the medium. The weight of liquid absorbed or lost was compared to the amount of liquid initially added to the paper. The amount of relative gain or loss of water from the paper filter was considered as RMP.

Experiment 3. In the third experiment the water loss from *Ptilotus* shoot cultures was measured. Each 250 ml screw-capped, polyethylene culture vessel contained 30 ml of gelled medium, with or without 4 explants. Culture vessels were weighed periodically over the 8-week culture period.

RESULTS

The *Ptilotus* explants in all cultures increased little in dry weight over the first two weeks following subculture but the control explants grew more rapidly between weeks 2 and 8 (Fig. 2). Final growth in the two treatments was about half that of the control, i.e., it was approximately proportional to the total mineral supply. The divergence of the growth curves indicates differences in growth rate up to week 8 after which growth stopped in all treatments. The growth rate was greater when the minerals were adjacent to the plant and hence final plant weight was nearly twice that of the remote treatment.

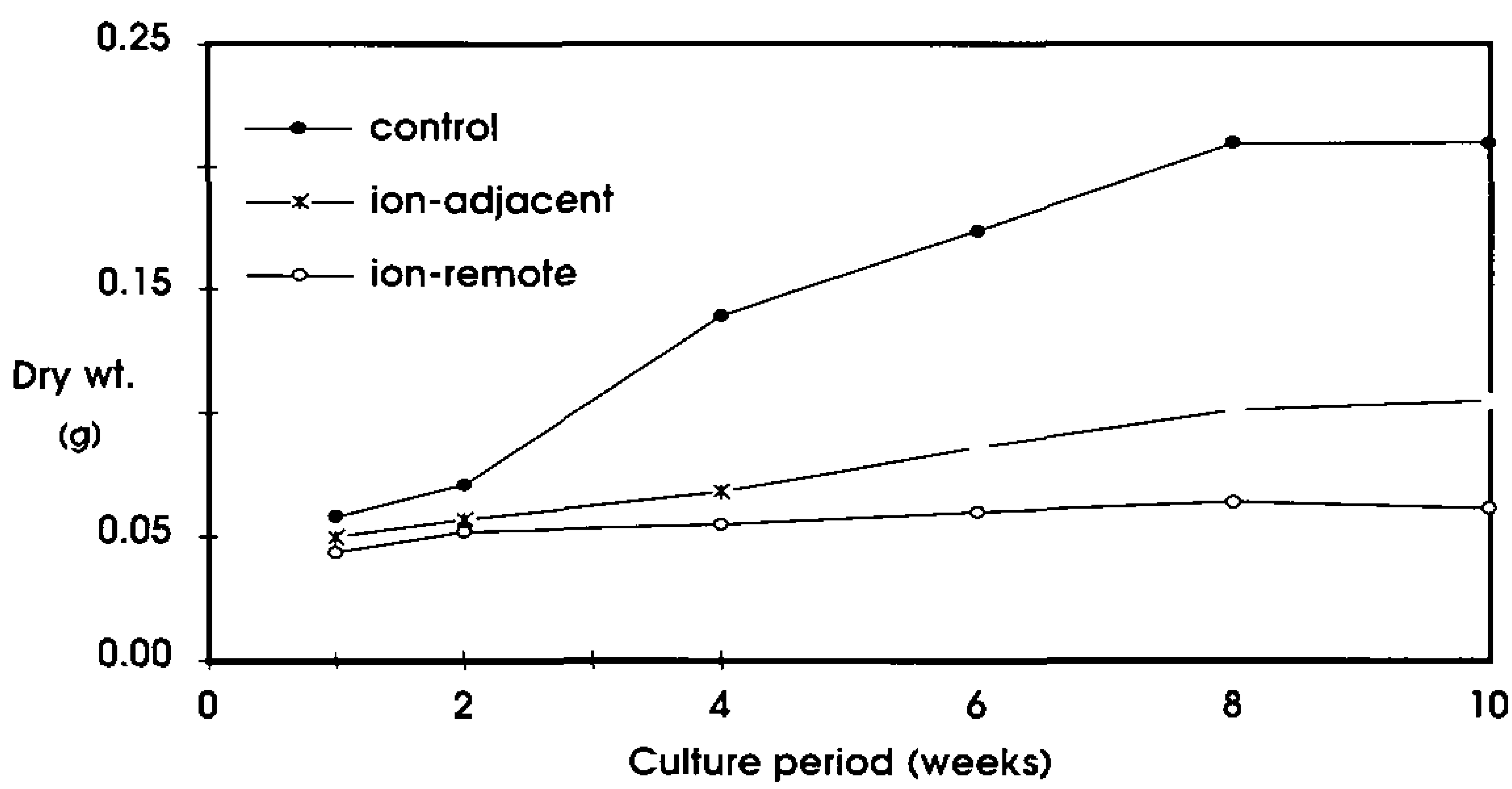

Figure 2. The effect of mineral proximity to explant on growth (dry weight) of *Ptilotus exaltatus* shoots in vitro.

Explant growth in dry weight was proportional to the RMP (Fig. 3). Growth was greatest when RMP was highest, i.e., when water availability was greatest.

The total water content of cultures declined over the culture period (Fig. 4).

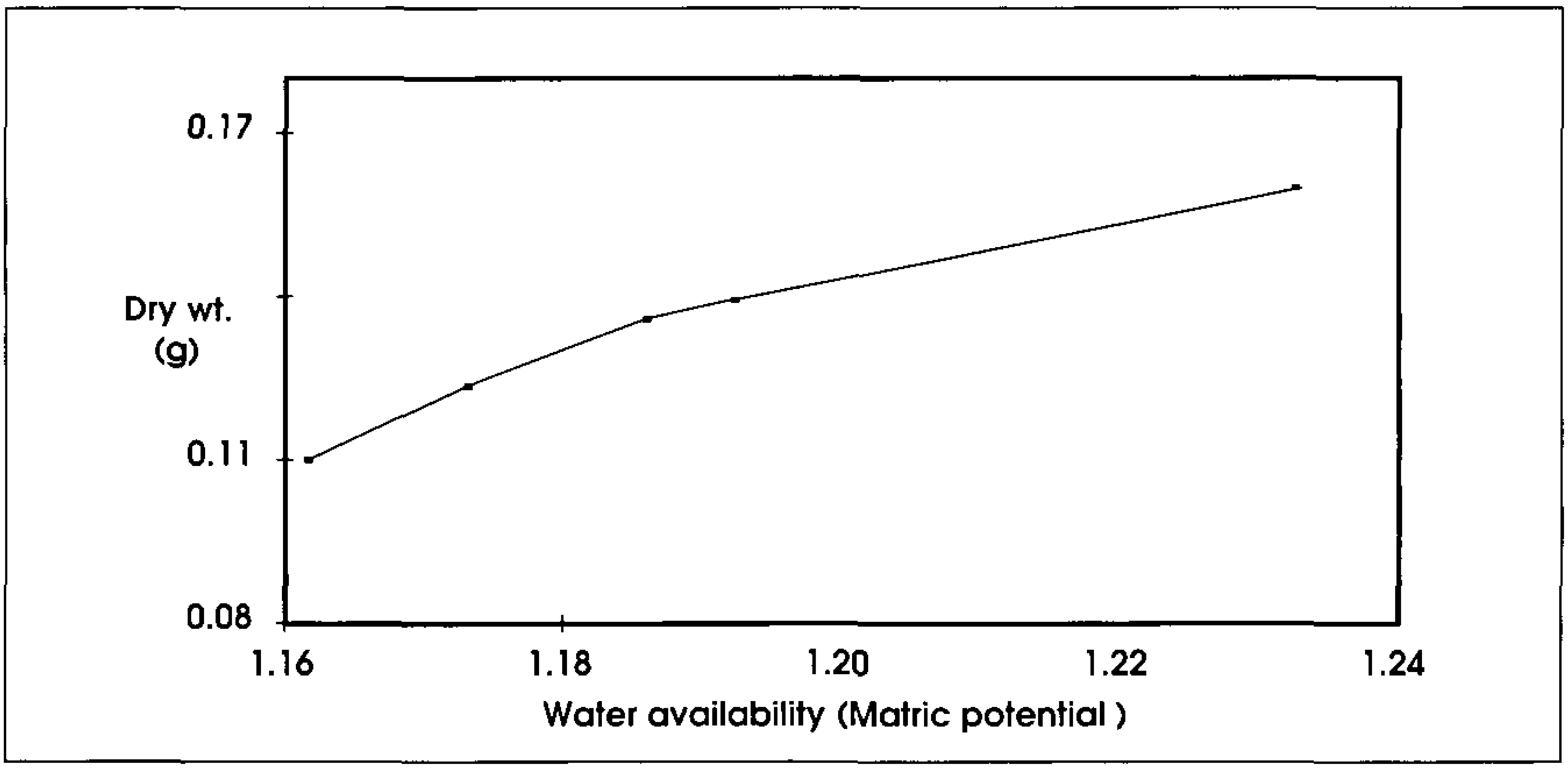

Figure 3. The relationship between plant growth and water availability in vitro.

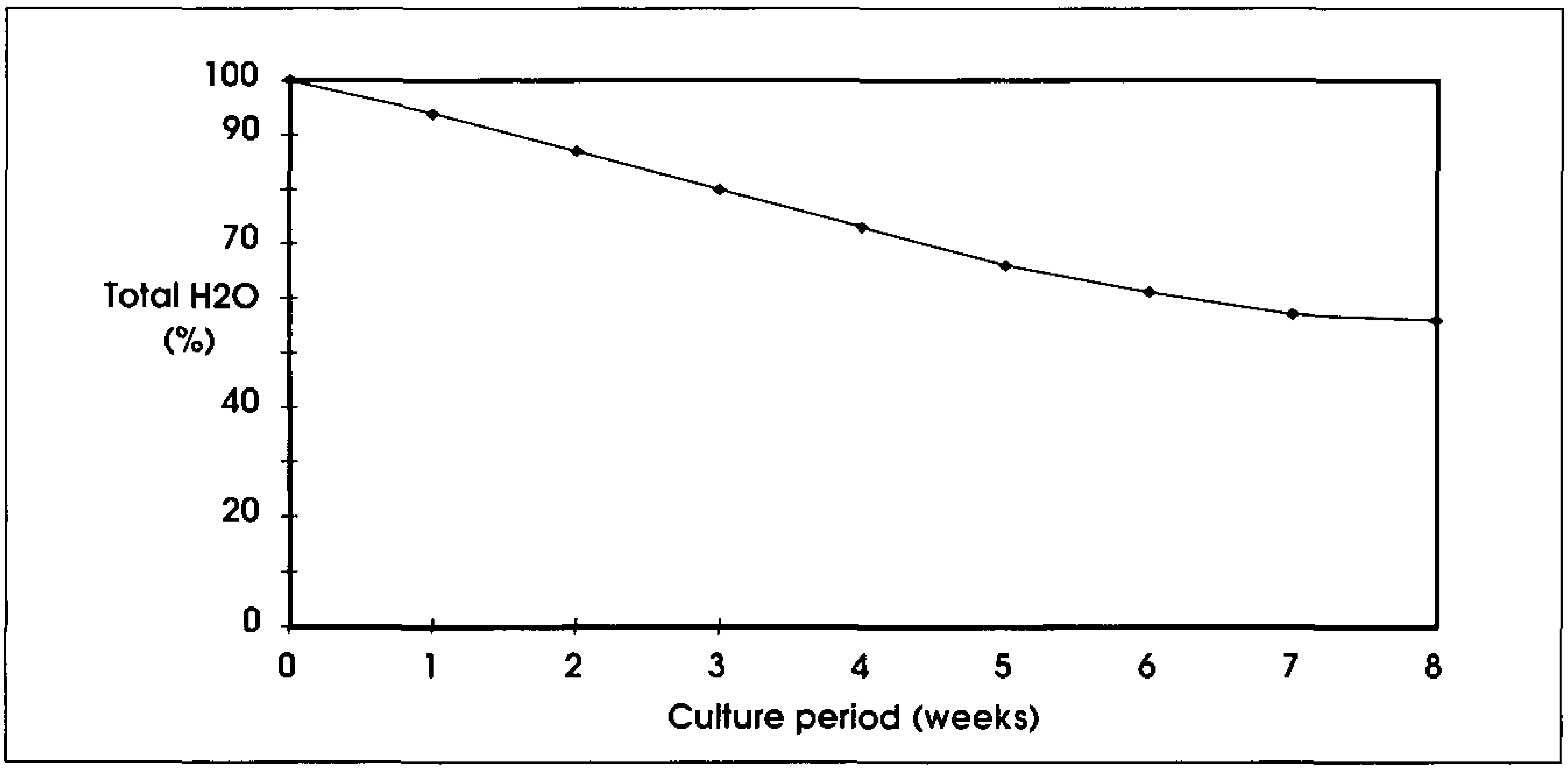

Figure 4. Water loss during the culture period.

DISCUSSION

The critical comparison in the first experiment is the adjacent versus the remote mineral supply. Growth was less when the supply was remote. This is consistent with the hypothesis that mineral uptake, and hence growth, is limited by the ability of minerals to diffuse through the gel. However, when the adjacent treatment is compared with the control it is clear that the total mineral supply has an even greater effect on growth.

It would be expected that total mineral supply would affect the final weight of the explants. A greater supply of minerals would take longer to be depleted thus supporting a longer period of growth and hence a greater final weight. But this does not explain the pattern of response observed. The greater final growth was due to a more rapid growth rate over the culture period with growth stopping after 8 weeks in all cases (Fig. 2). It has been previously shown that growth in vitro is dependant on the concentration of minerals in the medium (Pryce et al., 1993; Winney, 1988).

The concentration of minerals was initially the same in each of the mineral layers of the first experiment. However, if minerals do diffuse through the gel, the concentration would have been reduced to half in the two treatments as the minerals were distributed throughout both layers of gel. This might also explain the overall difference in growth in the control compared to the two treatments. Thus the cessation of growth in the control after 8 weeks could be due to a similar level of depletion of minerals in the gel; twice the growth rate would deplete twice the total amount of minerals over the same period.

The correlation between increased dry weight and RMP or water availability (Fig. 3), may be explained in different ways. One possibility is that explant growth is directly dependant on the availability of water and that mineral uptake follows growth. However, it has been reported that mineral uptake by *Ptilotus* shoot cultures (Williams, 1993) and *Juglans* (Barbas et al., 1993) declines before plant growth rate. Alternatively, the availability of water may directly affect the availability of minerals. This effect could be via a change in mineral solubility or a change in rate of ion mobility through the medium.

Water is lost from the gel over the culture period (Fig. 4). As this water is lost the RMP, and hence water availability, must decrease. A progressive reduction in water availability could in turn reduce the rate of mineral diffusion and thus account for the decline in growth rate seen after 8 weeks in these experiments (Fig. 2). This again suggests that water availability may be the prime limiting factor for growth in vitro. As a matter of fact, Murashige and Skoog in their classic 1962 paper, also suggest that the growth of tobacco callus was limited by the loss of water from the cultures.

This paper highlights the complexity of mineral nutrition in vitro. We have only covered some of the factors affecting mineral availability. It has been demonstrated that the availability of minerals in vitro is dependant on their rate of movement through the medium. Mineral availability is also dependant on the availability of water. We still need to determine the mechanisms involved.

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PIDAV—A New Plant Introduction Scheme for Victoria

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INTRODUCTION

In contrast to many comparable countries Australia has no history of formal plant introduction and evaluation schemes. Typically our botanic gardens have very good collections but often little consideration is given to how those plants could be made available to the professional user of plants or to the nursery industry. Botanic gardens, of course, have not been the only source of plant introductions. Specialist nurseries and enthusiastic amateur horticulturists have a long history of introducing plants into the Australian garden landscape. In the case of the specialist nursery, the motivation for introducing new plants is often a combination of plantsmanship and pure commercialism. With a few notable exceptions, these nurseries are small and often highly specialised and their influence on the broader nursery industry has been, and remains, limited. The enthusiastic amateur horticulturists who introduce plants into Australia, or who seek to improve existing plants, have as their motive the purely altruistic desire to enhance the aesthetic characteristics of ornamental horticulture. Typically these plantsmen and plantswomen, while being highly committed are also highly specialised, consequently their impact has been significant in some aspects of ornamental horticulture but negligible in the mainstream. Rarely is any attempt made to assess a plant's suitability to the broader Australian environment, or to evaluate its uses in the landscape. It would be equally unusual for any attempt to be made to determine if the plant was from the most suitable provenance source.

The lack of formal introduction and evaluation schemes, committed to promoting selected plant introduction, is one of the reasons, along with strict quarantine regulations and the difficulties often associated with the acclimatisation of introduced plants, for a more deprived state of ornamental horticulture than necessary. The absence of such schemes, and the objective assessment of plant characteristics inherent in them, has also contributed to the less than optimal development and use of our own unique flora (Hall, 1991).

In contrast to this situation, plant introduction schemes in North America, New Zealand, and parts of Europe are seen to be important programs contributing to the improvement of ornamental horticulture. Successful schemes such as the University of British Columbia Botanical Gardens Plant Introduction Scheme (PISBG) involve a cooperation, seen to be essential, between the professional plant user and the production nursery industry (Macdonald, 1983). Indeed the founder of this program referred to it as "an opportunity for a new relationship between nurseries and the public garden" (Taylor, 1988). In order to achieve a successful program an involvement is required from botanic gardens, landscape architects, and contractors—particularly those working in the public arena—and the nursery industry. The Plant Introduction and Development Association of Victoria (PIDAV) has such an involvement of all sectors of the Victorian horticultural community.

PIDAV is a new, non-profit association of horticultural organizations formed to fill the need for an industry-wide, independant, and credible way of trialling, evaluating, and awarding new plants for introduction.

At the time of formation PIDAV was an association of: Nurserymens Association of Victoria, Australian Institute of Landscape Architects, Landscape Industries Association of Victoria Inc., The Victorian College of Agriculture and Horticulture—Burnley, Royal Botanic Gardens—Melbourne, and Australian Institute of Horticulture.

Obviously such a scheme also needs a management structure dedicated to the pursuance of plant introduction and evaluation. PIDAV management consists of a Committee of Management, with representatives from each of the full members listed above, and a Technical Committee.

This latter committee is empowered to co-opt expertise from within the organisations comprising PIDAV and is responsible for the trialling and assessment of nominated plants.

OBJECTIVES

The purposes for which PIDAV was established include the following:

- To improve the aesthetic and biological quality of plant material available through nurseries by the provision of trial and evaluation facilities;
- To increase the diversity of plant material available through mainstream nurseries;
- To assess plant material for its landscape suitability;
- To better utilise botanic garden collections in the nursery and landscape industries;
- To encourage plant breeding and selection in the industry appropriate to local conditions;
- To make awards to organisations and persons successfully trialling plants and/or to plants successful in trial and to assist in the promotion of these plants.

SCHEME STRUCTURE

The management structure of plant introduction schemes depend, to some extent, on the local objectives. However, a number of stages seem obvious and have been outlined by a number of workers (MacDonald, 1987 Webster, 1988). They involve a nomination stage, trialling and evaluation, and the promotion and marketing of successfully trialled plants.

In the case of the PIDAV scheme, entrants can be individuals or companies who can legitimately claim rights to the plant material. The plant may be protected by trademark or plant variety rights but must be new, or sufficiently distinct, from previous introductions to be identified as a new variety or form or, of course, a provenance selection not previously introduced into Victoria. Comparison with existing forms may be used to determine the superiority of the new plant.

The entrant must provide information as to the origin of the plant material, sufficient for the technical committee to determine ownership and evaluate the potential of the plant and its suitability for inclusion in the trials. Several trial sites are located strategically around Melbourne and in country centres representing a reasonable range of growing conditions throughout Victoria. A judging panel will visit each trial site on two occasions throughout the year, however, at each trial site the trial field manager will make regular judgements throughout the year. These will be recorded and made available to the official panel to help formulate their assessments. The PIDAV Executive Officer will make regular inspections of the trial sites and carry out an assessment. The results of these evaluations will also be available to the panel. This regular evaluation of a plant's performance is intended to remove any bias associated with the timing of the official panel assessments. PIDAV will promote winning entries by presenting medals and certificates to the entrants at an official presentation function and by publication of the results in the media and commercial publications.

FUNDING

Initial funding to establish PIDAV was from the Nurserymans Association of Victoria.

A small nomination fee is required with each entry and, if selected for trialling, an additional fee is required.

A promotional logo or label will be applied to winning entries. A royalty will be paid for the use of the label or logo. This royalty will be used to support the Association's activities and to further develop the scheme.

CONCLUSION

A formal plant introduction scheme such as PIDAV is long overdue. The failure of the ornamental plants industry in Victoria and, indeed, in other Australian States to establish such a scheme prior to this has resulted in a more deprived state of ornamental horticulture than is necessary. In order for a scheme such as PIDAV to succeed it will be necessary for the key players in the ornamentals industry to develop a more holistic view of their industry. It must be, and is, a cooperative joint venture. Introduction schemes such as PIDAV promote to the gardening public only truly new plants which have been evaluated for performance from the nursery to the landscape. The establishment of a formal plant introduction scheme for Victoria will benefit all participants. PIDAV will result in a more integrated and professional ornamental horticulture industry in Victoria and, ultimately, an enhanced horticultural environment for Victorians.

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Pest and Disease Management in Plant Propagation

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A SHORT REVIEW

Diseases are a major constraint in the propagation of certain crop species. Losses have been so high that it was uneconomic to propagate some popular lines. With all the modern pesticides, technologies, and expertise, the problem has not been eliminated. But with an integrated approach, losses have been successfully reduced to non-significant levels in a number of crop species.

The actual crop loss due to pests and disease is difficult to estimate in the nursery situation. The high number of varieties propagated by cuttings vary in susceptibility to the endemic pests and diseases. In order to minimise losses, recognition of the value of maintaining strict hygiene procedures during all stages of taking and rooting cuttings must be made. It is easier to prevent attack by disease organisms than to try to stop their progress once established. From a disease attack where hundreds of thousands of cuttings are involved, losses can be considerable. Efforts to conduct propagation operations under clean, sterile conditions are of no avail, unless all steps of the operation are included, i.e.; the cutting material, rooting media, tubes/trays, working area, tools, rooting benches, water and irrigation systems, etc. It should be stressed that unless all agronomical procedures are followed correctly, chemicals alone will be of little use in the management of pests and disease.

It should be noted that modern intensive systems of plant propagation have frequently aggravated or provoked disease problems by being grown in "protected" environments, e.g., plastic covered houses, which create a warm and humid atmosphere conducive to the establishment and spread of a number of diseases.

Secondly the cuttings are stressed until they have rooted properly, and in this phase, they are more susceptible to diseases.

It is not easy to detect and correctly identify the pathogen(s) involved in various phases of propagation. At times batches of certain crops are unaffected by disease and hence no effort is made to protect the crop from disease. In some cases by the time the disease is detected and diagnosed, it would have spread significantly and hence apart from losing the cuttings, valuable time is lost in cleaning the propagation house as well.

Even with the present knowledge of diseases, control measures and new fungicides, it does not mean that the problems have been solved. However, by following an integrated approach, a lot can be achieved. This would mean that all the correct agronomical procedures are adhered to, the susceptibility of the crop to the pests and diseases are known and appropriate spray programs are to be used as protectants where necessary.

Propagation of Quandongs

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INTRODUCTION

Demographic studies illustrate quite clearly that it is not until the fifth generation after initial migration that people become fully integrated into a new environment. European settlement in Australia is in its fifth generation and it is only now that we are looking to commercialise our own fauna and flora. Part of this process is the development of an Australian cuisine. We are labelling it "Bush Tucker". With the guidance of aboriginal people and early settler records we are searching our native flora for new tastes and garnishing possibilities.

The quandong or native peach, *Santalum acuminatum*, is now being cultivated in commercial orchards to meet the demand for its highly prized fruit.

Some 20 years ago Dr. John Possingham, chief of the CSIRO Division of Horticulture, set about domesticating this delicate desert dweller. *Santalum acuminatum* has evolved as a partial root parasite of other plants for its survival. The species varies enormously in many of its characteristics such as tree vigour; fruit size, shape and colour; flesh to pit ratio; etc. In order to gather selections from the wild and monitor their characteristics in a controlled orchard situation, CSIRO first had to develop an asexual propagation technique. This was achieved by grafting selected scions to seedling rootstock. Success came through attention to hygiene procedures and by removing the seed from the extremely hard shell. To achieve the seed removal a hand operated nut cracker was developed. The two main disadvantages of this system were that a significant number of seeds were destroyed by exerting too much pressure, and that the whole process was most time consuming.

Our nursery was asked to commercialise the production of quandong trees and to this end we have been appointed the prime licensee for the production and sale of CSIRO selected quandong cultivars. We have followed the procedures as recommended by Grant and Buttrose (1978), Sedgley (1984), and in particular Dr. Brian Loveys. Dr. Loveys addressed the inaugural meeting of the Australian Quandong Industry Association (AQIA) in December of 1993. He described the following method of infiltrating the very hard shell of quandong seed with a solution of fungicide and growth regulator using a vacuum.

MATERIALS

- Surface sterilant (pre-germination treatment)—0.45% available chlorine solution;
- Fungicide and growth regulator infiltrate—Terrachlor (750 g kg^{-1} Quintozene) 1 g $litre^{-1}$ solution, Terrazol WP (350 g kg^{-1} Etridazole) 49 g $litre^{-1}$ solution, Pro Gibb (100 g $litre^{-1}$ gibberellic acid [GA]) 2 ml $litre^{-1}$ solution;
- 500 g quandong seed (approximately 200 seeds in shells);

- 500 g sterilised vermiculite (horticultural grade—steam at 100C for 30 min);
- Plastic bag.

Note: For all solutions described, preboiled rain water which has cooled to room temperature is used.

METHODS

- Weigh 500 g of quandong seed (approx. 200).
- Measure 500 ml of surface sterilant and soak seed in sterilant for 30 min.
- Rinse seed twice in pre-boiled cool rain water to remove sterilant. Seed must not dry out once moisture imbibing has commenced.
- Soak seed in pre-boiled cool rain water overnight.
- Drain seed—do not allow to dry out—soak in 500 ml of fungicide and growth regulator infiltrate and apply vacuum until bubbles cease. This indicates that the seed cavity is saturated with solution.
- Tip seed plus solution into 500 g of dry sterilised vermiculite in a plastic bag and seal with a twist tie.
- Place bag in a constant temperature of 15 to 18C.
- Observe weekly. When a seed has a radical approximately 1 cm long it should be "pricked off" into "grow tubes" approximately 50 mm x 300 mm, with a low phosphorus potting medium.
- Grow on, graft, and sell plant with a host plant well established in the grow tube.
- Transplant to orchard or garden with absolutely no root disturbance.

RESULTS

Forty thousand seeds have been sown using the technique described and although "pricking off" is not yet complete, indications are that germination will be 70% to 96%, depending upon cultivar. This result is similar to that achieved using the techniques of Grant and Buttrose (1978) and Sedgley (1984). However, the initial growth rate has been stimulated by the application of GA and the seedlings are protected against infestation by *Pythium* and *Rhizoctonia*.

CONCLUSION

Dr. Loveys' technique has not enhanced percentage germination, but has proved to be a great timesaver, particularly in the removal of the shell and subsequent seed destruction. Seed destruction during shell removal was approximately 20%. We have yet to determine the number of days from germination to graftable size but suspect this will also be improved due to the addition of GA to the infiltrate.

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Micropropagation of *Boronia*

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Successful micropropagation was achieved in four species of *Boronia: B. edwardsii*(Benth.), *B. filifolia*(Benth.), *B. pilosa*(Labill.) and *B. ruppii*(Cheel.). Shoot tips or nodal explants were initiated on half-strength Murashige and Skoog (MS) basal medium. A five-fold multiplication rate occurred every 4 weeks on basal medium supplemented with 1 mM each of 6-benzylaminopurine (BAP) and 6-furfurylaminopurine (Kin or Kinetin). All species produced roots on MS basal medium supplemented with various auxins. More than 90% of the rooted plantlets became acclimatized and flowered within 6 months from the date of transfer to the glasshouse.

Chemical names used: 6-furfurylaminopurine (kinetin); 6-benzylaminopurine (BAP); 1-H-indole-3-butyric acid (IBA); α-naphthaleneacetic acid (NAA); α-naphthoxyacetic acid (NOA).

INTRODUCTION

The genus *Boronia* (Rutaceae) contains about 95 species, all of which are endemic to Australia. Most species of *Boronia* occur in heath and dry sclerophyll forests where vegetation is thick and shade is available. They are mostly small, woody shrubs of 1 m or less with flower colour in varying shades of pink, mauve, red, yellow or brown. Flowers have four petals, opening widely like a star in some species (e.g., *B. edwardsii),* but remaining concave and cup-like in others (e.g., *B. megastigma).* Most have aromatic foliage and in some the flowers are highly perfumed. This genus includes some of the most popular ornamental plants in the Australian flora.

Tissue culture is one means of producing large quantities of uniform plants irrespective of season and climatic conditions. Our objective was to develop micropropagation protocols for 4 species of *Boronia*: *B. edwardsii* (Benth.), *B. filifolia* (Benth.), *B. pilosa* (Labill.), and *B. ruppii* (Cheel.). All are listed as threatened Australian species (Leigh et al., 1981).

EXPERIMENTAL PROCEDURES, RESULTS AND DISCUSSION

As the success of any tissue culture project depends upon a supply of healthy stock plants (Taji et al., 1992), cutting material was collected from field-grown plants. Cuttings were treated for 5 sec with a range of auxins in 50% ethanol (Table 1). Rooted cuttings were grown in a pasteurized mixture of 2 sand : 1 peat : 1 perlite (by volume) with 4 g/litre of Osmocote® slow release fertilizer (16N : 4.4P : 8.3K) in pots 15 cm in diameter. Resulting plants were kept in a dry glasshouse (25C day temperature and 15C night temperature) with no overhead watering and sprayed weekly with a 0.1% (w/v) Benlate solution (50% active benomyl). Pot-grown plants were 6 months old when shoots were taken for *in vitro* studies. Shoot tips 4 to 7 cm long were taken from recent growth flushes and washed under running tap water for 2 h. They were then surface sterilized by successive immersion in 70% ethanol for 30 sec; 0.5% (w/v) sodium hypochlorite containing 0.01% Triton (octyl phenoxy polyethoxy ethanol, a wetting agent) for 15 min, followed by two rinses in sterile water. Nodal and apical segments 0.5 cm long were placed in sterile medium. All media used included half-strength Murashige and Skoog's (1962) basal medium with 60 mM sucrose and 8 g/litre Difco BiTek™ agar. The pH was adjusted to 5.5 using 1 N NaOH or HCl before autoclaving at 121C and 103 kPa for 15 min. Ten ml of medium were used per 8 × 2.5-cm screw-capped polycarbonate tube. All cultures were incubated at 25C under cool-white fluorescent light with an irradiance of 50 mmol m^{-2} s^{-1} and a 16 h photoperiod.

Table 1. Effect of auxin concentration on the rooting response of shoot cuttings of four *Boronia* species to auxin[1].

	% of rooted cuttings					
	B. edwardsii		*B. filifolia*		*B. pilosa*	*B. ruppii*
Auxins (ppm)	Late Summer	Winter	Mid Summer	Early Spring	Mid Summer	Summer
Control	0	0	0	0	0	0
1000 NAA	75	30	0	0	0	15
500 IBA + 500 NAA	60	23	0	28	0	20
500 IBA + 500 NOA	63	28	0	36	10	25
1500 IBA + 500 NAA	81	40	0	26	0	10

[1] 100 cuttings per treatment.

For all species under investigation, the best shoot proliferation was achieved on half-strength MS medium supplemented with 1 mM each of BAP and Kin (Table 2). After five subcultures the shoots were transferred to basal medium (without added hormones) for 5 weeks to allow shoot elongation. Microcuttings 3 to 5 cm long were placed in basal medium containing auxins, as per Table 3, for root initiation.

Boronia species had specific auxin requirements for root formation. The highest percentage of cultures to produce roots was achieved on 2 mM IBA for *B. edwardsii* (65%) and *B. pilosa* (50%), 1 mM IBA + 1 mM NOA for *B. filifolia* (41%), and 1 mM IBA + 1 mM NAA for *B. ruppii* (20%) (Table 3).

Rooted explants were transferred to a pasteurized potting mixture containing 1 peat : 1 perlite : 1 sand (by volume) and adapted to glasshouse conditions under 30% daylight at 25C with gradual exposure to reduced relative humidity by gradually removing the glass cover over a period of 2 to 3 weeks. On transfer to a glasshouse plants were given intermittent misting for 1 week then watered daily with weak soluble fertilizer (N:P:K, 23:4:18; 25 g $litre^{-1}$). More than 90% of the rooted microcuttings survived the acclimatization procedure and produced flowers within 6 months after transfer.

Table 2. Cytokinin effect on *in vitro* shoot multiplication of four *Boronia* species cultured on half-strength MS[1].

Cytokinin	*B. edwardsii*	*B. filifolia*	*B pilosa*	*B. ruppii*
	Mean shoot number [2]			
0 µM BAP + 0 µM Kin	1.2±0.8	1.5±1.1	1.2±1.0	1.3±1.3
0.1 µM BAP + 0.1 µM Kin	2.0±1.5	2.6±1.6	2.5±2.3	2.1±1.3
1.0 µM BAP + 1.0 µM Kin	5.6±0.8	5.5±1.1	5.4±1.3	4.9±1.0
10 µM BAP + 10 µM Kin	x[3]	x[3]	x[3]	x[3]

[1] Subcultured every week.
[2] Means of 3 experiments each with 5 replicates, standard error.
[3] In all the species, dense clumps of very short shoots were produced in which it was difficult to count shoot numbers.

Table 3. Auxin effect on *in vitro* rooting of *Boronia* cultured on half-strength MS after four weeks.

Auxin	% of Cultures with roots[1]			
	B. edwardsii	*B. filifolia*	*B. pilosa*	*B. ruppii*
0	0	0	0	0
2 µM IBA	65±21	0	50±10	0
1 µM IBA + 1 µM NAA	15±7	37±14	0	20±7
1 µM IBA + 1 µM NOA	10±0	41±17	0	0

[1] Means of three experiments each with 15 replicates, standard error.

CONCLUSION

This paper outlines methods for rapid propagation of four species of *Boronia*. Work in progress is aimed at improving the percentage of rooting of these species of *Boronia*, particularly *B. ruppii*. In vivo rooting is also under study which could expedite commercial propagation of these attractive species.

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The Germination of *Bursaria spinosa* var. *spinosa*

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INTRODUCTION

Bursaria spinosa, commonly known as sweet bursaria, is a widely distributed member of the Pittosporaceae family. Variously described as a shrub or small tree, the species is found in all mainland states except the Northern Territory. It is a common and widespread member of many different vegetation communities. *Bursaria spinosa* var. *spinosa,* one of a number of named variants of the species, is identified by its smaller, obovate leaves (to 25 mm) and spines located along the branches. The inflorescence consists of a terminal panicle of fragrant, white-cream flowers in late summer/early autumn, followed by brown clusters of two-celled, purselike capsules, each housing a small number of seeds (Costermans, 1981; SGAP, 1991).

Both seed and cuttings are used for propagation of the species, however, seed is the preferred method for most revegetation activities. Information gained from a number of nursery propagators (see acknowledgments), suggests that there are a number of difficulties with seed propagation of *B. spinosa* var. *spinosa.* These difficulties include: poor and uneven rates of germination, seedling survival and, production scheduling.

MATERIALS AND METHODS

A trial was conducted at Victorian College of Agriculture and Horticulture Ltd - Burnley to examine germination of the species under various conditions and to observe the morphology of germinants.

Seed was collected from specimens of *B. spinosa* var. *spinosa* located at Bushy Creek Reserve, N. Croydon in April, 1993. They were stored in darkness at 5C in a sealed foil sachet. Three lots (100 seeds in each with five replicates) were sown from January 28 to 31, 1994 under the following conditions:

- In 9 cm paper-lined petri dishes (growth cabinet);
- In 12 cm × 6 cm seedling punnets (growth cabinet);
- In 12 cm × 6 cm seedling punnets (glasshouse).

Growth cabinet conditions included artificial light for 12 h with 15C maximum and 5C minimum temperatures. Glasshouse conditions over the period included natural daylight and approximate maximum and minimum temperatures of 34C and 18C. Seeds sown in punnets were covered with 5 mm of screened vermiculite. The glasshouse punnets had daily overhead sprinkler irrigation. Petri dishes and punnets in the growth cabinet were moistened as required. All sowings were maintained for up to 60 days and checked for germination every 2 to 3 days.

RESULTS

Germination. Germination during the trial was defined as being either the protrusion of the embryonic root or shoot through the testa (2 mm) petri dishes; or emergence of the hypocotyl through the medium (punnets).

Petri-Dish Sowings in the Cabinet. First germination was recorded on Day 28 when some 18% of seed had germinated. The maximum germination was reached at Day 46 when 54% of seed germinated (Figure 1). Approximately 25% of seed in the petri dishes "rotted" following imbibition and failed to germinate. The remaining 21% of seed also failed to germinate within the time period. No viability tests were made.

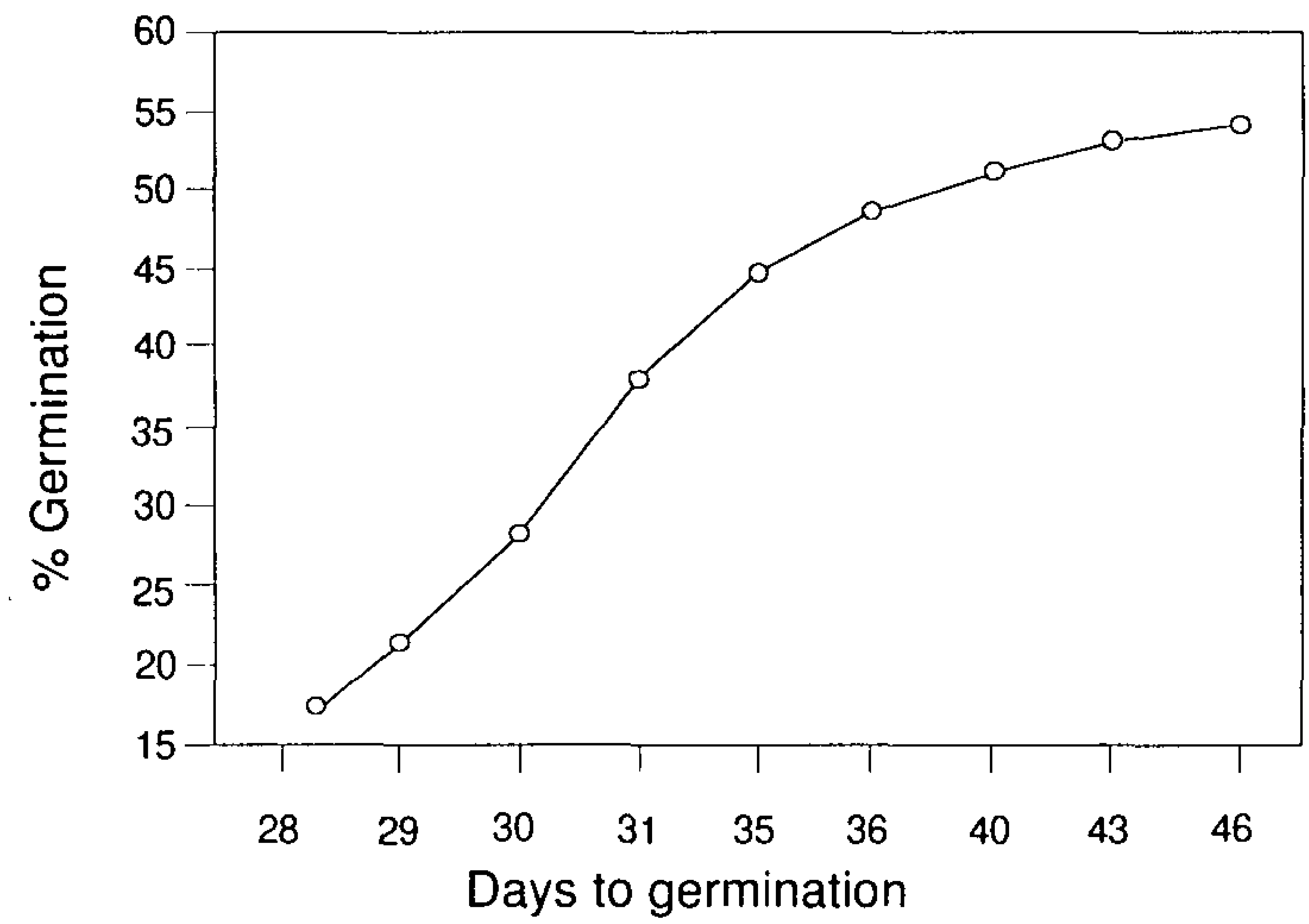

Figure 1. Germination of *Bursaria spinosa* var. *spinosa* at 15/5C and 12 h light.

Seedling Punnets in the Growth Cabinet. First germination was recorded on Day 32 when some 6% of seed had germinated. Maximum germination was reached at Day 58 when 15% of seed had germinated. The vermiculite covering the seed proved to be an unsuitable material in the conditions as it dried out too quickly between irrigations. This seems likely to have had an effect on the overall rate of germination in the punnnets.

Seedling Punnets in the Glasshouse. No germination of seed was recorded over the 60-day period.

DISCUSSION

A comparison of germination under growth-cabinet temperatures, (15/5C) and glasshouse temperatures, (34/18C) would indicate that the species has a relatively low optimum temperature requirement for germination. This is consistent with some other *Pittosporaceae* species studied. *Hymenosporum flavum* and *Pittosporum phylliraeoides* have requirements for either winter germination or cool temperature germination respectively (Fox et al., 1987; Dunlop and Galloway, 1984). Optimum conditions for germination of *P. undulatum* have been identified as being between 18 and 21C, with seeds germinating after 35 days under these conditions (Gleadow, 1981). This study also showed that germination was slower (50 days) under lower and higher temperatures, with no germination being recorded at 4 and 30C (Gleadow, 1981).

Lower optimum germination temperatures would certainly favour the establishment of *B. spinosa* var. *spinosa* during winter, with subsequent seedling growth continuing into spring. In southern Australia at least, this provides some advantage over germination occurring immediately after seed dispersal in the less favourable conditions of late summer/autumn. This requirement for exposure to certain environmental conditions before germination can proceed is described elsewhere (Mott and Groves, 1981).

The examination of *B. spinosa* var. *spinosa* suggest that some form of embryo dormancy exists in this species, although further work would need to be undertaken to confirm this. There is some debate as to whether embryo immaturity is a cause of dormancy (Bradbeer, 1988). Others have developed clear definitions and identifiable characteristics of embryo dormancy (Come and Thevenot, 1982).

Future work on the species could be directed towards testing seed viability, and examining appropriate storage conditions and a greater range of germination treatments. I trust this will ultimately lead to developing a protocol for maximising germination of the species and improve the scheduling of tubestock production.

Acknowledgements. I would like to acknowledge the assistance and information I received from many sources. Particularly from Sophia Bolton at the Victorian Indigenous Nursery Cooperative, who provided records, results of their own work and of course seed. I would like to thank Mark Coffey from Greening, Australia (Victoria) who also provided information and his experiences with the species, and also provided the seed I used in the growth trial. Thanks also to Julie Franke, Mark Trengrove, Graeme Stockton, and Murray Ralph who all provided information on their own propagation experiences with *B. spinosa*.

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Propagation of Threatened Australian Plants with Horticultural Potential

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INTRODUCTION

The Australian flora is unique, with 80% of species being endemic. We have the opportunity to maintain and develop this flora but this chance may be lost. There are already 76 species of Australian plants that are extinct and another 952 which are known to be threatened. This represents about 5% of all the species of vascular plants in Australia. Education of the public is the key to preserving this valuable resource.

WHY HAS THIS HAPPENED?

Essentially it is the loss of, or changes to the natural habitat of a species. If the habitat of a native plant is destroyed, or even slightly changed in some way that is incompatible with its basic requirements, it may become extinct from the area (ANCA, 1992). There are many factors which have contributed to the loss of habitat, these include agricultural and urban expansion, changes in the frequency and intensity of fires, competition from weeds, and the grazing of introduced animals.

While many threatened species are relatively secure in National parks and reserves, a large percentage are found only in strips of unmaintained land like road verges, beside railway lines, and in cemeteries. These small patches of land are called remnant vegetation and are particularly vulnerable to disturbance.

SO WHAT ARE THREATENED PLANTS?

There are two categories—ENDANGERED and VULNERABLE (Leigh et al., 1981).

Endangered (273 species). These are species which are in serious risk of extinction from their natural habitat over the next 10 to 20 years if present land use and other causal factors continue to operate.

Vulnerable (679 species). These plants are not presently endangered but may be at risk over a longer period if present rate of depletion continues, or species which largely occur on sites likely to experience changes in land use which could threaten the survival of the species in the wild.

In addition there are 2189 poorly known species. There is insufficient information about these species to categorise them. However, approximately 1700 of these are found in the Western Australian wheat belt and many are almost certainly at risk.

For this paper 10 species of plants have been selected which are threatened in their native habitats. These plants have horticultural potential and have been grown at the Australian National Botanic Gardens.

ENDANGERED

Grevillea iaspicula, Wee Jasper spider.
Habitat: Open woodland, New South Wales—Southern Tablelands, Wee Jasper.
Threats: Goats and sheep.
Cultivation/description: Shrub of approximately 1.5 m, leaves bright green, flowers cream and red pendant clusters, prolific spring/autumn, suitable for use as a feature or for screening.
Propagation: cuttings throughout the year, 4000 ppm IBA.

Grevillea wilkinsonii.
Habitat: Open woodland, New South Wales, Tumut.
Threats: Sheep, goats, weeds.
Cultivation/description: A spreading shrub to 2 m, leaves light green, flowers pale pink clusters.
Propagation: Cuttings, 4000 ppm IBA.

Swainsona recta, small purple pea.
Habitat: Woodland and open forest, Southern New South Wales, ACT.
Threats: Urban development; this plant is known to be growing on a few sites, the main site being along a railway line.
Cultivation/Description: Slender erect perennial herb, stems to 35 cm bearing 10 to 21 purple pea flowers, September to December, dies back after flowering.
Propagation: Seed.

Rutidosis leptorrhynchoides, button wrinklewort.
Habitat: Grasslands, Southern New South Wales, ACT, Victoria.
Threats: Urban development.
Cultivation/description: Slender perennial herb, 25 to 35 cm tall branching mainly from the base, leaves narrow green to 2.5 cm long, yellow button flowers 2 cm in diameter are borne at the ends of erect stems, October-April, Suitable for most garden situations.
Propagation: Seed.

Epacris hamiltonii.
Habitat: Rocky forest slopes, New South Wales, Blue Mountains.
Threats: Fire.
Cultivation/description: Small shrub to 1 m, leaves ovate light green, slightly hairy, redden in winter, flowers bell shaped and white in spring.
Propagation: Cuttings, 500 IBA/500 NAA.

Zieria prostrata.
Habitat: Low coastal heath, north coast New South Wales.
Threats: Weeds, trail bikes, recreational vehicles.
Cultivation/description: Dense prostrate shrub, 100 mm high by 1 m wide, leaves glossy dark green and strongly fragrant, flowers star shaped, light pink in winter/spring.
Propagation: Cuttings 1000 IBA/250 NAA.

VULNERABLE

Correa baeuerlenii, chef's hat correa.
Habitat: Sclerophyll forest, south coast New South Wales.
Threats: Agricultural development.

Cultivation/description: Medium rounded shrub to 2 m, glossy dark green lanceolate leaves, green bell-shaped flowers with a unique calyx which looks like a chef's hat, autumn-winter, responds well to pruning and attracts birds.
Propagation: Cuttings, 2000 ppm IBA year round.

Microstrobos fitzgeraldii, dwarf pine.
Habitat: Spray zone around waterfalls and rocky ledges on sandstone, New South Wales, Blue Mountains.
Threats: Polluted water courses, fire.
Cultivation/description: Low spreading shrub to 50 cm, leaves light green, gymnosperm suitable for wet site or around a water feature.
Propagation: Cuttings 500 IBA/500 NAA throughout the year.

Eremophila serpens.
Habitat: Mallee eucalypt scrub, southwest WA.
Threats: Road maintenance, weed invasion.
Cultivation/description: Prostrate to 1 m, dark green leaves, flowers green and red with prominent stamens, intermittent throughout the year, suitable for rock garden or well-drained site.
Propagation: Cuttings, 500 IBA/500 NAA throughout the year.

Ricinocarpos gloria-medii, glory of the centre.
Habitat: Deep gullies or well-shaded areas of south facing slopes on quartzite or sandstone, NT, Macdonnell Ranges.
Threats: Repeated fires.
Cultivation/description: Medium shrub to 2 m, leaves slender to 6 cm, light grey, flowers are white, 5 petalled, either male or female, autumn/winter, this plant is hardy in Canberra and is suitable for a rock garden or other well-drained site.
Propagation: Cuttings, 4000 ppm IBA, autumn.

CONCLUSION

As concerned individuals and propagators we must take steps to ensure the continued existence of all Australian plant species. Our responsibility to future generations is to make sure that all of our natural resources are conserved. We can do this by becoming a part of the plant conservation movement, familiarising ourselves with the plants that grow in our regions, and by growing threatened Australian plants.

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Cyclamen Species

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INTRODUCTION

Cyclamen are native to parts of Europe, Western Asia, and North Africa, with the majority of species indigenous to the Mediterranean area. The genus belongs to the family Primulaceae and consists of 19 species which are generally suitable for growing as massed drifts in the garden in dappled shade under trees. Florists cyclamen, which flowers from early autumn to late winter/early spring and are familiar to everyone, are all derived from the species *Cyclamen persicum*. Unfortunately, the majority of species are rare in cultivation.

SPECIES

I intend to highlight eight species which I have some limited experience in growing.

Cyclamen africanum. This species is native to Algeria and can be confused with *C. hederifolium* with which it will cross to produce hybrids. The true species supposedly differs from *C. hederifolium* in that the leaf petioles arise directly from the tuber and that the tuber develops roots over the whole surface instead of just developing from the upper surface of the tuber as is typical of *C. hederifolium*. This species flowers in autumn and ranges in colour from rose pink to light pink.

Cyclamen cilicium. This species is native to the mountains of southern Turkey. The flowers are pale pink and scented and it flowers during autumn to winter. It should grow well in light shade under trees and responds well to an annual mulching of compost.

Cyclamen coum. A widely distributed species, occurring in areas on the Black Sea coast of Bulgaria, northern and central Turkey, Northern Iran, Syria, and Lebanon. *Cyclamen coum* is probably the second most commonly available species in Australia. The leaves are round and generally dark green, although there are some silver-leaved varieties available. This species flowers during winter and the flowers can vary in colour from white with a crimson eye, to pink and carmine.

Cyclamen graecum. This is a widely distributed Mediterranean species and occurs in Greece and the Greek islands; it also occurs in Cyprus and southwest Turkey. *Cyclamen graecum* grows in sunny rocky areas and has long thick roots unlike any other cyclamen species. The flowers are pink and occur in autumn. It requires warm dry conditions during its dormant period of summer to produce a good crop of flowers.

This species will grow in sunnier spots better than other species, in fact I suspect it will grow in full sun.

Cyclamen hederifolium. A widely distributed species in the Mediterranean area also and its distribution stretches from southeast France to southern Turkey. It is by far the most commonly available species in Australia, flowering in early autumn prior to the growth of the marbled ivy-like leaves which persist throughout the winter and spring.

The flowers vary in colour from white to pink to rose; occasionally scented plants are available. This plant is noted for its scent in the wild but generally the plants in cultivation are not scented.

Cyclamen hederifolium is best planted into shaded areas in the garden, particularly under deciduous trees where it can self seed and eventually form large drifts.

Cyclamen persicum. This is the plant from which all the florists' cyclamen are derived. It is native to the eastern Mediterranean area with plant populations in Algeria and Tunisia.

The flower of the species varies in colour from white and pink to mauve and are sweetly scented; this attribute of scent seems to be missing from most varieties of the hybrids. The species flowers during winter and spring.

Cyclamen purpurascens. This is the most northern occurring species with plant populations in France, Switzerland, Austria, Yugoslavia, Hungary, Poland, Czechoslovakia, and Bulgaria. This species, with very sweetly scented flowers and evergreen foliage, use to be extensively picked as a cut flower but is now a protected plant, as are all cyclamen species in the wild.

The species flowers in late spring and the colour ranges from light pink to deep rose pink. In cultivation it requires shade and as it occurs naturally in limestone areas, an occasional top dressing of lime would be advantageous.

Cyclamen rohlfsianum. This species is native to Libya. It is distinctive in appearance with dentate leaves which are broader than they are long. The flowers are pink, scented, and slightly larger than those of *C. hederifolium*. The plant flowers in Autumn and the scent is said to resemble that of lily of the valley.

This species is sought after by collectors but it is rare in cultivation.

CULTIVATION AND PROPAGATION

As the majority of cyclamen are native to the Mediterranean area they are well suited to growing in the temperate states of Australia. The plants grow well in pots in shade houses and also naturalised under trees in the garden.

Cyclamen require the following conditions:

- Shaded conditions in summer
- Shelter from winds
- Good drainage
- Dry conditions during dormancy period

The seed of most species ripen in early summer, and should be collected as soon as the seed capsule starts to open. This should be sown immediately into trays of a good quality seed-raising mix into which some coarse sand has been incorporated to improve drainage.

The seedlings generally appear at the same time as the parent plant produces its foliage. Germination of old seed is patchy, but a higher percentage of seedlings may be induced to germinate by soaking the seed for 48 hours in water before sowing it.

The seedling trays should be covered with a pane of glass and placed into an area where the temperature does not rise above 16C. An area in a shade house is ideal. As soon as the seed germinates the glass should be removed from the tray, and the seedlings left to grow on undisturbed for at least one season before being pricked off into small pots. Excess seedlings can be left in trays for a number of years and potted on when needed, without any ill effects.

Cyclamen species have produced few hybrids in the wild or in cultivation. Only four hybrids being substantiated. These are:

C. africanum × *C. hederifolium*
C. balearicum × *C. repandum*
C. creticum × *C. repandum*
C. cyprium × *C. libanoticum*

The species *Cyclamen* should, in theory, be susceptible to all the various pests and diseases that afflict the *C. persicum* cultivars. These include vine weevil, cyclamen mite, aphids, and *Botrytis,* however, these species are relatively untroubled by pests and diseases provided that the plants are not forced too much and become soft.

The Importance of Selection and Root Pruning in Container-Grown Seedling Production of Ornamental Trees and Shrubs

Ian G. McCure
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The purpose of this paper is to raise some very important factors which are sometimes overlooked by nursery growers in the raising of tubestock from seed. Certainly many factors are involved in successful production, not the least of which are selection and root pruning in the development of reliable nursery stock. Occasionally in our nursery we come across a plant or a group of plants that stay alive, but do not grow on to a marketable size. In order to ascertain what is wrong the following factors need to be considered:

- The plant origin—50-mm tubestock from a reliable source
- The potting mix used—moisture and nutrient levels
- Problems associated with pests and diseases
- Environmental conditions

In this case everything appears to be satisfactory. The potting mix drains well, there is adequate moisture and nutrient levels, and there is no sign of stem rot or problems with insect pests. The leaves have a slight yellowing but are generally healthy. It's winter time in Queensland, with temperatures for the past 3 weeks between 10 and 25C.

Good growing conditions prevail. It is not until the potting mix is removed from the plants root system that we are aware of the real problem—the root system itself. There are two categories to this problem:

1) Root malformations
2) Weak root systems

Root malformations are the result of serious kinking and circling of roots which restrict growth and do not allow adequate nutrient uptake. When planted in a landscape situation such plants often die or break at ground level. Root conditions of this type usually commence during transplanting from seedling stage to the tube or pot.

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Weak root systems are those with short fibrous roots barely able to support the stem and leaf growth; these plants generally lack vigour. Seed taken from old parent plants which are no longer vigorous, or from plants under stress due to climatic conditions, will often produce weak plants.

Problems associated with poor root systems can largely be overcome by applying a few simple management techniques. In the case of root malformations effective root pruning and transplanting is the solution. When the seedling is removed from the germination container approximately 50% of the total root length should be removed. The trimmed seedling should then be planted into the new container without bending or kinking the root system.

Seedlings left in the germination container for an extended period, and then transplanted with an extensive root system, will increase the incidence of malformed roots. When selecting a suitable container, consideration must always be given to the type of root system likely to be developed by a particular plant. To avoid the problem of plants with weak root systems it is important that seed is selected from only healthy vigorous parent plants. If selection of the parent is not possible then ensure that the seed comes from a reliable source.

Selection of the germinated seedlings is also important as variation in type often occurs. Weak and overly vigorous seedlings can be discarded. Similarly plants grown for their leaf colour will need to be rigidly selected and "off" types discarded.

To summarise, production of ornamental seedling-grown trees and shrubs can be improved by:

- Pruning the germinated seedling root at transplanting;
- Planting the seedling root without bending or kinking;
- Selecting seed from healthy vigorous plants which are true to type, or obtaining seed from a known reliable source;
- Selecting out uniform seedlings for growing on and discarding the rest.

Design Trends in the Use of Amenity Planting in the U.K.

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INTRODUCTION

In the last 20 years there have been many changing fashions in the landscape designer's use of amenity planting. In the early 1970s, the emphasis on the rehabilitation of derelict sites encouraged the use of plant species that were tolerant to impoverished or contaminated ground conditions. The landscape design profession was small, relatively young and inexperienced, having had few opportunities to design large amenity planting schemes.

Most of the projects were restricted to the public sector using government grant aid, such as, Derelict Land and Urban Programme Grants. In the private sector, there was not a sufficient level of commitment to landscaping, as it was generally seen as a cosmetic addition to building development.

Towards the end of the decade, there was much debate on the malaise of British cities, with large areas of derelict land particularly in former dockland areas. This led to the setting up of urban development corporations in Liverpool and London to encourage public development initiatives to halt the decline. The "greening of cities" was seen as a key to unlock the potential of such sites in the regeneration process.

At the same time there was a new awareness of the landscape and its value in the private development sector, particularly with reference to green field site development in science and business parks. Here the emphasis was on creating new parkland and lake settings around which pavilion style buildings could be located in harmony with their surroundings.

Furthermore, major new infrastructural projects were being carried out in increasing numbers, including: new motorways and urban bypasses; thermal, nuclear and pump storage power stations; reservoirs and river regulation schemes; north sea oil and gas developments; new towns and town expansion projects.

These large scale projects were ideal opportunities for landscape designers to experiment with substantial planting schemes, primarily using indigenous plant material.

THE ERA OF THE BRITISH GARDEN FESTIVAL

The British Garden Festival era began in 1981 with the announcement of the International Garden Festival to be held in Liverpool in 1984 by the Merseyside Development Corporation on a 70-ha derelict refuse and oil tank farm site on the banks of the River Mersey. The two demanding constraints—2.5-year time scale and a heavily polluted site—weighed heavily on the design and technical challenge for landscape designers.

In Germany and Holland there were 30 years of experience of such events but constructed over longer time scales of around 6 years and on greenfield sites with little or no technical and environmental constraints. In both cases, the 10-year internal International Buntesgartenchaus in Germany and Floriades in Holland are shop windows for the respective horticultural industries which both have important export markets.

In the U.K. there was no such tradition, exhibitions were restricted to short term events such as the popular Chelsea Flower Show.

At Liverpool IGF, however, the time and technical site constraints were outweighed by the opportunities of designing on a 70-ha highly visible river bank site, with a substantial public and private budget that encouraged the use of a broad palette of plant material. The structure planting designed for permanency on the new landform used indigenous plant material influenced by the new landform and the exposed aspect of the site. This structure in turn provided the necessary framework for the more ornamental planting of the international and national theme gardens created for the event. Even on such difficult site conditions a significant amount of large size tree planting was achieved with girth sizes from 20 to 30 cm possible in selected locations. It was also possible to specify the bulk of the smaller trees and shrub material in a containerised form, supporting the growing trend in the U.K. nursery industry.

NURSERY SUPPLY INDUSTRY

The 6-month event in 1984 proved to be a great success, attracting 3.2 million visitors to Liverpool despite its poor image. The site had been reclaimed and totally transformed in under 30 months—a major design and technical achievement. Ten years later, 50% of the site is maturing as a festival garden theme park associated with the indoor leisure facilities housed within the former Festival Hall. The remaining area has been developed for private and public housing effectively using the landform and maturing landscape framework of the festival site.

Although the remaining four garden festival events were restricted to a national status, they followed on from the achievements of Liverpool. At Stoke, on the site of the former Shelton Steel Works a 75-ha national event was staged in 1986. The site was designed with a strong central ridge which was heavily planted with indigenous plant material. To the west, a series of themed landscapes were located around several new lake features and to the east a major outdoor events area and temporary retail village was developed. Again, the opportunity was taken for using a wider range of more ornamental tree stock and containerised shrub planting. In contrast to Liverpool, there was more effective use made of herbaceous and annual plants providing strong seasonal colour effects. Probably the major success of Stoke has been its after-use. The permanently planted central hillside became an effective backdrop to a leisure park to the west and a retail and business park to the east, now completed and fully occupied.

The third festival was staged in 1988 on a former derelict dock on the banks of the River Clyde in Glasgow. In contrast to Liverpool and Stoke, the site was privately owned and was leased to the Scottish Development Agency for 5 years to mount the festival and was then handed back to the private owner with a new landscape infrastructure for the provision of a mixed end-use of housing, office, and waterfront leisure uses. At Glasgow the permanent structure of planting and mounding used a mix of indigenous and ornamental plant material and a preparation period of four planting seasons encouraged a more mature landscape into which a variety of temporary theme garden displays were located. Although it was an extremely successful event attracting 4.5 million visitors, the end use has yet to be achieved due to the recession and is now likely to require at least 5 years to make any real impact. However, much of the structure planting has been maintained as an important backdrop to new development.

The fourth event, held in Gateshead in 1990, was prepared during the depths of the latest economic recession and it struggled to attract sufficient support from the private sector. However, it was organised by Gateshead Metropolitan Borough which encouraged a wide participation from other local authorities resulting in a strong array of seasonal bedding displays. Much of the site has now been retained as a permanent park with new associated housing development.

The final event was held in Ebbw Vale, in a steep-sided South Wales valley, on the site of a former steel works. It had distinctive advantages over the other events. Firstly, it had 6 years of preparation time, similar to Continental examples. This allowed for thorough site preparation and up to five planting seasons to allow structure planting to be in good condition for the event. Secondly, the site was in a rural location some distance from a major urban location—on the edge of the town of Ebbw Vale with a population of 20,000. This allowed woodland and farmland to be incorporated with the derelict site and broadened the range of displays from new landscapes through to the conservation and management of countryside.

Thirdly, the site was prepared with the end-use in mind. As a result, some 70% of the site has been retained as parkland and managed countryside that will be an attractive setting for a proposed new village settlement and an employment centre.

Although the British Garden Festival experiment came to an end with the Ebbw Vale event in 1992, it was an important period for the U.K. landscape for the following reasons:

- It raised the profile of what could be achieved with derelict, apparently useless sites.
- It encouraged new planting and establishment techniques for the rehabilitation of difficult sites.
- It provided a shop window for the wider landscape industry.
- It attracted large numbers of people to view new landscapes in an attractive atmosphere.
- It kept the issue of the landscape on the wider political agenda.

CURRENT AND FUTURE TRENDS

The recent demise of garden festivals and the recession of the last 5 years has severely curtailed a considerable number of public and private sector amenity landscape projects. Also, major infrastructural investments, with the exception of the Channel Tunnel, have greatly reduced in number. There are also changes in emphasis, such as, road construction in and around large town and cities being curtailed in favour of integrated transport schemes.

This has all contributed to a reduction in the number of design opportunities available for landscape architects to create significant new landscapes with amenity planting. Many small and large design practices thrived on the opportunities of business and retail parks in the 1980s, but these have all but dried up in the 1990s. Also the leisure boom of the 1980s, with new golf courses, heritage centres, hotel and conference centres, and new village developments, has declined.

There are, however, a number of exceptions, two of which our practice is currently involved in:

1) The new European Research Headquarters for Glaxo near Stevenage. A 50-ha campus costing £700 m, it is the second largest capital project in value in the U.K., after the Channel Tunnel. A £6 m hard and soft landscape budget has enabled a bold planting scheme to be prepared which utilises a strong structure of large trees to respond to a strong massing of buildings.

2) The New Theme Park for the LEGO Toy Group on the Site of the Former Windsor Safari Park. The mature parkland landscape is being recycled for a family event experience. Again, a hard and soft landscape budget of around £5 m will ensure a strong contribution from the landscape plantings. Furthermore, this is a unique design opportunity to exploit the use of bold amenity planting in association with conservation and woodland management as part of the site is situated adjacent to the Windsor Great Park and the remnants of an ancient English oak forest.

These exceptions, amongst others, will not be sufficient to stave off a decline in major landscape schemes of distinction. Although, we are in an era of so-called "green awareness" this seems to be more political rhetoric than reality, in terms of new projects. Take the decline of the urban park, for example, where the majority were Victorian in origin and products of philanthropic concern in the mid to late 19th century. Many are now subject to severe decline resulting from municipal neglect with insufficient maintenance and public interest. Yet at the same time, interest in private gardening never seems to wane—could it be private space at the expense of public space?

As we move closer to the new millennium, the industry badly needs a number of new initiatives to reawaken public interest in public and private amenity landscape.

In this context, a small think tank was set up by the Joint Council for Landscape Industries last April to explore ways of bringing landscape back onto the political agenda. This group has recommended a major new landscape initiative called "The Landscape Challenge—The Next Heritage", which was debated at a specially convened seminar in September 1994.

Its key features will be partnership, innovation, competition, and substainability. It will not only demonstrate the relevance of our green landscapes to the achievement of sustainable development but also secure their most effective long-term management as an integral part of the project. It is the intention to organise a pilot project in 1998 and a millennium project in 2001, following an invitation for competing bids from towns and cities throughout the U.K.

It is also hoped that such a scheme will attract funding from the new Millennium Fund, being financed by proceeds from the new state lottery which begins operation in the autumn of this year.

The key criteria for schemes competing in Landscape Challenge include:

- The completed schemes will be innovative serving to demonstrate the best design, construction, and management skills of today's landscape industry.
- The physical area of competing schemes must be substantial and be of demonstrable benefit to an urban catchment area of not less than 100,000 people.
- The subject area may be currently available public open space, such as parks and recreation grounds. However, competing proposals must be able to demonstrate greatly enhanced public benefits with a wide diversity of intended use, together with high visual amenity. Both the construction work and subsequent maintenance should provide for extensive training.

It is hoped that this or a similar initiative will be the catalyst for a re-awakening of amenity landscape in the U.K. This will also encourage a renewed demand for plant material of the highest quality.

Applications of Grodan in Hardy Ornamental Nursery Stock

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INTRODUCTION

Grodania A/S, Manufacturers of Grodan stonewool products for horticulture, has in recent years been diversifying into new sectors of horticulture, in addition to the traditional glasshouse salad markets. Many horticultural substrates and additives have tended to be waste products from other industries (bark, coir, etc). Grodan stonewool is made from a natural raw material, diabase rock, and is fabricated into various shapes of slabs, blocks, multi-blocks, and granulates.

Some of the new products which have been developed include:

- Single Block System (SBS) for rooting cuttings
- Water repellant granulates for peat mixes
- Water absorbing granulates for peat mixes
- Stonewool Mix—total growing medium for nursery stock, interior planters, orchids, pot plants
- Special slabs for roof gardens, sound-absorbing walls
- Stonewool for hardy ornamental nursery stock
- Granulates as an ingredient of growing media mixes

Stonewool can be made water repellant or water absorbent, and in two different grades—fine and medium (Table 1).

Table 1. Grodan granulates.

Product	Code	Approx. loose volume (litre)	Final pot size
Fine, water repellant	BU 10	300	Less than 1 litre
Medium, water repellant	BU 20	450	1 to 3 litres
Fine, water absorbent	GU 10	300	Less than 1 litre
Medium, water absorbent	GU 20	450	1 to 3 litres

Water repellant granulates will increase air-filled porosity (AFP) in peat mixes. The AFP of a mix containing peat and water repellant granulate increases as the proportion of the granulate increases. At an incorporation rate of 30% (by volume), AFP has increased by 7% compared to an increase of 5% with bark (Cambark 100) and a decrease of 5% with sand (Fig. 1).

The benefits of a growing medium with a high AFP (15% to 20%) include: better root growth, increased winter survival of less hardy subjects, and quicker spring growth.

Water repellant granulates can be added to a peat mix at a cost of about 2.5 pence per loose litre which makes the additive cost effective when compared to other

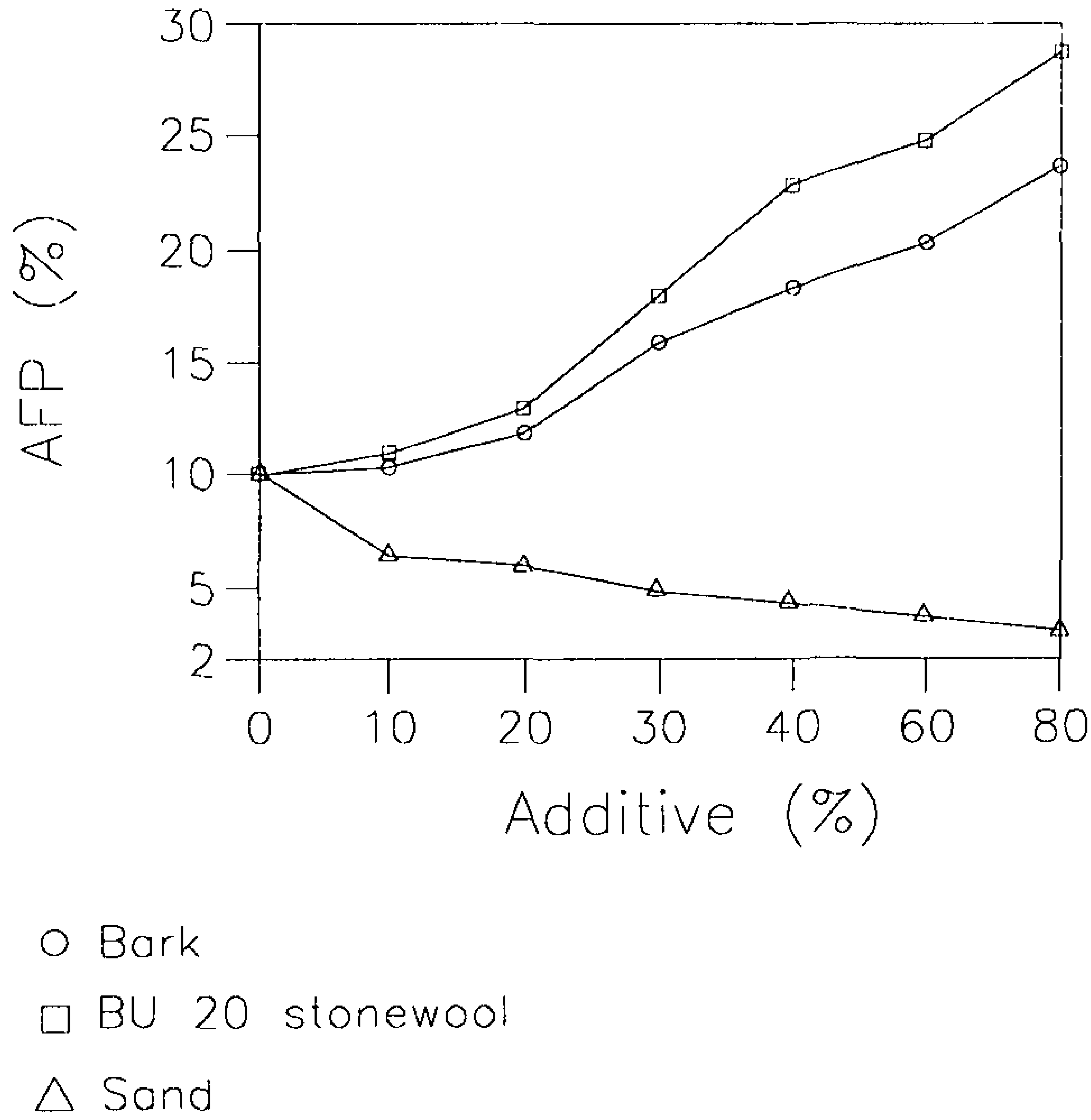

Figure 1. AFP of peat media amended with stonewool, bark and sand.

amendments such as perlite and bark.

When water absorbent granulates are added to peat, there will be an increase in water holding capacity (Table 2). In addition, more water in the mix is available for plant uptake since the water in the granulate fraction is only weakly held.

Some of the more general properties and features of granulates in mixes are described in Table 3.

Table 2. *Water holding capacities (%) of a medium sphagnum peat amended with* stonewool granulates.

Peat	30% BU 20/peat	30% GU 20/peat
60.4%	56.2%	66.2%

Table 3. Features of Grodan granulates in hardy ornamental nursery stock growing media.

Repellant granules increase AFP (%)	Absorbent granules increase WHC (%)
High out-turn volume	Granulates visible in mix
Inert—no fertilizer lock up	Lime only for peat fraction
Produced under ISO 9001	Compact bale/palletized
100% rooting volume	*Homogeneous flock size*

Cleaning of Recirculating and Surplus Water in Container Plant Production

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INTRODUCTION

A general water shortage, expensive or bad-quality water, or environmental pressures may force container plant growers to collect rain water and to use a closed, recirculating irrigation system. If done in a proper way, economic and ecological advantages can be achieved together. Utilizing such a water management procedure means two potential problems have to be taken into account. Firstly, re-used irrigation water should be free from pathogenic organisms that attack plants, because the risk of spreading diseases throughout the crop is increased. Secondly, with closed systems water may be collected in excess, and if leaving the nursery site it may not meet local or EC standards for quality and freedom from residues. Run-off water may need to be disinfected for recirculation and/or purified for discharging into ground or surface water.

RISK OF DISEASE SPREAD

In open (i.e., not recycled) irrigation systems single diseased plants within a crop can only infect the plants immediately next to them. Soilborne fungal diseases,

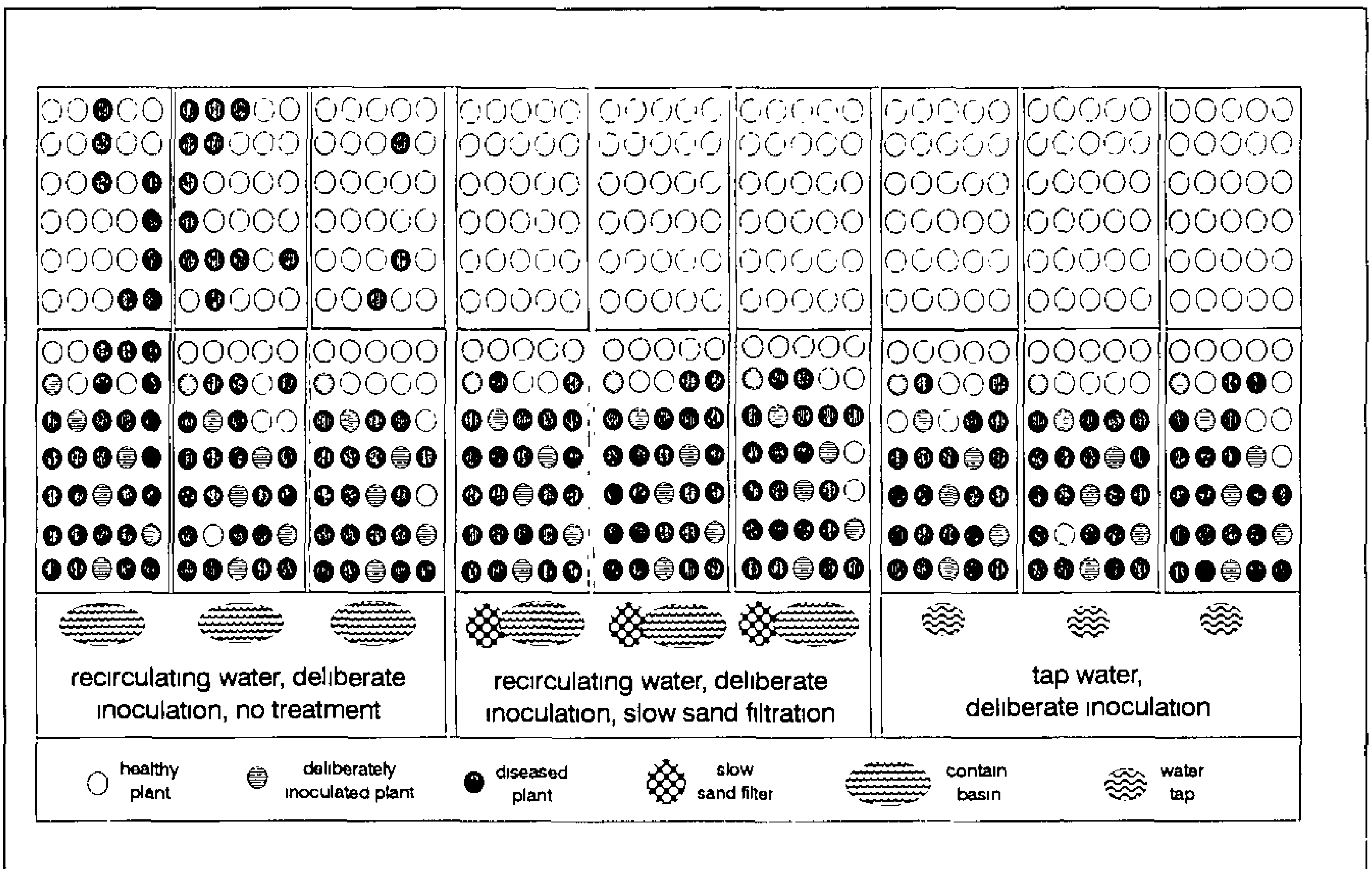

Figure 1 Spread of *Phytophthora cinnamomi* as influenced by water origin and water treatment. *Chamaecyparis lawsoniana* 'Columnaris' (syn. *Cupressus lawsoniana* 'Columnaris'), six plants per plot inoculated deliberately, overhead irrigation, poly film lined beds, 23 weeks after potting.

such as, *Phytophthora*, are spread by splashing and by the water running across the bed surface. When irrigation water is recycled, pathogenic organisms might be transported to all plants in the crop via the water. This may result in additionally infected plants everywhere in the bed.

Figure 1 shows the results of an infection trial with *Chamaecyparis lawsoniana* 'Columnaris' (syn. *Cupressus lawsoniana* 'Columnaris') (Kemp et al., 1992). The data were recorded 23 weeks after potting up and placing deliberately inoculated plants in the lower (downstream) end of the beds. On beds irrigated with mains water, two thirds of the initially healthy plants in the lower end were diseased or dead. All plants stayed healthy in the upper end of the beds. On the beds irrigated with untreated recycled water only a few more (71%) were infected at the lower end. But, at the upper end of the bed, 25% of the plants became infected.

Disease spread from plant to plant is faster and more extensive than spread via recycled water. The latter causes only minor problems, as long as no susceptible crops are cultivated or if the surplus water is stored in a biologically active, open pond. The risks can be reduced further by starting the crop with healthy young plants, by immediately taking out every obviously diseased plant, by diluting the spores via long ditches, and using large ponds to store the water accumulated from a number of beds.

SLOW SAND FILTRATION TREATMENT FOR IRRIGATION WATER

A slow sand filter can be included in the recycling system to protect plants from water-borne disease and is especially recommended when cultivating plants of the Ericaceae family, false cypress, or other susceptible crops. Spores of *Phytophthora* and other fungal diseases can be eliminated completely by using this simple and very old technique (Wohanka, 1992). Figure 1 shows that spores could effectively

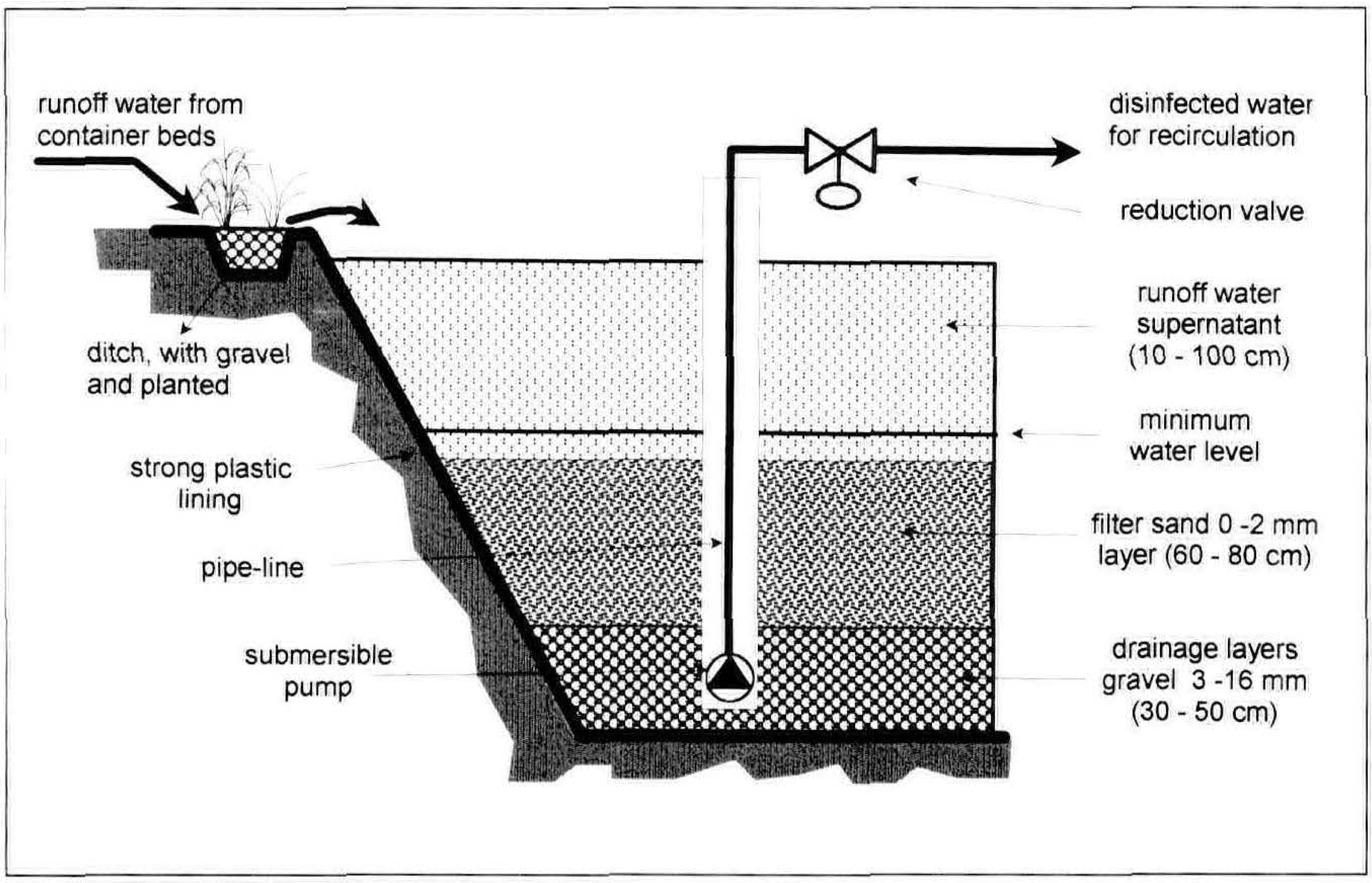

Figure 2. Cross section view of a slow sand filter, a pond-like construction in a commercial nursery with a capacity of 0.5 $m^3 h^{-1} m^{-2}$ (based on Wohanka, 1992).

be prevented from spreading via the recirculating water. No diseased plants could be found in the upper part of the beds 23 weeks after potting on beds using filtered recycled water. Filtered water was as good as mains water.

After vertical percolation through a 60 to 80 cm layer of biologically active sand within a barrel, no spores could be detected in the water, if a flow rate of no more than 200 to 500 litres h^{-1} m^{-2} filter surface was used. The elimination of spores does not only take place by a simple sieve effect, but mainly by beneficial fungi and bacteria living on the surface of the sand, within the so-called filter skin. There are many types of microorganisms breaking down organic matter.

This bioactive sand filtration system is an economic way to disinfect irrigation water or nutrient solutions, if a water-saving capillary or trickle irrigation system is used. A very simple, pond-like construction is currently working perfectly in a commercial nursery (Fig. 2). For irrigating the crop, water is directly pumped from underneath the sand layer. A capacity of 0.5 m^3 h^{-1} m^{-2} and a surface of 100 m^2 results in a capacity of 50 m^{-3} h^{-1}, sufficient to irrigate 1.5 ha of capillary beds.

In order to make the sand filter look more attractive, and to hold back rough organic matter like compost or leaves, a gravel-filled ditch was constructed around the filter and planted with marsh plants. Such plants will probably colonize the filter, too. Studies with different species of marsh plants growing on top of sand filters showed no negative influence on the disinfection effect. Even in the supernatant water no active spores could be found after several hours.

PLANTED GRAVEL FILTER TO REDUCE NITROGEN LOAD

During high rainfall, closed container units may lead to the collection of too much water. The most environment-friendly use of this surplus water would be to become groundwater. But nursery run-off may contain pesticide or fertiliser residues which may exceed official levels (currently a limit of 10 mg/litre nitrate-nitrogen per litre and soon a limit of 1 mg/litre phosphorus for drinking water in this part of Germany).

Various versions of planted sand filters are known under different names, such as, plant covered purification filter, reed bed treatment systems, root zone purification system, reposition plant filters, etc. (Börner, 1993; Schütte and Fehr, 1992; Wackerle and Gradl, 1993). They are known for purifying sewage from private households and wastewater (Gersberg et al., 1984, 1986; Geller et al., 1991; Soeder et al., 1986). Various microorganisms, living in the rhizosphere of plants, can break up organic and inorganic molecules. Under aerobic conditions some of them nitrify ammonium, although NH_4 is found in runoff water in very small amounts only. Under anaerobic conditions, however, others break down the nitrate for their oxygen supply and set free nitrogen. In addition they need a soluble carbon source which comes preferably from root exudations of marsh plants.

Another reason for growing plants on the filterbody is to prevent plugging. Moving stalks and growing rhizomes and roots avoid a deterioration of hydraulic conditions.

Basin-like sand filters planted with different species of marsh plants were used to investigate the influence of plants on cleaning nitrogen from run-off water. Generally the cleaning capacity of such filters is much lower than their microbial disinfection capacity. Depending on plant species, season, temperature, and salt concentration an inflow rate of 4 to 10 litres h^{-1} m^{-2} filter surface may not be exceeded. Because of transpiration the outflow rate varies.

Two years after planting, *Phragmites australis* proved to be the most efficient plant for this type of water treatment during the growing season. Concentrations of 240 mg nitrate per litre could be purified to drinking water quality at an inflow rate of 10 litres h^{-1} m^{-2}. In other words, the *Phragmites* filter eliminated 8 g nitrate per m^2 of filter surface per day from 160 mm of irrigation water.

Other species like *Iris pseudacorus* were less effective, only removing 25% of the material removed by *Phragmites* and were no more effective than unplanted filters. With these filters drinking water quality was only reached at very low inflow rates. In autumn, when growth and metabolic processes cease, the purification capacity of the *Phragmites* filter also fell to match the unplanted filter.

For eliminating phosphorus, filters containing iron are needed. Under aerobic conditions iron phosphate is formed, which is virtually insoluble and precipitates. After passing throught the planted gravel filter the water is passed through an iron wool filter. In the present study water contained 3 mg $litre^{-1}$ phosphorus which was completely captured by the iron.

A planted gravel filter, similar in construction to a reed bed, is presently working on a large scale in a commercial nursery in Germany. Figure 3 shows a cross section view of this filter. A filter body of gravel was chosen for hydraulic reasons only. Surplus water of a container plant unit flows horizontally and slowly through the root zone of different marsh plant species.

In the first year after planting it was not yet working perfectly, but it showed great promise. During summer a concentration of 150 mg nitrate/litre could be cleaned to drinking water standard, if the inflow rate was no higher than 4 litres h^{-1} m^{-2}. That is similar to the cleaning capacity of an unplanted sand filter. Possibly the root growth in the filter body was not yet well enough established. It takes some time

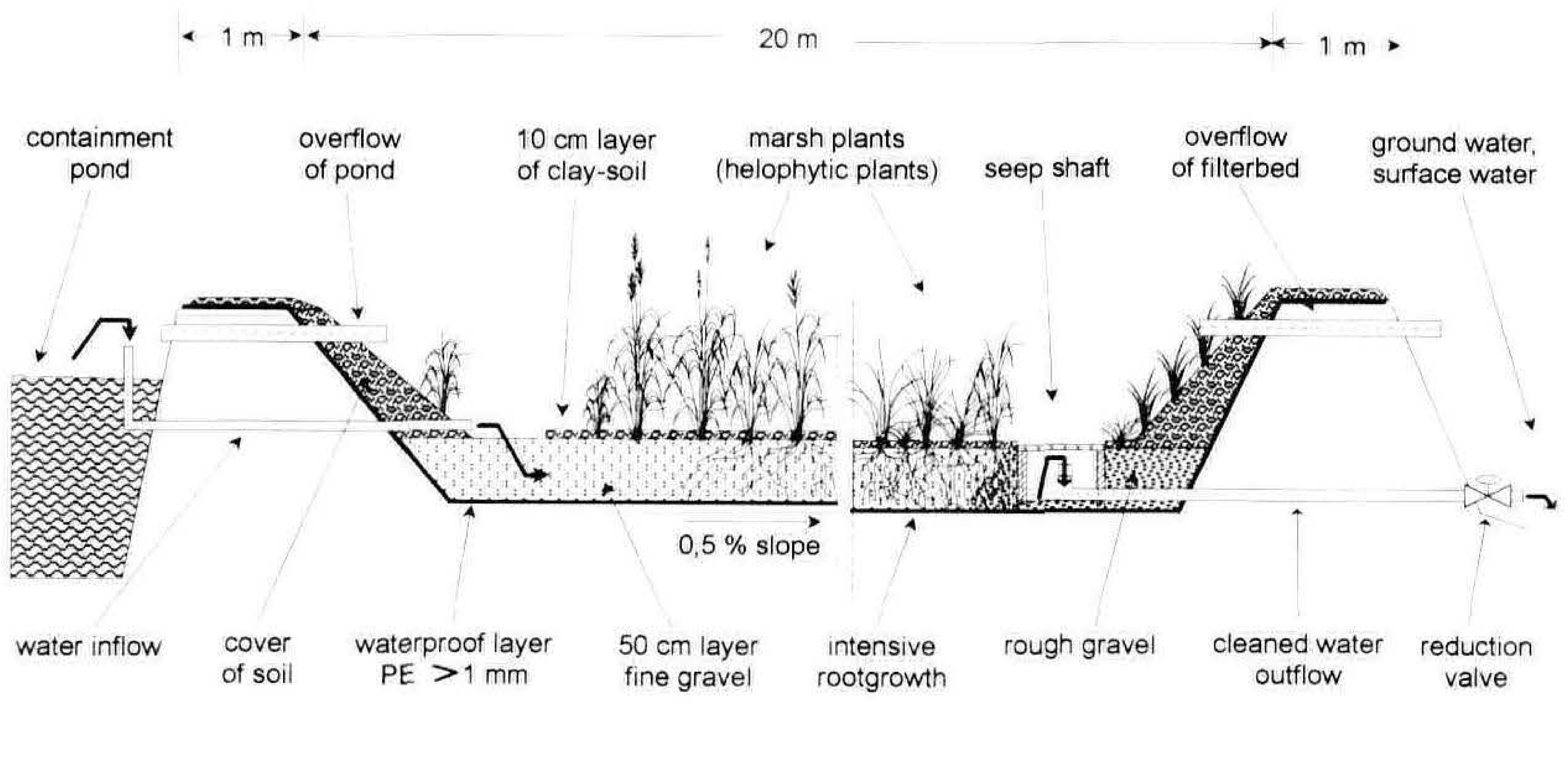

Figure 3. Cross section view of a planted gravel filter (reed bed type) for cleaning surplus water in container plant production.

before a proper environment for the micro-organisms develops and they might suffer from a lack of carbon sources during the establishment phase. Rotting straw or similar material added to the filter could only partly substitute for the plants and their root exudations.

Further investigations will concentrate on the elimination of pesticide residues, on the combination of cleaning and disinfesting, and on purifying all kinds of effluent from nurseries.

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The Latest Environmental Restrictions on Nursery Production in Germany: Is Nursery Production Still Possible?

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INTRODUCTION

In Germany there are approximately 4000 nursery companies; 1500 of them are members of the Federation Bund Deutscher Baumschulen or BdB. The total area in production is approximately 25,000 ha. The production volume is worth 1.5 billion marks (1994), making Germany the biggest producer of nursery stock in Europe. Production is scattered throughout the country but there are three centres.

1) The district of Pinneberg in Hamburg, with 300 nurseries and 2200 ha of land.
2) The Ammerland, also with about 300 nurseries and more than 2000 ha of land.
3) The Rheinland, with 150 nurseries and 1300 ha of land.

In these three areas some 50% of the total plant production in Germany is concentrated. This is partly a result of very long nursery tradition but mainly because of the perfect climate and the excellent soil. It is primarily in these areas with highly concentrated nursery production that we are having most of the problems with environmental restrictions.

ENVIRONMENTAL POLICY IN GERMANY

Environmentalism started in Germany 15 to 20 years ago. Initially the main concern was the safety of atomic power stations. So a new party was founded which was named in Germany "Die Grünen", the Green Party. They receive between 5% and 10% of the votes. The Green Party pointed out the risks and problems with not only atomic power stations but also with industrial production.

This party or a similar party now exists all over Europe. In the beginning and still today the nursery industry benefits, from the fact that the environmental party is making people more aware of nature, green issues, and of course plants.

Not only private people but also politicians of the other democratic parties in Germany became more aware of the environmental idea. This helped us to sell more plants to local authorities for street planting or reconstruction of city centres, and industrial projects have also been well supplied with plantings. Banks, insurance companies, and other private investors, and also private homes, are paying more attention to their landscaping.

This gave a big push to the whole industry not only for the nurseries but also for landscape architects and landscape contractors. More and more universities offered courses of study in environmental and landscaping studies. The landscape architecture curriculum became more fashionable and was in as much demand as, for example, medicine. Today landscape architects are working for landscape architect offices, for local authorities, and local or state government. There is no doubt that environmentalism helped to increase nursery sales in Germany by bringing more people's attention to their natural surroundings.

But today environmentalism is also causing us problems because over-reaction has resulted in government-imposed environmental restrictions. A lot of the people developing and administering policy only have a theoretical background but are supported by some of the politicians.

EFFECT OF ENVIRONMENTAL RESTRICTIONS ON GERMAN NURSERY STOCK PRODUCTION

Field Production. Field production accounts for 80% of production in Germany. It is endangered by environmental policy on water quality, peat conservation, and landscape protection.

Over the last few years large amounts of land have been declared water conversation areas with such strict laws governing the use of pesticides and fungicides that it is hardly worthwhile planting there at all. There are water conservation areas in the Pinneberg area north of Hamburg and they cover large areas for the water supply of the city of Hamburg. There are also water conservation areas in Oldenburg which have expanded over the last few years.

Peat protection areas exist in Oldenburg which protect 28,000 ha of peat. The environmental regulation programme which is coming out this year will cover another 70,000 ha. We have to expect that in all the peat areas, some of them used for decades for intensive agricultural production, restrictions will be enforced. These restrictions endanger, in the area of Bad Zwischenahn and Edewecht, alone, 16 nurseries with 1000 ha of production and 1200 employees.

During discussions between the Home Office Minister for Lower Saxony and the German nursery association of Weser-Ems, an agreement was reached stating that areas already existing in nursery production can continue to produce in the future, but there will be no possibility of expanding these areas.

Landscape protection schemes have also been established by the authorities. The scheme set up for the Ammerland region, for example, asks for necessary steps to develop and conserve protection-worthy areas as follows:

- Removal of unnatural or non-indigenous plant material.
- Revert arable land and nursery land to permanent pasture.
- Prohibit “antisocial” plant material.
- Reinstate natural bog land.
- Raise the natural water table by filling in open drainage ditches

In the future the peat-bog region will be included in these protection-worthy areas. In sensitive areas no new nursery establishments may be founded or expanded.

In such areas nursery production is only possible with many restrictions, these are beginning to cover not only the use of fertilizers or pesticides but the aesthetics of the nursery layout. For example, should the trees be planted in rows or scattered about like in a park? I know one example where it was forbidden for a nursery to plant larger trees in rows on a field which was in a landscape conservation area. It was forbidden only because the district magistrate of that county had a personal dislike for the planting of trees in straight rows.

Container Production. Container production amounts for 20% of nursery stock production in Germany. To prepare fields for container production in Germany most of the companies are leveling the ground, putting several centimetres of sand on top, and then covering this with a plastic sheeting plus an extra Mypex sheeting. Irrigation is by overhead sprinklers. The water is pumped out of the ground into ponds or a reservoir and from there onto the fields.

A year ago a new law was passed which states every container field has to be approved by the local government. The argument for this law is that the politicians, mostly the Green Party, are saying that container fields which are covered by a plastic layer have to be treated for planning purposes in the same way as, for example, a concrete car park.

At Bruns nursery we can still get permits to build container fields but we are having problems in sensitive areas. For example, the hard frosts mean we have to provide winter protection for our container plants and, therefore, we are using polythene tunnels or for larger plants Filclair polyhouses. These polyhouses, up to a height of 4 m, can be constructed without any permit, but I am sure that it won't be long before a new law is passed under which a permit from the government will also be required to erect them.

Our container nursery is now recycling 100% of its irrigation water. This is done at the present time without enforcement from the government, but I am also sure that legislation enforcing this will come in the future. We are using slow-release fertilizer as a top dressing and have stopped using liquid fertilizer in order to avoid high concentrations of fertilizer and chemicals accumulating in the recycled water.

We now have a new law in Germany regarding the packaging of goods which makes the producer responsible for recycling. That means we have tenders coming through local authorities in which the nursery is responsible for the collection of the empty container pot and the one-way pallets. The same problem applies also to supplying garden centers. Now there are some garden centers which are asking a percentage of the turnover for recycling costs from the nursery. The nursery supplies container plants to the garden center and the garden center sells them to its customers. The customer can bring back the empty container to the garden center and then from the garden center it is sent back to the nursery.

At the present time the pot suppliers are working on finding an organic paper or similar material for rigid containers. In my opinion these organic pots can be used for groundcovers for the landscape industry, but not for the garden center trade. Garden center customers are still wanting a clean black rigid container which can't be made at the present time from organic materials.

Today most of the nurseries are still using container media of 80% to 100% peat. The research station in Bad Zwischenahn and also the other research stations in Germany are working on a material to substitute for the peat in container production.

NURSERY INDUSTRY RESPONSE TO ENVIRONMENTAL RESTRICTIONS

Nursery associations are employing more people to follow all the new laws and to help to find solutions during discussions with the politicians, to influence legislation before it is passed. They are also printing brochures and giving information to politicians and other interested people about environmentally friendly production methods.

The local nursery association in Oldenburg has now employed one person who spends 50% of his time dealing with the problems of environmental restrictions in our area.

At Bruns Nursery we are using almost no chemicals for weed control, using hand or mechanical weeding instead. Only in container production is chemical herbicide still used.

Bad Zwischenahn, where the nursery is located, is a large tourist area and we offer a half-day tour once every month through our nursery to show groups of 55 to 60 people that we produce our plants in an environmentally friendly way. The tour is not only frequented by the tourists but also by the local people from Bad Zwischenahn.

In these days we are not only facing the problems of plant production, making sales, and getting paid by the customer, but we also have to face new environmental restrictions and spend a lot of our time negotiating with people who mostly have only a theoretical knowledge.

But we have to face these new problems and I am confident that the German nursery production will continue to be strong and healthy.

Green Issues and Growing Media—Progression or Digression?

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INTRODUCTION

Since environmental lobbyists began their scrutiny of growing media, enormous sums of money have been spent on research projects, conferences, insurance claims, and even failed companies. This paper aims, from a manufacturer's viewpoint, to consider whether progress has been achieved as a result or whether it has all amounted to a time-wasting digression.

Progress can be monitored in terms of increased profitability, but increasingly the effects of our activities on the environment must come into the equation. Although there can be sound marketing reasons for considering growing media from an environmental standpoint, it is extremely important that the considerable advances that have recently been made in compost quality, with their consequent benefits for profitability, are not compromised in any way.

USE OF WASTE PRODUCTS IN GROWING MEDIA

Few growers will be unaware of changes in waste legislation in both the United Kingdom and at European level. Waste is not an issue which can be dodged anymore. It has to be managed, controlled, and usually licensed. Most significantly, there are costs involved which were not there before. One result has been that those organizations, which generate waste products, have looked to markets, such as agriculture and horticulture, to find cheaper outlets than the increasingly restrictive and costly option of landfill.

There are those who believe that waste is a resource in the wrong place. However, it is estimated that the U.K. generates about 200 million tonnes of organic waste per annum, which is a large resource. Given that the entire horticultural industry uses less than 0.5% of this amount (Bragg, 1990), it would be easy to ignore the issue on the grounds of the negligible impact horticulture could have by using it. Indeed, there could be strong arguments for not allowing horticulture to be perceived as the dumping ground for other peoples waste.

However, there are other reasons why the issue of waste should not be overlooked. Firstly, there are marketing advantages to be gained from promoting methods of production which are environmentally favourable. There are many examples of large multi-nationals who consider it worthwhile promoting products from the environmental standpoint. Most major do-it-yourself (DIY) outlets in the U.K. have a policy on the use of peat, and one of the largest has started to exclude suppliers who do not have an acceptable environmental policy.

Secondly, governments in other countries are beginning to exert considerable power either legislatively or by awarding contracts preferentially to companies with proven environmental credentials. The U.K. government is currently engaged in an extensive study of the requirements of the horticultural and landscape industries for peat and alternative products, as a prelude to formulating their future policy on peat.

Thirdly, there is evidence that some materials in the waste stream can be as effective or exceed the performance of peat, as discussed later, and finally, considerable cost savings are possible.

ASSESSMENT OF INGREDIENTS

Proper assessment of wastes as potential growing medium ingredients is essential if long-term success is to be achieved. Before any practical work begins it is possible to assess the suitability of materials in terms of their availability, consistency, geographical accessibility, cost, and ease of handling. Those which look suitable must then be tested in trials. Some which appear good on paper, will prove to have hidden problems when used in practice. One example is spent coffee grounds; the waste from the instant coffee industry is currently being landfilled at a cost of £18 per tonne. It is very similar to coir in appearance, has a low pH, low soluble salt content, and is available in suitable quantities at geographically favourable sites in the U.K. Unfortunately, in trials to date it has performed extremely badly, and so work on its use as a potential growing medium ingredient is unlikely to continue.

A composted blend of straw and sewage sludge performed very well in trials, but faecal aversion amongst the general public, and high production costs have prevented further development. Composted bracken has also performed extremely well in trials but until it is available in larger quantities, it remains unviable for large scale commercial exploitation.

Composted waste generated by parks, gardens, and vegetable food processing, collectively known as composted green waste, is rapidly becoming available at sites throughout the country, due to the changes in waste legislation already mentioned. Quality varies enormously, but there are indications that well-produced green waste can be effective when used at proportions of up to 30% in the mixes for easy-to-grow plants.

Local initiatives will be a key feature of the use of such products, as variability from one source to another and transport costs are likely to prevent the large-scale uptake by compost manufacturers. Nurseries growing large quantities of nonsensitive stock who are local to a composting plant could lower their production costs significantly given that current prices for green waste vary from nil to £3.50 per m^3. However, success will only be achieved if the green waste is well-produced and consistent. The Composting Association is currently drawing up standards so that potential users may purchase with confidence from approved producers, but extensive trialling will always be necessary before uptake on a commercial scale is feasible.

Some growers, such as Wyevale Nurseries at Hereford, successfully produce and use their own composted green waste, and in the United States of America (U.S.A.) the practice is well-established.

TIMBER RESIDUES AS WASTE INGREDIENTS OF GROWING MEDIA

A by-product with potential for development on a far wider scale is derived from residues generated in British forests. Fulfilling all the above paper criteria and giving excellent performance in trials to date is Melcourt Sylvafibre. This is the matured natural pine fibre resulting from chipping the residue left on the forest floor after the removal of the logs. Sylvafibre is consistent and sustainable, and has been extensively trialled in both glasshouse and outdoor situations. It is currently included in several nursery stock trials in the U.K. and, being very competitive with peat, it looks likely to play a major part in growing media of the future.

Bark is another forest product, considered a waste twenty years ago, which now provides sawmillers with a significant income and could certainly not be classed as a waste nowadays. Although its use in growing media can reduce the quantity of peat needed, its purpose in the mix is different and complementary to that of peat. As an environmentally acceptable and extremely effective product, bark is set to remain an important ingredient of both propagation and container media, while helping growers achieve environmental credibility.

CHOICE OF GROWING MEDIUM TO REDUCE PESTICIDE USE

Pesticides have been a green issue for many years and the trend is undoubtedly away from their use. There have been considerable advances in the field of biological control, but the armoury is still far from complete, particularly for outdoor crops. However, research both in the U.S.A. and the U.K. has demonstrated that growing media can be used as suppressors of root pathogens such as *Pythium*, *Phytophthora*, and *Rhizoctonia*.

It is believed that the mechanism of control varies with different organisms, but that the main effect is suppression due to competition created by microbial diversity. Hence the much greater effect seen in composted materials, which characteristically host a large and diverse microbial population, compared to peat, which holds only very low levels (Hoitink et al, 1993).

In the U.K., HDC-funded ADAS research has demonstrated significant control of both fusarium wilt in cyclamen and *Phoma* root rot in gentian using bark in the growing medium. In each case the best results have been achieved with a combination of fungicide and bark (HDC, 1993).

Field grown crops can also benefit from the same mechanisms. Many examples of significant control of soil-borne pathogens on soils dressed with composted materials have been noted by U.S.A. researchers (Logsdon, 1993).

Approved herbicides for nursery stock production are also becoming fewer, and increasingly the grower is being left to bear the risks of phytotoxicity himself. Pot mulching as a method of reducing weed, moss, and liverwort incidence is a useful alternative in some situations. Potting-grade bark is an effective material when applied to a 2 cm depth, giving excellent control of moss and liverwort, and reasonable suppression of weeds. Wool pellets also show potential. A disadvantage of any loose fill mulch is that they cannot survive the effects of the pot tipping over.

Woven mulches such as coir and wool mats also show great potential, although unlike loose mulches their use is generally restricted to single-stemmed subjects.

Cost comparisons depend very much on the scale of operation. The use of bark is currently extremely competitive with herbicides, whereas the coir and wool "pot toppers" are more expensive. However, it is likely that the costs of wool and coir will fall as volume sales increase.

CONCLUSIONS

Green issues have caused some digressions, but these are an inevitable consequence of progress. Consideration of the effects of nursery stock production on the environment has presented us with new marketing opportunities; opened our eyes to the existence of materials other than peat; forced us into positive steps to protect the environment; and caused us to fundamentally and beneficially re-evaluate the way we operate.

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Integrated Production of Nursery Stock

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INTRODUCTION

The total area of nursery production in the Netherlands has grown rapidly during the last 10 years. More than 50% of the plants are exported. High standards of quality lead to the use of large amounts of fertilizers and pesticides, especially soil fumigants. These amounts are still way above the long-term targets associated with government environmental policy. The Multi Year Plan for Crop Protection aims to reduce the use of pesticides in nurseries by 25% by 1995, 39% by 2000, and 58% by 2010. In addition, the use of fertilizers is to be restrained to avoid polluting surface and ground water.

As growers will continue to face competition from imports they will have to maintain high standards of quality so economic and environmental aims have to be optimized. In 1990 the Research Station for Nursery Stock at Boskoop developed a programme to investigate alternative production methods (Dolmans, 1992). This has resulted in research projects at three different levels:

1) Analytical research, in which alternatives are investigated in "normal" scientific experiments.

2) Development of three prototype integrated nurseries, at which alternative growing methods are evaluated in relation to one another and to economical consequences at a semi-practical scale.

3) Implementation in practice, where alternative methods are introduced to nurseries.

Researchers are working at different levels. This guarantees a close interaction and constant evaluation of the results.

DEFINITION OF INTEGRATED PRODUCTION

The integrated nutrient management for field grown nursery stock implies maintaining soil fertility and nutrient balance, and preventing leaching. Chemical analysis of soil samples must be the basis of the nutrient management on the nursery. Organic manure is used as the basic fertilizer. Additional nitrogen (N) and potassium (K) fertilization can be given during the season, preferably in the rows. Special attention has to be given to the level of organic matter in the soil because the use of organic fertilizers is restricted. Organic content can be maintained using low nutrient manures such as compost and green manures.

The most common soil diseases and pests in open-ground nursery stock production are *Phytophthora cinnamomi*, *Verticillium dahliae*, *Meloidogyne hapla*, and *Pratylenchus* spp. A long-term crop rotation plan, based on host ranges of these diseases and pests must be used instead of chemical soil sterilization. *Tagetes* spp. can be used to suppress *Pratylenchus* spp.

The amount of pesticide applied can be reduced through better application techniques, good monitoring, and decision support systems. In integrated systems, selective compounds must be used. Mechanical weed control is preferred. All these measures require better disease and weed management. This can only be achieved on a nursery when the number of crops is limited, allowing the grower to develop special techniques and to make specific investments.

Container growing raises additional problems because it is very intensive. The main environmental problem is leaching and run-off of irrigation water, which takes fertilizers and pesticides into the ground water or streams and lakes. This can be solved by water recirculation systems. Various alternatives are possible, depending on the size of the container and the irrigation system in use. The ultimate control, although rather drastic, is to grow the plants indoors—this also offers new opportunities for biological pest control measures.

ANALYTICAL RESEARCH

Biological and Integrated Control of Insects and Mites. Trials on the biological control of spider mite, aphid, and black vine weevil were undertaken. The predatory mite, *Phytoseiulus persimilis*, gave good control of spider mite in greenhouses and tunnels when air humidity was kept high enough and when the predator was introduced soon after the first spider mites were found. Biological control of aphids was tried with the parasitic wasp, *Aphidius colemani*, and the predatory midge *Aphidoletes aphidimyza*—the former to control new infections, the latter to eradicate established colonies. Most of the common aphid species could be controlled successfully.

Biological control on outdoor crops was not successful, although a research programme is still under way on the use of the lace-wing fly, *Chrysoperla carnea*, and the lady bug, *Hippodamia convergens*. Broad-spectrum insecticides currently used to control the black vine weevil, *Otiorhynchus sulcatus*, interfere with biological control measures. Pesticides with a more selective activity are being trialled against adult vine weevils. Parasitising nematodes (*Heterorhabditis* spp.) give good control of the larvae, but are not effective at low temperatures and are expensive. Trials are under way to find strains active at lower temperatures (van Tol, 1994).

Integrated Control of Fungi. A computerised decision-making aid is being developed to help growers control rose powdery mildew, *Sphaerotheca pannosa*. This program is fed meteorological data collected by an automated weather station. In trials the number of sprayings has been reduced by between 30% and 50%.

Crop Rotation. The nematode, *Pratylenchus penetrans*, has a very broad host range, which makes it difficult to find a good rotation scheme. However, there are possibilities when more is known about the host suitability and the damage threshold of the main crops. This is being investigated for a range of different crops.

Fertilization. To help us understand leaching of nitrogen in field-grown crops, different aspects of the nitrogen balance are being studied. Several trials are under way to determine the optimal level for soil nitrogen. It appears that this level in May and June is between 50 and 100 kg ha^{-1}—depending on the crop. Application of fertilizers by fertigation and slow-release formulations are being tested.

PROTOTYPE NURSERIES

Three prototype nurseries are in use to help develop integrated production systems for growers to use. At each prototype nursery one person, acting as nursery manager, is supported by a counselling group of nurserymen and extension officers.

Field-Grown Seedlings for Forests and Hedges and Rose Rootstocks. This nursery is located on 1.5 ha of reclaimed peatland. For crop rotation, plant species are divided into four main groups plus *Tagetes erecta* for nematode control. In principle, for each group a crop rotation system of 1 : 6 (or 2 : 6 for the biennial crops) is planned. So far, nematode populations have been kept low by the use of *Tagetes*, although there are infestations of *Pratylenchus penetrans*. As the soil is phosphate saturated, animal manure cannot be used for fertilization. Use of composted waste materials and *Tagetes* can just compensate the loss of organic matter by mineralization. The level of nitrogen in the soil can easily be lowered to 50 kg ha^{-1} for first-year seedlings and 75 kg ha^{-1} for transplanted plants without loss of growth or quality. Weeds are controlled mechanically between the rows by hoeing, ridging, and brushing. In the rows it is still necessary to use a soil herbicide, as hand-weeding is very expensive. On seed beds, weeds are killed by infra-red burning. There is a list of acceptable pesticides that can be applied with technically advanced spraying equipment. By good monitoring, the use of pesticides can be reduced without noticeable pest damage to the crops. Integrated control of beech woolly aphid (*Phyllaphis fagi*) and oak midge (*Arnoldiola quercus*) appears to be very difficult and both need more research.

Field-Grown Ornamental Shrubs and Conifers. This nursery is located on 0.8 ha of sandy soil. Plants are grown from planting stock to saleable plants in 2 years. The crops are divided into six rotation groups plus *Tagetes*. The crops are grouped according to susceptibility to nematodes and *P. cinnamomi*, and general cultural practices. After 4 years (two crops) *T. patula* is grown for 1 year. In principle for the groups, a crop rotation system of 2 : 15 is planned. The nursery has quite high infestations of *Pratylenchus* and the rotation scheme had to be adjusted, but so far no pest damage has occurred. Fertilization and plant protection are generally the same as described above for seedlings, except that more organic material has to be applied because some plants are sold with a root ball. The mineralization rate at this site is high so nitrogen additions can be very low. The use of pesticides in this nursery is very low, as only selective chemicals are used and natural enemies are abundant.

Container Grown Ornamental Shrubs and Conifers. A nursery composed of an outside container bed of 0.2 ha plus a greenhouse of 0.2 ha with a removable polythene roof (convertible greenhouse) protecting the system from excess rain. The roof can be opened to obtain a mild climate for growing and hardening-off. The water in the system is recirculated. Shrubs and conifers are grown from rooted cuttings to saleable plant. Plants are grown in 1- to 3-litre containers in lots of 100 or 200 m^2 on a concrete floor to facilitate mechanization. An automated system for potting, transporting, placing, and spacing the containers avoids undesirable working conditions and reduces labour costs. Plants are fertilized with every irrigation, the leachate is collected and reused. So far, no undesirable effects of recirculation have been found. Biological control of aphids, spider mites, caterpillars, and black vine weevil works very well, although pesticides are sometimes used for correction or to control other diseases and pests.

IMPLEMENTATION IN PRACTICE

Although the results of the research on integrated production are promising, Dutch nurserymen have been slow to introduce the techniques on their own nurseries. To overcome this, the Research Station, the Advisory Service, and other organisations made a plan for the introduction of integrated control of general nursery pests and diseases, integrated nitrogen-management, and integrated control of powdery mildew in rose. In 1994 approximately 25 nurseries were involved with one or more of these areas. Practically all nurserymen are positive about the results and see the advantages of better monitoring and using less pesticides and fertilizers.

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The Development of Lignocell Coir as a Propagating Medium

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INTRODUCTION

Initial screening of peat-free container growing media at this nursery in 1991 identified various products with potential as alternatives to peat. Surplus material from these trials was tried in propagation to see what would happen. Results suggested that these materials were worthy of further investigation and a decision was taken in 1992 to investigate their potential.

MATERIALS AND METHODS

Three out of the five products trialled were commercial products and the proportions of their constituents were known (Table 1).

Table 1. Constituents of growing media used in trial.

Supply company	Product	Contents[1]
UF Horticulture	UF8s	Pine bark Pine chips Straw
Camland Products	Propagation mix	Fine pine bark Wood fibre
Golden Grow	Own mix	50% coir 30% perlite 20% fine pine bark
SHL	Propagation mix	50 : 50 DIY Pine bark Perlite
Hensby Biotech	Own mix	50% lignocell coir 30% perlite 20% fine pine bark
Darby peat mix	Own mix	50% Medium peat 30% perlite 20% fine pine bark

[1] To each mix was added 1kg/m^3 of Osmocote 5-6 month mini granules.

Materials were mixed in a paddle mixer and transferred via a Universal fabrications tray filler into PG Horticulture PG96D 75-cm^3 cell trays. Two trays per species, per mix, were used in the trial.

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Softwood cuttings, stripped and nodal (with the exception of *Clematis* which are a standard 7.5 cm length), dipped in Synergol (IBA, NAA + Dichlorophen) at 1 : 9 strength, were inserted and placed in open mist with a variable floor temperature around 18C. Mist burst length was 10 sec, with the interval between bursts varying dependent on weather conditions, but usually 20 min. Removal from the mist was based upon individual species' rooting time, but whichever mix rooted first (to around 60% capacity) were removed. Average rooting period was 3 to 4 weeks.

Once removed, trays were placed in the weaning houses and in October 1992 a visual assessment was undertaken. This was followed in March 1993 at the point of potting into an 8-cm liner, by a count of cuttings rooted and a measure of grade quality.

RESULTS

Comments by the staff regarding the ease of inserting and setting the cuttings into each medium were noted. The Camland mix was impossible to insert into, often resulting in prepared cuttings breaking as they were pushed into the medium. The SHL and Golden Grow mixes were also difficult in this respect. All mixes except the

Table 2. Visual assessment of percent of cuttings rooted in various growing media (October 1992).

Plant species	Peat[1]	UF	GG	SHL	Camland	Hensby
Buddleja davidii 'Royal Red'	3[2]	4	2	0	4	5
Cotoneaster horizontalis	3	0	2	2	2	4
Clematis montana var. *rubens*	3	0	5	1	5	5
Escallonia 'Apple Blossom'	3	5	4	-[3]	3	4
Euonymus fortunei Emerald 'n' Gold®	3	1	5	4	4	5
Genista lydia	3	3	3	-	3	3
Hebe ×*fransicana* 'Variegata'	3	0	2	5	5	4
Hypericum calycinum	3	2	5	3	4	5
Jasminum officinale 'Argenteovariegatum'	3	4	5	4	4	-
Ligustrum ovalifolium 'Aureum'	3	3	3	3	3	-
Lonicera nitida 'Baggesen's Gold'	3	0	1	0	2	5
Polygonum baldshuanicum	3	4	5	2	2	3
Santolina chamaecyparissus	3	5	4	-	2	5
Brachyglottis greyi (syn. *Senecio greyi*)[4]	3	2	5	2	2	3
Spiraea japonica 'Little Princess'	3	5	3	-	4	5
Viburnum tinus	3	4	4	-	4	5
Average	3	2.6	3.6	2.6	3.3	4.5

[1] All peat scores were set at "3" for comparison purposes.
[2] Key: 0 = dead to 5 = best.
[3] Means no material trialled.
[4] Botanical Editor: this may refer to one of the Dunedin hybrids such as *B*. Sunshine.

peat mix and the coir based mixes were difficult to set, with cuttings tending to lean over when placed in the mist. A general comment was that it was easier to insert and set cuttings in the Hensby lignocell coir mix than the peat equivalent.

Visual assessment of the cuttings (Table 2) based on colour, growth, and fullness, suggested early on that the Hensby lignocell coir mix was out-performing other mixes, with both the Golden Grow and Camland mixes a close second.

Watering requirements in each of these mixes were different. The SHL, Camland and UF mixes were very free-draining, making it difficult to keep cuttings turgid. The peat mix however, dried out unevenly making watering difficult with a tendency to over-compensate. Both the Hensby and Golden Grow coir mixes, although appearing to dry out on the surface were easy to re-wet. Surplus water was found to move more freely through the coir mixes, with sufficient moisture being retained in the rooting zone.

The final assessment in March 1993 (Table 3) further confirmed the initial findings that the Hensby lignocell coir mix had, overall, performed between 10% to 15% better than peat.

Table 3. Rooting percentage of cuttings in various growing media (March 1993).

Plant species	Peat	UF	GG	SHL	Camland	Hensby
Buddleja davidii 'Royal Red'	60.1	56.8	45.8	49.5	50.0	81.7
Cotoneaster horizontalis	76 0	58.9	82.8	74.5	77.1	67.7
Clematis montana var. *rubens*	22.2	41.7	55.2	52.6	67.7	55.4
Escallonia 'Apple Blossom'	84.0	95.8	94.3	-[1]	87.0	85.4
Euonymus fortunei Emerald 'n' Gold®	96.5	81.8	95.3	98.4	99.0	97.1
Genista lydia	9.7	0	56.3	-	68.8	46.9
Hebe ×*fransicana* 'Variegata'	94.8	81.3	91.1	96.9	95.3	94.2
Hypericum calycinum	77.1	82.8	88.0	78.1	89.1	88.8
Jasminum officinale 'Argenteovariegatum'	6.3	45.8	71.9	53.1	71.9	-
Ligustrum ovalifolium 'Aureum'	93.8	93.2	94.8	88.5	99.0	-
Lonicera nitida 'Baggesen's Gold'	71.5	59.4	76.6	70.8	67.7	65.6
Polygonum baldshuanicum	26.7	11.5	50.5	45.3	31.3	31.8
Santolina chamaecyparissus	93.1	64.6	51.0	-	31.3	87.9
Brachyglottis greyi (syn. *Senecio greyi*)[2]	93.8	53.6	66.1	60.4	73.9	92.5
Spiraea japonica 'Little Princess'	91.3	78.1	80.2	-	88.0	96.9
Viburnum tinus	76.0	75.0	95.8	-	93.8	91.0
Average	67.1	61.3	74.7	69.8	74.4	77.4

[1] Means no material trialled.

[2] Botanical Editor: this may refer to one of the Dunedin hybrids such as *B.* Sunshine.

CONCLUSIONS

Results show that both the coir-based mixes and the Camland bark mix performed better than the peat mix. Although no conifers were trialled on this occasion, work continued in 1993-94 on these products.

Out of 44 species rooted in the lignocell-coir mix, 24 species rooted better than in the peat equivalent, 19 performed as well as they did in peat and only one species performed worse. As a result, a decision was taken to gradually move into lignocell coir for propagation. By 1994 all plants being propagated were rooted in lignocell-coir-based mixes and although problems have subsequently occurred which were not entirely unexpected, work is continuing to solve them.

Christmas Tree (*Abies fraseri*) Production

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INTRODUCTION

As winner of the Richard Martyr Award, I attended the Southern Region International Conference held at Greensboro, North Carolina (N.C.) in October 1993. After the Conference I drove west up into the Appalachian Mountains where I spent more than a week looking at the production of *Abies fraseri*, the Fraser fir, from seedling transplant to 7-m tall, competition-winning Christmas trees. Though many of the natural stands of Fraser fir are dying due to balsam woolly aphid, these are now being replaced by farmed trees as *A. fraseri* becomes an increasingly popular Christmas tree. I visited many Christmas tree growers but this report describes two, Bob Jennings of N.C. State Forestry Station and Wayne Ayers of Roan Valley Tree Farm.

PRODUCING QUALITY THREE-YEAR-OLD TRANSPLANTS

At the Forestry Station I observed the production methods for growing top-quality transplants for the Christmas-tree growers of N.C. The station is at an elevation of 760 m in the hills close to the aptly named town of Spruce Pines.

Before sowing a piece of ground it is cropped with rye for 4 years, then cultivated and sterilised using methyl bromide. Seed is then sown from June 10 through to the beginning of July when the temperature can be as high as 80F (26.5C). This facilitates speedy and unchecked germination with a possible two flushes of growth before the autumn. The seedlings should then be approximately 30 mm tall. Summers are hot and so the seedlings are covered with 30% shade netting and are irrigated once the temperature is above 85F (29.4C). *Phytophthora* can be a problem, especially during a wet summer, so Subdue (metalaxyl) is applied to the seed beds twice a year—once in the spring and again in the autumn when the soil temperature is above 55F (12.7C). In November, the netting is removed and the seedlings are covered with straw to a depth of 15 cm as a frost protectant.

The seedlings are grown on for a further 2 years, and they should be between 10 and 20 cm tall by the autumn of the third year. That autumn, in advance of lifting, they are undercut if *Phytophthora* has not been a problem or just laterally pruned if it has. Lifting takes place from the middle of February onwards during mild weather and light winds. A potato harvester is used for lifting if the ground is sufficiently dry, otherwise the job is done by hand.

Grading the transplants is very important. A transplant must be a minimum of 10 cm, have a single straight stem, a well established terminal with good buds present, a strong root system, and be free from mechanical damage. These are then tied in bundles of 25, dipped in Viteria or Agragel to reduce transpiration, and then sold to the N.C. Christmas tree growers for $175 per thousand.

AWARD WINNING CHRISTMAS TREES

Wayne Avers, of Roan Valley Tree Farm, grows his trees at between 1200 to 1500 m on the hillside of Roan Mountain, within a 300 m of its summit and its natural stand of *A. fraseri*.

The steps involved in producing first class Christmas trees include the simple tasks of planting the crop in straight lines, ensuring the crop is upright, annual pruning to maintain symmetry, and pesticide applications to control red spider mite and woolly aphid. Ayers, who has 30 years experience of Christmas tree production, won the National Christmas Tree Championship in 1993, with a presidential reception and the right to provide the President of the United States with a 7 m Fraser fir for the Blue Room in the Oval Office of the White House. It is a great honour for Roan Valley Tree Farm but also provides national recognition for the Fraser fir growers of N.C. as they strive to increase their share of the lucrative Christmas tree market above 15%.

In all I spent 3 weeks in North Carolina and Virginia looking at many different aspects of horticulture. May I take this opportunity through the pages of the *Combined Proceedings*, to thank everybody I met for the help I received and the information I gained.

Can Disease Control Ever Be Environment Friendly?

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INTRODUCTION

Modern horticultural crop protection involves a number of practices which are claimed to damage the environment. Growers still make considerable use of pesticides despite a reduction in available chemicals. Diseases continue to be wrongly diagnosed, which may lead to use of inappropriate fungicides and in some cases application of too many chemicals. Many nurseries still allow used irrigation water to drain into water courses and lakes which can result in loss of nutrients and pesticides and a build-up of these potentially damaging chemicals in the environment. The need for good nursery hygiene as part of integrated pest and disease management means many growers use pots, trays and other plastic materials only once before discarding them, thus dumping huge quantities of plastics annually. Specialisation and "factory" nursery methods have created increased risks of epidemic disease development and effective control remains the key to economic production of quality plants.

Some opportunities do exist for the development and application of acceptable disease control programmes. These include the use of rapid disease detection kits and the biological control of plant diseases.

INTEGRATED DISEASE CONTROL PROGRAMMES

There is considerable scope for the development of integrated disease control programmes, in which a combination of cultural and management practices, together with fungicides and biological control measures, are used to control one or more diseases. Such programmes have been successfully developed for some groups of diseases in horticulture, for example apple scab where a knowledge of the effect of weather conditions on spore germination and disease development enables growers to apply the minimum number of sprays to achieve economic disease control.

SAC Auchincruive has developed an integrated control programme for root and stem-base diseases of heaths and heathers. Work began in 1987 to look at the important and damaging fungal disease, rhizoctonia (caused by *Rhizoctonia* spp.). The biology of the fungus and a range of factors which affect the disease were studied. The aim was to develop a programme which would enable growers to achieve complete control of the disease at minimum cost, with minimal fungicide use, and with minimal damage to plants.

It was found that there are several potential sources of *Rhizoctonia* infection on nurseries, including diseased stock plants, cuttings, nursery soil, used pots and trays, capillary matting, benches and polythene, and used compost or compost containing unsterile loam. A disease control programme must, therefore, cover all these. The life-cycle of the pathogen was studied in an attempt to discover how the fungus reproduces and spreads. In the case of *Rhizoctonia* species, spread is comparatively slow as the fungus relies on growth of mycelium to spread. The speed of fungal growth is largely dependent on temperature, relative humidity, compost moisture content, and available nutrients. It was found that certain fungicides give good control of the disease, but that the successful use of chemicals is complicated for several reasons. Heathers, and in fact ericaceous crops in general, are very sensitive to the use of crop protection chemicals. The use of any fungicide on cuttings results in reduced root development and foliar browning. Older plants are much less susceptible to damage from fungicides.

Three years of work provided new information about *Rhizoctonia* on heaths and heathers. A blueprint for control was compiled.

BLUEPRINT FOR RHIZOCTONIA CONTROL ON HEATHERS

It is important to use only new or sterilised nursery materials and fresh or sterilised compost components, since the fungus can exist for long periods on used materials and soil. Old diseased plants are a primary source of the disease so it is important to remove them from the nursery. Stock plant vigour should be maintained by annual re-potting and trimming. Cuttings should be taken from shoot tips where possible, since the risk of *Rhizoctonia* contamination of shoots is less at the top of the plant. Humidity should be reduced by ventilation and plant spacing wherever possible, as the growth of the fungus is much faster in high humidities. If the pH of the propagation compost is less than 4.0, growth of *Rhizoctonia* is slowed or stopped. Plant stress should be avoided, as stressed plants are much more susceptible to disease. This underlines the need for an understanding of the requirements for vigorous plant growth. The correct levels of irrigation and drainage, adequate light, ventilation, and nutrition must be ensured. Fungicide use should be restricted, if possible, to older rooted plants which are less susceptible to phytotoxic damage.

OTHER DISEASES

It is recognised that this blueprint, while effective, may be an over simplification of the situation on most nurseries. Inevitably, more than one potential pathogen is likely to be present. There is little point in altering management or cultural conditions to control one disease if this promotes the development of another. The main root and stem-base diseases which affect heaths and heathers are *Rhizoctonia, Pythium, Phytophthora, Cylindrocarpon, Cylindrocladium, Pestalotiopsis*, and *Fusarium*. Following the work carried out on rhizoctonia, studies were continued to look at some of these. The disease control blueprint for rhizoctonia was extended and modified to include diseases caused by the pathogens *Cylindrocarpon, Cylindrocladium, Pestalotiopsis*, and *Fusarium* species. Many of the control measures which were employed in the rhizoctonia blueprint also apply to the control of these other diseases, but further fungicides are required at some stages of production, also the use of low pH compost may encourage the development of diseases caused by *Cylindrocarpon* and *Fusarium* species. A detailed study of the life cycle and biology of these fungi has enabled control measures to be developed which are genuinely effective in controlling the diseases. In addition to this, fungicide use, phytotoxic damage, and the cost of crop protection are minimised.

RAPID DISEASE DETECTION KITS

Kits for the rapid detection of *Phytophthora, Pythium*, and *Rhizoctonia* were introduced to the U.K. by ADGEN Diagnostic Systems, the commercial arm of

Scottish Agricultural Colleges, in 1994. Marketed under the name ALERT, they enable growers to identify important stem-base and root pathogens in just 10 min, on the nursery with no requirement for scientific skills or special equipment. Conventional laboratory diagnostic procedures may take up to 14 days to identify *Phytophthora*, by which time serious crop damage may have occurred. Rapid diagnostic kits mean growers can take early action to prevent epidemic disease development based on informed decisions. Fungicides can be applied at the beginning of a problem when they are most effective. The correct products can be selected and pesticide inputs optimised. Crop losses are reduced and plant quality and profitability enhanced. Rapid diagnostic kits can also be used to:

- Check the health of cutting material and to monitor the health of crops and stock plants during production.
- Determine the health status of bought-in material prior to potting and setting out on the nursery.
- Guarantee the health of plants about to be dispatched for sale.
- Determine the health status of all crops thereby allowing fungicides to be applied only when required.

BIOLOGICAL CONTROL OF PLANT DISEASES

There is a wide range of successful biological control agents which are commercially available to combat horticultural pests including aphids, whitefly, mealybugs, nematodes, and caterpillars. Growers appreciate that biological control is safe, environment friendly and minimises the chances of resistance developing in the target pest. The development of biological control agents for diseases of horticultural crops has proved much more difficult. Biological controls for plant diseases are still relatively few and far between because there are several criteria which a biological control agent must meet if it is to be commercially successful. It must:

- Be able to be grown in large quantities.
- Survive and remain active in a range of environmental conditions both before and after application.
- Be genetically stable and non-toxic to animals, plants, and the environment.
- Give good control of the target pathogen.

Root-attacking, soil-borne diseases are better targets for biological control than foliage attacking diseases.

There are two reasons for this. Firstly, few chemicals are really effective against soil-inhabiting plant pathogens, so new control methods are desperately needed. Secondly, the soil environment is moist in comparison to the aerial foliage environment and this is more likely to be favourable to biocontrol agents. Examples of target fungal pathogens for disease biocontrol include *Rhizoctonia, Fusarium, Phytophthora, Pythium, Sclerotinia*, and *Verticillium* species. Due to the sensitivity of biological control agents to the physical environment, protected crops are the most suitable candidates for biological protection.

Biological disease control agents occur naturally in many soils and can be divided into three main groups—actinomycetes, bacteria, and fungi. Some of these agents produce antibiotics that inhibit plant growth; others parasitise plant pathogens, obtaining nutrients and growth factors from them; and yet others suppress pathogen growth by competing with the pathogen for space, light, or food. Some biocontrol agents use only one of these modes of action, others use all three. There is an increasing number of commercially available biocontrol agents. One of the most widely studied is the soil-inhabiting fungus *Trichoderma viride*. It is marketed in the U.K. by the Swedish company BINAB Bio-Innovation AB, as Binab T, to control silver-leaf disease in trees, which is caused by the fungal pathogen *Chondostereum purpureum*. It is available as a wettable powder which is used to paint pruning cuts and as 2-mm and 5-mm pellets. The pellets are inserted in infected trees to fight the disease. Binab-T is used more extensively as a control in countries other than the U.K. In Holland and Sweden, for example, it is used on many different flower and vegetable crops against *Botrytis* and many soil-borne fungal pathogens including *Rhizoctonia, Pythium, Fusarium, Verticillium*, and *Sclerotium* species. Mycostop is an example of a actinomycete biocontrol agent. It is marketed by Kemira Biotech, a Finnish company, and is being used extensively in Europe at present. It is currently undergoing registration procedures for use in the U.K. Its main application is in the protected cultivation of bedding and pot plants, cut flowers, bedding, cucumber, melon, and pepper. It is also suitable for use as a seed dressing. Its main targets are the root and stem-base pathogens*Fusarium* and *Alternaria* species, but it also prevents attack by other soil-borne pathogens. Blue Circle is an example of a bacterial biocontrol agent which is marketed for use in the U.S.A. by the American company Stine Microbial Products. It consists of live, naturally occurring, soil bacteria of the species *Pseudomonas cepacia*. The bacteria are applied as a seed treatment or as liquid inoculum. Blue circle is primarily used to control nematodes on corn crops, but it is also being used on horticultural crops such as tomatoes, carrots, peppers, and lettuce to control fungal pathogens such as *Rhizoctonia, Fusarium*, and *Pythium*.

DISEASE SUPPRESSION

Vaminoc is an example of a different type of organism. It is not strictly a biocontrol agent because it does not set out specifically to control disease. It is sold as a high quality vesicular-arbuscular mycorrhizal inoculant for horticultural crops. In other words, it contains beneficial fungi which colonise crop roots. In normal soil conditions, most plant roots form associations with mycorrhizal fungi. This benefits the plant by effectively extending the root system, increasing the availability of water and nutrients, and protecting the root system against certain diseases. Mycorrhizal fungi may be absent from commercial growing media, and Vaminoc aims to replace these naturally occurring organisms. It is claimed that the organism improves nutrient uptake and helps plants to withstand stress due to poor light levels, high temperatures, and root disease. Large-scale trials with commercial cucumbers has shown that crop yield and quality is significantly improved through its use.

There is increasing interest in the use of disease-suppressive growing media as an aid to disease control in ornamentals. Work has been going on in the U.S.A. for several years to look at the effect of naturally occurring disease-suppressive organisms in peats and barks. Certain peats, particularly young, relatively non-decomposed sphagnum peats and some bark products, particularly composted hardwood barks, can make a positive contribution to disease control. Results have shown that damping-off and root rot in bedding plants, pot plants, and hardy ornamentals can be significantly reduced through the use of disease-suppressive media.

CONCLUSIONS

The days of routine applications of fungicide sprays to protect against frequently undetermined risks or fire-brigade approaches to emergency disease control are numbered. In many ways this is not a bad thing, as in many situations it never has been a satisfactory approach to quality plant production. Inevitably, there will be a greater management input required on the part of the grower. However, the end result will be a better and more reliable production which will be done in such a way that the industry can claim that its procedures and products are more environment friendly.

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Monrovia Nursery's Response to New Environmental Restrictions

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WATER

Water quality and quantity has probably been the hottest environmental topic in the past few years. In the western U.S.A. precipitation has been below normal for the past 8 years and this has led to numerous clashes between city authorities, environmental groups, industries, and agriculture, over who has rights to the water and how much should be used and how much conserved.

At Monrovia Nursery Company, water management has always been a top priority. Since 1968 we have been involved in water research and recycling. Our research director, Conrad Skimina, was instrumental in developing our water recycling system 20 years before it became a public issue. He has presented several papers on our findings at past I.P.P.S. meetings. In 1984 when Monrovia's Oregon nursery was started, 100% water recycling was built into its design. On our 565 acres there, each production bed slopes to its center drain tile to carry irrigation water back to the drainage canal and on to the collection ponds. The water collected is chlorinated and pumped to storage reservoirs for reuse. Daily water samples are taken and tested to monitor pH and fertility levels. Detailed water analysis is done monthly in our lab.

On a national level the efforts of nurserymen to manage water resources was further complicated by Congress passing the Federal Clean Water Act which set nutrient limits on run-off or effluent entering public waters. To start to enforce this on the local level, the Oregon Department of Environmental Quality (DEQ) focused on container nurseries and the high nutrient loads entering low flow streams during Oregon's dry summers. Most container nurseries were not prepared to deal with the DEQ demands individually, so the Oregon Association of Nurserymen organized an irrigation run-off group. This group negotiated with the DEQ for years to prevent the container nurseries from being reclassified as point source (industrial) run-off, losing agricultural status and subject to all the associated permits, mandatory testing, bureaucratic paperwork and possibly fines.

The efforts worked and the container nursery growers realized the advantages of collection of irrigation run-off and voluntarily agreed to develop and adopt the Oregon Statewide Container Nursery Irrigation Management Plan. From June 1993 all container nurseries in Oregon have to have a plan on file with the Oregon Department of Agriculture on how they will prevent nutrients in irrigation run-off from entering Oregon streams. Most container nurseries were able to change irrigation practices to meet the deadline and prevent irrigation run-off—a few required site modification, some at significant cost.

With the Clean Water Act, Monrovia's fertilization practices have also changed. In the past we relied on injection of liquid fertilizer during irrigation to feed our plants. Recent advances in slow-release fertilizers make it possible to incorporate fertilizer in the soil mix even on long-term crops. We still liquid feed but now at much lower levels.

One fact had became apparent, the public perceived that farm ponds were toxic pools collecting the pesticides and herbicides from the fields. To counter that idea and educate the public, we installed floating duck houses on all of our reservoirs and have quite a population of domestic and wild ducks living and nesting at the nursery. The ducks do a great job at public relations.

Another public perception is: "Every time I drive past that nursery those sprinklers are running. Boy, they must be using a tremendous amount of water". To counter this we emphasize the fact we recycle 100% of our irrigation run-off to all nursery visitors: garden clubs, school groups, politicians, neighbouring farmers, etc. If 1000 gal of water is applied 500 to 700 gal is recaptured for reuse, depending on weather conditions.

Ground water quality is the next area of concern facing nurseries. To establish a data base, Monrovia installed test wells near all our reservoirs to monitor ground water quality. The wells are tested quarterly and no change has been found in the ground water.

ORGANIC MATERIALS

Burning used to be an acceptable means of disposal for leaves, pruning debris, clippings, etc. The Federal Clean Air Act and local air quality standards have made it unacceptable. The other method was to load up the dumpster and bury it in the landfills; again, this is no longer allowed. Landfills and dumps are filling up and new ones are not being developed fast enough because of all the environmental impact studies needed. So what do we do with the mountains of green waste material off the 1250 acres of container nursery stock?

The answer is to collect, grind, compost, and recycle. By collecting all the pruning debris, propagation clippings, leaves, and culled plants at the nursery, we generate enough organic material to produce about 15% (by volume) of our potting media. Weeds are excluded from the recycling pile. Grinding the material helps speed up the composting and produces a more uniform size particle. The ground material is composted for about 60 to 90 days depending on the season. Many city authorities are also producing compost from homeowners' garden waste and it is being used by some nurseries in their potting mixes. More work remains to be done with garden debris compost.

PLASTICS

Nurseries use a large amount of plastic products. Our Oregon nursery uses about 20 million containers and 110 acres of polyethylene film for winter protection and greenhouse coverings each year. Many of the plastic items are reused for several years, but then what? Plastic recycling as a viable business in the U.S. still has a long way to go. The recycling of nursery plastics is further complicated by the degree of its cleanliness. Any soil, leaves, and residues require the plastic to be washed prior to recycling.

Part of Monrovia's solution has been to encourage the fledgling plastic recycling business. The majority of the plastic pots and flats we purchase are made in part of recycled plastics, creating a demand. Broken and discarded pots and flats are collected at the nursery and given to our local pots manufacturers to be recycled.

The poly film used to cover the 1200 overwintering hoop houses is stored for reuse by baling it into large 5-ft diameter bales using a John Deere 535 hay baler or rolling it into smaller rolls on 10-ft lengths of PVC pipe. We tried keeping the plastic as clean as possible but the fact is the weather is against us at that time of year. Poly film to recycle is marked and baled separately. The recyclers like the compactness of the large bales over loose folded plastic and it is more economical for them to handle, haul and store. Another problem with polyethylene film recycling is the nursery industry overwhelms the processors in the spring when the plastic is removed. So at Monrovia, we bale and store our scrap poly film until the processors can take it. We are also working with the local nursery association and a local recycler to ship baled plastic over to China where it can be economically cleaned and recycled. We donated bales for several shipments this past spring. Plastics are vital to our business and recycling should be encouraged.

CHEMICALS

The Environmental Protection Agency's (EPA's) Worker Protection Standards, coming into effect in Jan. 1995, limits re-entry into an area that has been sprayed for 12, 24, or 48 h. All agricultural chemicals are in the process of having the label directions of use rewritten. New re-entry time intervals (REI) are being incorporated in the new label. Many low-toxicity chemicals used to have a re-entry time of "when spray has dried". The REI is based on the chemical toxicity, its persistence, and the method of application. The notification of workers about chemical applications has been expanded to include written and oral notification about the treated area.

At Monrovia Nursery Company, worker safety is a priority for us. We have at three locations in two states a combined total of 1450 employees working on 1250 acres producing 1400 taxa for a grand total of 42,000,000 plants per year. Given the volumes we grow and ship, the crops must be readily accessible. To do so we have tried to control our pest and disease problems through changes in our cultural practices, biological controls, sanitation, and integrated pest management techniques using low-toxicity chemicals applied as spot sprays. When chemical applications are needed, treated areas are marked with small blue flags indicating workers should not enter the area until spray has dried and the flags have been removed by a supervisor. The flag system has worked well. It is understood by the employees and easy to implement.

The new Worker Protection Standard, however, called for large placard signs to be placed at the treated area, a cumbersome and expensive proposition given our nursery's size and diversity. So we helped organize a nursery task force through our state nursery association to work with the Federal EPA and Oregon Occupational Health and Safety Administration to develop a modified flag system that meets the Worker Protection Standard posting requirements. It worked and is being implemented serving as a model program for other states too.

Still the re-entry intervals will have a big impact on how we operate the nursery on a daily basis. To accomplish spraying in a more timely fashion we had two versions of a boom sprayer built with a 50-ft folding boom spray arm. This allows us to reach halfway across the blocks of plants when spraying and cover a lot of ground in a short time. Also the spraying schedule has been shifted to after hours, nights, and weekends when fewer employees are working. We have increased our scouting to determine pest populations and thresholds before applications are made.

Another important part of the Worker Protection Plan is education and access to information. All employees will go through pesticide safety training before January 1995. Pesticide handlers will receive additional special training.

FUTURE CHANGES

Methyl Bromide fumigation will be eliminated and we are looking for an alternative. Many other agricultural speciality chemicals will be lost because it is uneconomical for the chemical companies to spend the money required for reregistration of chemicals for minor use crops. Water will continue to be a major topic as ground water legislation is put forward. Bark as a soil mix component is in jeopardy due to Endangered Species Habitat Protection and reduced logging. Land use legislation is pending. The mandatory use of native plants in government projects will affect the range of stock grown.

POTENTIAL FOR ACTION BY NURSERY GROWERS

Get Involved. Join your local or state nursery association to stay up to date on the changes pending.

Be Proactive. Don't wait for changes to be handed to you and then try to live with them. Have a say in how the changes will affect your nursery.

Conduct an In-House Environmental Audit. See if your nursery complies with existing and pending environmental and safety laws. Use this information in planning your business to avoid creating bigger more expensive problems later on. We conduct an environmental audit covering all aspects of our nursery each year.

Support Nursery Research. Many of the changes we face cannot be solved by individuals due to cost and complexity. Collectively the answer may be achieved for the benefit of all the nurseries.

Educate. Conduct in-house training sessions for employees. Broaden their skills and awareness. Allow the public to see the how and why of your nursery business to clear up the misconceptions and stereotypes.

It's going to take some time, effort, and money but the viability of the nursery industry in these environmental times is in our hands.

Environmental Policy for Nursery Stock Production

Brian Humphrey
Production Director, Notcutts Nurseries, Woodbridge, Suffolk

INTRODUCTION

The significance of the so-called "green movement" should not be underestimated. Apart from the importance and significance of public attitudes to green issues, a well implemented and thought-out environmental policy can make economic sense in the propagation department and throughout the rest of the nursery.

THE ENVIRONMENTAL POLICY—WRITTEN STATEMENT

There is no doubting the importance of a written statement of company environmental policy. It provides the framework within which implementation of the various issues takes place. It is also the focus of the inevitable changes and amendments to the policy which will occur over time as a result of implementation, experience, and new legislation.

Formulating the Written Statement. An example of Notcutts Nurseries' environmental policy statement is shown in the following section. This deals with the issues as follows:

A) An introduction or general section describing the company, emphasising its significance as a positive force for environmental improvement, and making a written commitment to safeguard, as far as practicable and appropriate, the local, national, and global environment.

B) A section covering general organisation and responsibilities including, if appropriate, a line management structure.

C) A section covering the following aspects of the policy:

1) A description of the methods of communication used to transmit the environmental policy throughout the company.

2) Other aspects of company environmental policy, such as reducing pollution, aims for energy conservation, etc.

D) A section covering specific departmental procedures to deal with the various points raised in section C as appropriate.

NOTCUTTS NURSERIES, WOODBRIDGE—ENVIRONMENTAL POLICY

As an example, our current policy is set out as follows: (The text has been omitted or reduced in some sections because it is very specific to our requirements.)

General Procedures. The management will ensure that they and their staff are made aware of environmental issues which might be influenced by nursery activities. This information will be transmitted by the following procedures:

- Discussion
- Memos and notices
- Training

The environmental issues involved are:

1) Recycling
2) Pollution

3) Wildlife issues
4) Conservation
5) Energy conservation

Specific Departmental Procedures—Field Department.

1) *Recycling*. Opportunities for recycling in this relatively low input section are rather limited, but use will be made of procedures existing in other departments, such as plastic recycling for waste plastic root wrapping bags, etc. Where possible, bamboo canes used for staking will be reused for subsequent crops, e.g., whips staked with recycled standard tree canes. Bud clips are always to be recycled numerous times.

2) *Wildlife and Conservation*.

***Cropping Plan*.** Areas unsuitable for cropping will be planted with appropriate trees and shrubs, normally native, to create wildlife havens throughout the nursery areas. The field department will follow a cropping policy which ensures the land is rested between crops. Crops will be rotated to avoid a build up of pests, diseases, and weeds. Cutting, etc. will be timed to avoid unnecessary damage to ground nesting birds.

***General Cultural Operations*.** These will be timed as far as possible to avoid damage to wildlife. Hedge trimming will be timed so that it does not coincide with the bird nesting period. Fencing will be erected for rabbits, hares, and deer to reduce the need for shooting. Timing of cultural operations, etc. will be designed to reduce soil erosion and surface water run-off.

***Pollution Control—Pesticides*.** The use of pesticides will be restricted as far as possible and only used according to the recommendations of a suitable consultancy service, such as ADAS. Where possible an integrated pest-management (IPM) policy will be adopted. Due attention will be paid to danger to bees.

Specific Departmental Procedures—Container Department.

1) Recycling.

- All recyclable plastic will be separated, collected, and packaged as appropriate for collection.
- All recoverable compost from unsold stock, etc. will be knocked out of the container and saved. After suitable processing it will be added to new compost.
- Rainfall from glasshouse roofs, sheds, and polythene tunnels is piped into water storage reservoirs. Run-off water from growing beds is similarly collected in storage reservoirs by means of underground drains, concrete ducts, or ditches.

2) Pollution Control. The same conditions for pesticide use as set out for the field department will apply. Crops grown under protection are suitable for an IPM programme, and this will be used on all appropriate occasions. The use of slow-release fertilisers with controlled-release characteristics ensures nutrient run-off is minimal. The storage of run-off water in company reservoirs further reduces nutrient levels.

3) Wildlife and Conservation. The same general policy as set out with the field department will apply. The firm has a commitment to reducing peat usage as far as practicable. Trials to investigate locally produced materials are on-going.

4) Energy Conservation. The use of artificial heat in growing structures will be maintained at a minimal level on all occasions.

Specific Departmental Procedures—Liner Department. The same general conditions apply as for the container department.

Maintenance Department. Recycling procedures for waste plastic are as for other departments. Waste oil is to be collected under contract for re-processing by others.

Transport Department. Recycling of suitable materials will be as previously noted. Company cars will on all possible occasions be powered by diesel engines. Routes and loads will be planned to reduce the need for travel as far as practicable. Biodegradable packing materials will be used on all possible applications. Plants will be sent out in returnable containers/pallet boxes where feasible and possible.

Propagation Department. The same general conditions apply as for the container and liner departments. Artificial heat will only be applied at levels which current research and development has indicated is necessary to achieve acceptable results.

ENERGY USE STRATEGIES FOR PROPAGATION DEPARTMENTS

Undoubtedly one of the biggest energy consumers on the nursery is the provision of heat for propagation, either in the air or as bottom heat. The requirement for this heat may be reduced or eliminated by:

A) Using polythene systems for propagation rather than fog or mist. If mist is used enclose the system in polythene. With polythene systems accurate management of shading is important because continuous heavy shading may result in an additional need for bottom heat.

B) Propagate at times of the year when free sun heat is readily available. With cuttings this may often be easily achieved. Grafting is traditionally carried out in the winter. The requirement for bottom heat at this time is obvious but a number of species can be propagated equally or more successfully in the summer or autumn and thus substantially reduce heat inputs. The following genera are among those which may be considered for such treatment: *Abies, Alnus, Arbutus, Carpinus, Cedrus, Cornus, Fagus, Juniperus, Liquidambar, Liriodendron, Magnolia, Quercus,* and *Rosa*.

C) Use low-energy systems for propagation. The difficulty here will be to decide whether the system is sufficiently efficient to consider its use in the modern situation. There must be a question mark over systems such as the use of bell-jars, but the sun tunnel system applied to certain groups of plants has a great deal to commend it and is among the most energy-efficient systems available to the propagator.

The Desirability of Rare Alpines in the Trade

Jim Jermyn
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INTRODUCTION

When I first started growing alpine plants as a student at Ingwersen's nursery in Sussex, the industry was very different from the one we know today. The market for alpine plants was mainly split between retail sales direct from the nursery and mail order. There were relatively few wholesale nurseries supplying garden centres.

The current decade has seen a large surge in the market for alpines. Many small retail nurseries have launched themselves onto the circuit of horticultural and other types of shows in the U.K., both direct selling and as a way of publicising their mail-order business.

But where have all the rarer alpines gone? Nurseries seem to have been forced to mass produce fewer lines for sale to the public at their popular shows. This has led to an upsurge of trade for mass production propagators of plug plants, churning out countless seedlings of lewisias, dianthus, saxifrages, and campanulas. However, the demand from the retail industry is for choice cultivars and rarity, as well as for large quantities of common plants. The gardening public has an increasing awareness of the unusual plants they see in botanic gardens and private collections and, of course, in gardening magazines and TV programmes.

This should be where the small specialist nursery comes into its own. As well as joining the band-wagon with the common taxa, we should be looking at ways of filling the gap in demand for more unusual plants by supplying rarer species or new introductions to cultivation. Many of these are less profitable because of heavy losses in production and longer production times so costs need to be offset against more profitable "bread and butter" lines.

Our aim should be to propagate more lines from seed, preferably from known sources, as well as looking at new possibilities from tissue culture.

PROPAGATION

Even for many of the more unusual lines, seed propagation is straightforward. Seed can be sown in a standard loamless seed compost with added vermiculite and covered with fine grit. Sowing should be made in December, or whenever seed becomes available. A natural chilling should be given, with trays placed in cold frames over winter.

As soon as germination takes place, good light is essential and pricking out into cell trays as soon as possible is necessary. Propagators may prefer to direct sow some larger seeds such as *Cremanthodium* and *Saussurea*, to reduce root disturbance in these sensitive genera.

With subjects such as cyclamen and hepatica, seeds can be space sown into cell trays but it is essential that it is sown fresh as soon as it is collected. The same is true with pulsatilla and adonis.

For many of the rarer alpines to be grown successfully it is useful to understand a little of their cultural requirements by looking at the conditions they experience in nature, before attempting to grow them in cultivation.

For example, *Dicentra peregrina* is a rare plant growing in volcanic screes in Japan. This is why it grows very well in pumice aggregates in cultivation. It flowers profusely in late spring and as the flowers are pollinated and fertilised the pink colour changes to a deeper red. At this point the flower can be carefully detached to reveal a clutch of six to 10 ripe seeds which should be sown right away.

Lewisia rediviva is another choice plant whose seeds ripen while the plant is still in flower. This is known as bitter root in its native U.S.A. However, with this plant the seed does not loose its viability and can be sown around December.

PROFITABILITY OF GROWING RARER PLANTS

I was interested to meet a Japanese alpine grower recently who seemed to be able to experience a lifestyle that did not seem to fit with the kind of income normally associated with alpine growing. He told me he earned a good income from selling a plant called *Tussilago*, which we know in the U.K. as the pernicious weed, coltsfoot. He forced them into flower for one of the Japanese festivals, sprayed them with growth retardant and apparently they sell like hot cakes.

Some Environmental Aspects of Chemical Weed Control in Nursery Stock

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INTRODUCTION

Nurserymen must achieve high standards of weed control. Herbicides have been used effectively for this purpose for decades but despite campaigning by environmentalists to eliminate their use, herbicide application is likely to continue, albeit at a reduced level. Legislation to control the amount of chemicals applied, leached, or discarded will intensify and so alternative methods of weed control, which eliminate or minimise herbicide use, are being studied. A greater understanding of the principles of chemical control and of alternative methods of weed suppression can also reduce herbicide use.

GENERAL PRINCIPLES

Most of the literature on weed control deals with specific chemicals to control certain weeds. Less attention is given to application techniques which could ensure that the correct dose for effective weed control, consistent with both crop and environmental safety, is achieved. Errors in calibration, or faulty applicators, often result in crop damage, inadequate weed control, and wastage of herbicide through overdosing or non-target application.

An understanding of the mode of action of the main types of herbicides and of the growth habits of the species grown is critical in making correct decisions about herbicide use in nurseries. For example, there should be sufficient leaf development of perennial weeds before spraying with glyphosate; substrates should have a suitable moisture content prior to the application of a soil-acting herbicide—these can often be applied effectively shortly before the crop makes a flush of growth to form a closed canopy.

Understanding the susceptibility of weed species to different herbicides enables the correct herbicide to be selected for specific weed problems. For example, Bond (1977) showed that propyzamide is over 100 times more effective against *Polygonum arenastrum* (syn. *P. aviculare*) than against *Senecio vulgaris*. Simazine is weak on polygonums, cleavers, and atriplex and usually gives poor control of speedwells. In contrast, propyzamide gives good control of these weeds but is weak on Compositae.

Selecting the right nozzle and optimum application method for each weed control operation is essential. For example, when spot treating small patches of perennial weeds in lined-out trees with a leaf-acting herbicide, a single nozzle wetting a narrow swath will enable more of the herbicide to reach the target than would wide-angle nozzles. In some situations, herbicides can be more effectively applied by means of rope wicks or sponges; with these, all the chemical applied reaches the target weeds.

Different herbicides, with their varying toxicities, carry different degrees of environmental risk. Long-term trials suggest that glyphosate has little or no environmental risk if used in accordance with the manufacturers' instructions and a case can be made for substituting glyphosate, where appropriate, for more environmentally hazardous chemicals. Like any other herbicide, however, the repeated use of glyphosate alone, in the absence of any other weed control measure, is likely to result in the build-up of resistant biotypes (Robinson, 1992).

Thermal Techniques. The development of new machinery, including flame guns and microwaves during the 1980s, increased the interest in the possibility of high temperatures at the soil surface to control weeds. Modern flame guns, using liquified petroleum gas, are being used by some local authorities on hard surfaces to suppress weeds either by direct heat or by infrared radiation.

Good results have been obtained in Denmark with "flame cultivation" on bare ground, but the selective use of high temperatures among growing plants is very difficult (Vester, 1988). The results of this work showed the importance of a level soil surface and vigorous crop growth at the time of treatment. In general, flame control is more expensive than chemical or cultural control and so its use is likely to be restricted to situations where cultivation (e.g., on hard surfaces) or herbicides cannot be used.

Biological Control. The prospects for biological control of weeds in nursery stock using insects, nematodes, and pathogens are not encouraging. Although striking successes against weeds have been achieved in a number of countries, the weeds have tended to be introduced species, such as *Opuntia* spp. controlled in Australia using the Argentinian moth, *Cactoblastis cactorum*. In this type of control the introduced agent is self-sustaining once established. Despite research programmes in many countries, developments have been slow, largely because of the risk that an introduced agent may damage desirable plants. In any case, control of one or two weed species only would be of limited value in nurseries which are normally affected by a dozen or more species.

Endemic Mycoherbicides. A mycoherbicide contains the spores of a naturally occurring pathogen, specific to a particular weed species, but which is not normally present in the environment in sufficient quantity to kill the weed. When bulked up and applied in high concentration at a vulnerable growth stage of the weed, mycoherbicides can be effective. Some mycoherbicides, e.g., Devine (*Phytophthora palmivora*) and "Collego" (*Colletotrichum gloeosporiodes* Penz. f. sp. *aeschynomenae*), have been registered in the U.S.A. (Cullen and Hassan, 1988). Work is also in progress with mycoherbicides for the control of some of the most common weeds of northwestern Europe, including *Senecio vulgaris*, *Stellaria media*, and *Chenopodium album* (Sunderland, 1990). Further research is likely to produce other fungi that could be developed as mycoherbicides but which are ineffective in nature because of poor overwintering. Although some progress along these lines is expected, there is no practical application for mycoherbicides in nurseries at present, and the possibilities for the future in this area are not bright in the short to medium term.

Mulches. Weeds can be successfully controlled by mulches of plastic film or organic material. Provided a 75-mm layer of bark mulch is properly applied, 95% weed control should be achieved over a 3-year period (Campbell-Lloyd, 1986). Apart from the smothering effect of mulches, chemicals in the materials used can also affect weeds. In general, however, mulches are more suitable in long-term amenity plantings than in nurseries.

Perennial weeds can emerge through deep layers of organic mulch and, if present when the mulch is applied, are likely to thrive because of the absence of competition from annuals. Opaque plastic materials give excellent control of annual weeds and are more effective than organic mulches against perennials. However, some of the more aggressive perennial species, or those with sharply pointed shoots such as couch grass (*Elymus repens*) can penetrate thin polythene (38 micron) film (Davison, 1983).

Despite the general efficacy of mulches against weeds, problems can arise with both opaque synthetic and organic mulches. If plastic mulches are torn, accidentally or to assist water penetration, weed growth through the holes will be vigorous (Rowe-Dutton, 1976). Even with undamaged plastic vigorous weed growth can occur at the gap around the stem or stake.

Although mulching is generally regarded as a good horticultural practice, undesirable side effects can also occur, so mulches must be used with care. The value of mulching, like many other horticultural practices, depends very much on local circumstances, such as soil, climate, and the type and growth stage of the plants to be mulched. Organic mulching material is bulky and costly to transport. Consequently traditional organic mulches are likely to be of more use in prestige amenity plantings than in nurseries where high costs are likely to limit their use.

Recently, discs of geotextiles, paper, fibreglass, and black polyethylene placed on top of the substrate after potting have been used for weed control in containerised stock. In a comparison with the herbicides oxyfluorfen plus pendimethalin, oxydiazon, and oryzalin plus benefin, best weed control was obtained with a combination of a geotextile disc plus preemergent herbicide (trifluralin) (Appleton and Derr, 1990). The other disc covers did not result in good weed control due, in some cases, to poor fitting in relation to pot size.

Mulches can often be used in association with soil-acting herbicides to achieve superior weed control, but in experiments at Kinsealy, using a bark mulch on *Picea excelsa*, best results were achieved when the herbicide was applied before the mulch.

SOILS

The herbicidal effect of many soil-acting compounds, such as simazine, is influenced by the physical characteristics of the growing medium, especially clay and organic matter content. A good knowledge of the soil or container substrate and its adsorptive capacity helps the judicious use of herbicides and the selection of the optimum herbicide dose for a specific weed population.

CONCLUSIONS

It is clear from experiments at Kinsealy and elsewhere that the solution to the weed problem does not lie in any one method of control. Reliance on the repeated use of one herbicide only will result in time in the build-up of resistant biotypes. Organic mulches are generally too expensive for use in nurseries. Here, the future of weed control lies in an integrated management approach where physical and other methods can be used, with the judicious application of chemicals, to reduce herbicide use.

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Water Recycling Trials in Hardy Nursery Stock Production

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Concern over potential ground water pollution and the cost of water in hardy ornamental nursery stock (HONS) production have initiated trials which started in 1992. The 1994 experiment consisted of three systems where water was recycled and compared with a standard Efford capillary bed (control bed). The objectives of the trial were to measure water usage, to monitor for pest and disease, to monitor nitrate levels in leachate, to assess plant growth and quality, and to assess rooting through (growth of roots out of the bottom of the container).

The four beds constructed were the standard Efford capillary bed, a capillary bed with water recycled, an overhead-watered bed with recycled water, and a flood bed (ebb and flow system) with recycled water.

***Pyracantha rogersiana* and *P.* 'Orange Glow' were the two trial plants potted in 3-litre pots into compost containing controlled-release fertiliser.**

The recycling-capillary bed showed a significant water saving. There was no significant build-up of pests and diseases in any treatment. Although nitrate levels increased during the season, some of the rise was due to a rise in the levels in the mains water used and at no time did the levels reach phytotoxic concentrations. There was no significant difference in plant growth and appearance between the four treatments and this suggests that the use of recycled water does not adversely affect the plants while offering potential savings in water and fertiliser costs. It is recognised that commercial nurseries will treat the water to avoid the risk of disease.

INTRODUCTION

Over the past few years there has been considerable concern about water pollution. The agricultural industry cannot be held solely responsible for the levels of fertilisers and pesticides which may be found in ground water supplies. However, several member countries of the European Union have enforced legislation in recent years in order to reduce the quantity of pollutants released by the horticultural industry. These countries include Germany and Holland, and in the latter, legislation is built into the Dutch Horticulture Structural Bill (Vale, 1993). It is quite possible that enforcement of legislation which is designed to reduce nitrate release into ground water will occur in the United Kingdom before the year 2000 and it was with this in mind that water recycling trial work was started at Writtle College in 1992. A secondary objective in recycling is to conserve water supplies and thus reduce the cost of water for use in the production of hardy nursery stock. A trial aimed at assessing the effects of recirculating overhead-applied water was conducted in 1992, and a follow-up trial based upon recirculated flood bed irrigation was conducted in 1993. Results from these trials appeared promising showing no significant difference in plant growth, no pest or disease build-up, and additional savings in water used.

Details of these trials are not within the scope of this report but are available upon application to Writtle College. The 1994 trials are described in the following report.

MATERIALS AND METHODS

The 1994 trials had the following objectives:

1) To measure water usage in three systems where water is recycled compared with a standard capillary bed.

2) To monitor for pest and disease build-up.

3) To monitor nitrate levels within the leachate.

4) To assess plant growth and quality between the systems.

5) To compare rooting through (i.e., growth of roots out of the bottom of the container) between the systems.

Four trial beds were arranged as shown in Fig. 1. Each bed was 4 m × 5 m × 0.15 m deep and had an independently metered water supply.

The standard Efford capillary bed, the control bed, was constructed on a level site using 60-mm plastic field drainage pipe over 125 µm (500 gauge) black polythene sheeting. The pipes were covered with Agrifleece (spun polyester) in order to prevent the entry of sand and the bed was filled to a depth of 75 mm and levelled. In this bed both irrigation and drainage were achieved through the same pipe with the excess drainage water running to waste. This is illustrated in Fig. 2.

The capillary bed with water recycled used the same layout as the control plot, but provision was made for the storage of spring and summer rainwater which could then be recycled for irrigation (Fig. 3).

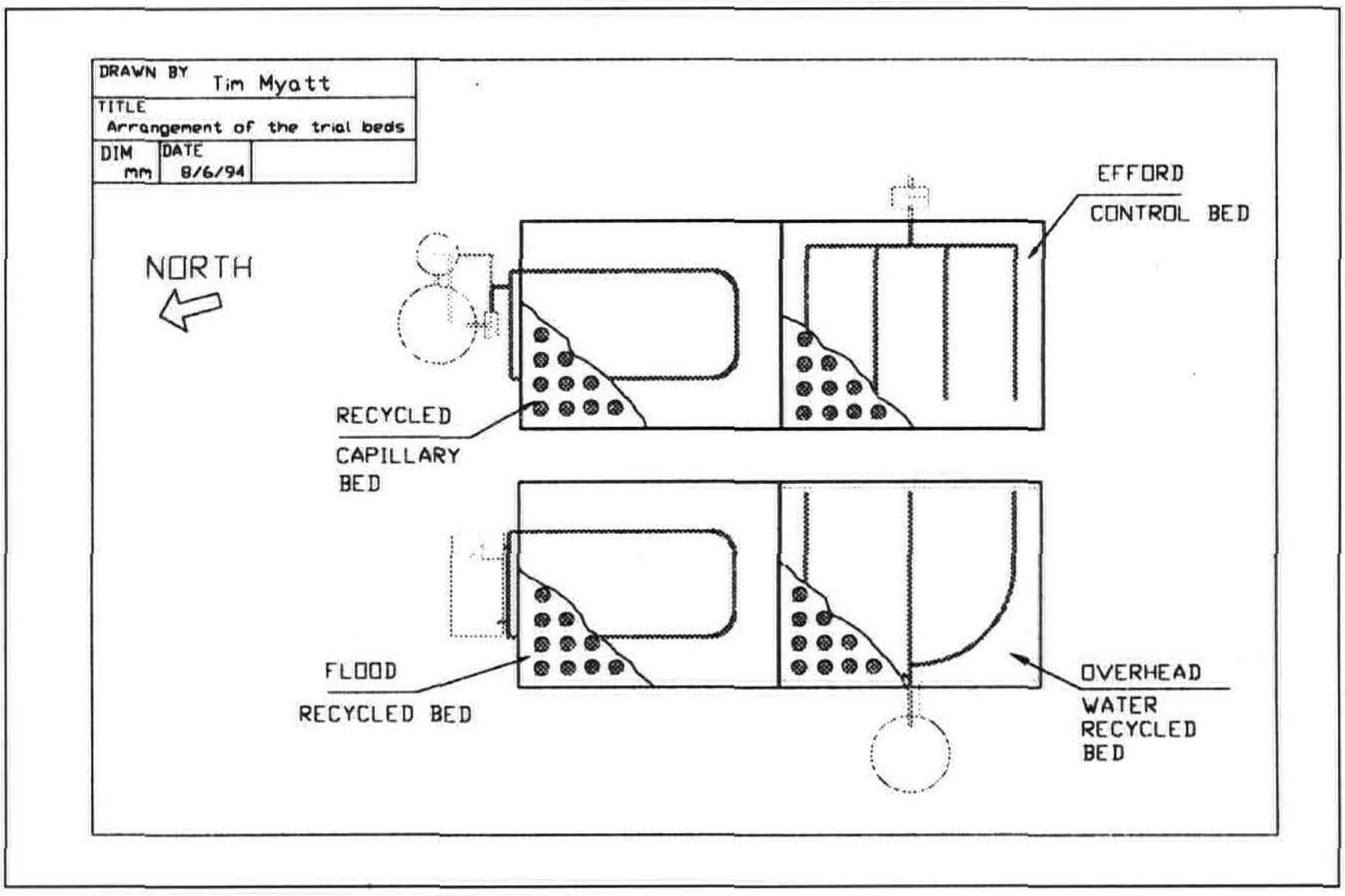

Figure 1. Arrangement of the trial beds.

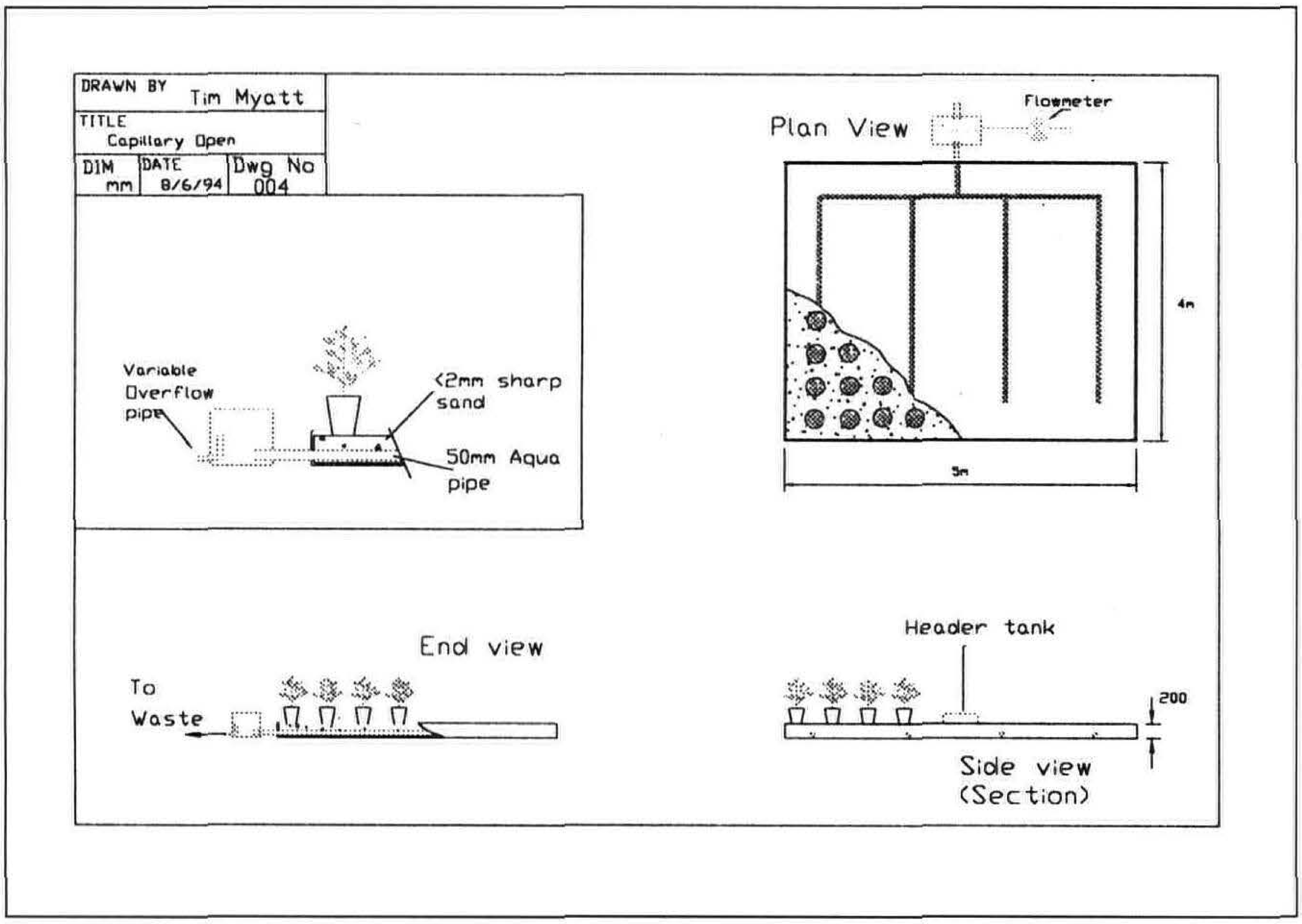

Figure 2. Details of the Efford bed (control plot).

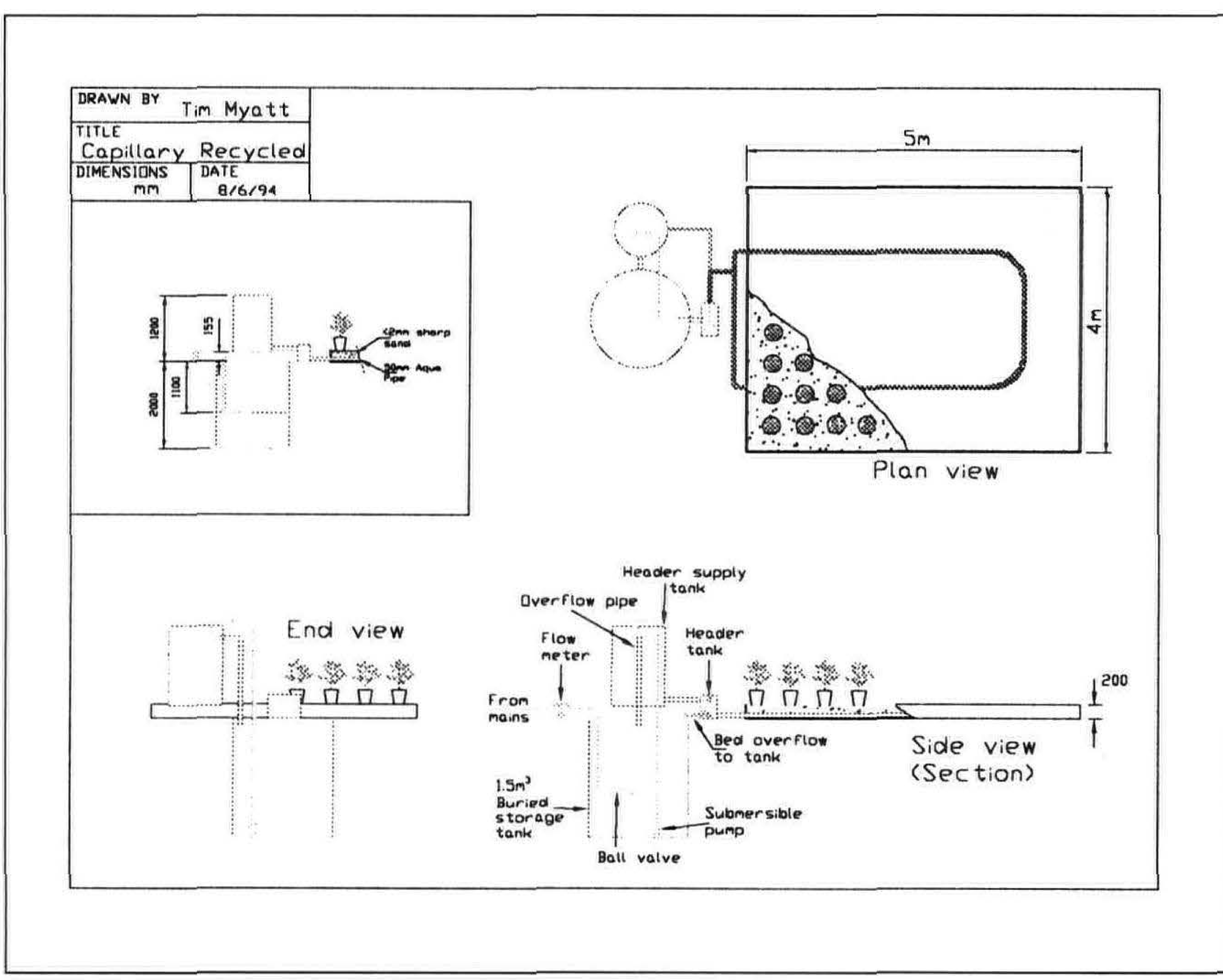

Figure 3. Details of the capillary bed with water recycled.

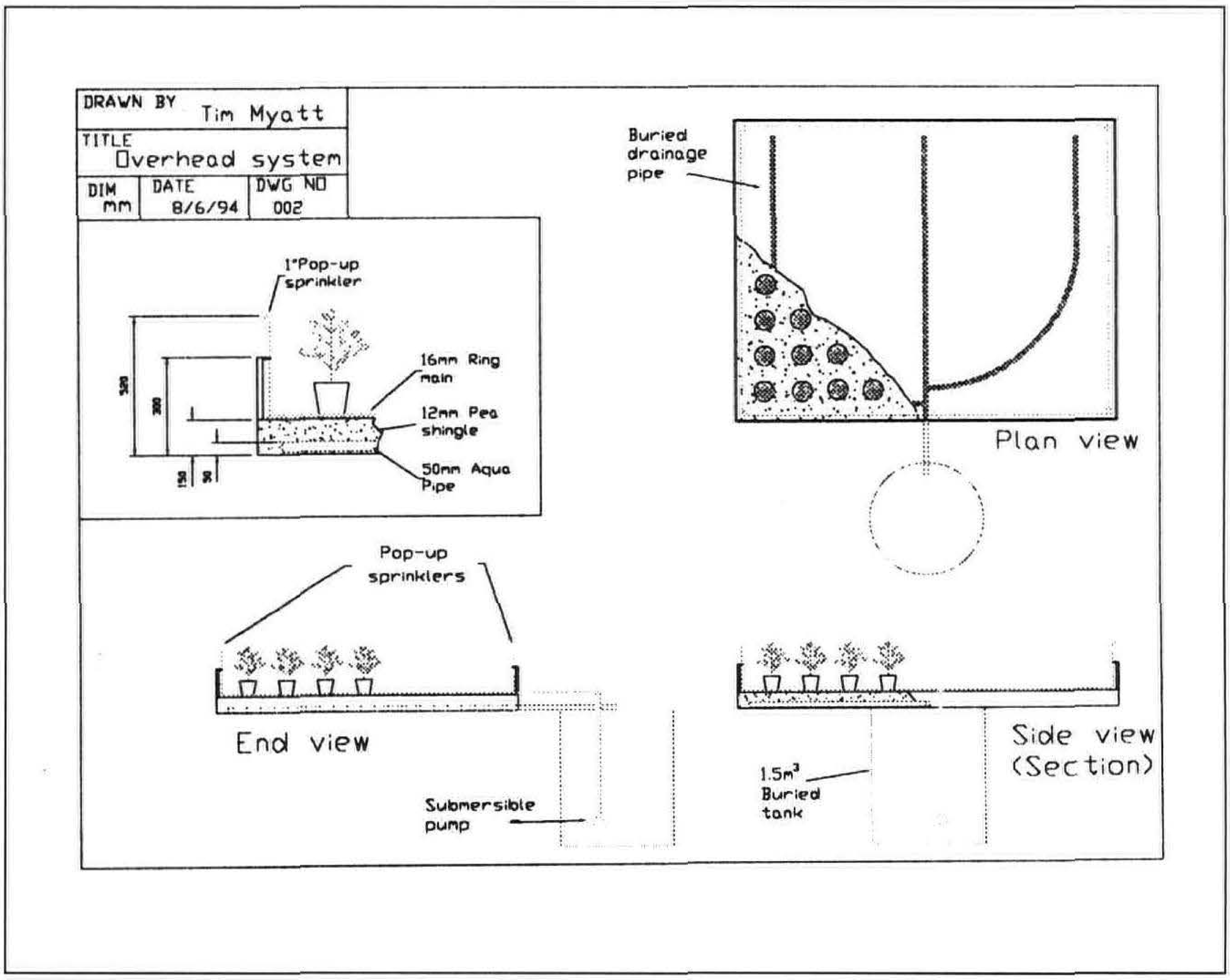

Figure 4. Details of the overhead recycled bed.

The overhead-watered bed with recycled water also had drainage pipes installed, as described for the other beds in the trial, but the substrate was gravel rather than sand. Spring and summer rain and irrigation water were channelled back to a reservoir tank to be recycled through the overhead sprinklers. This is illustrated in Fig. 4.

The flooded bed (ebb and flow system) with recycled water was constructed in the same way as the overhead water bed with recycled water system. In this case rainwater was collected and held in a reservoir tank and was applied to the base of the plant pots by flooding the bed to a depth of 12 mm above the surface of the gravel for 1 h daily. This is illustrated in Fig. 5.

In all of the recycling systems provision was made to supplement the water level in the storage tanks from the mains supply via a flow meter.

Pyracantha rogersiana and *P.* 'Orange Glow' were used throughout the study. These were potted in 3-litre pots in a medium mixed from: 9 peat : 2 bark : 1 grit (by volume). Three kilograms of Osmocote 12 - 14 month with 0.5 kg Micromax and 1.2 kg Dolodust per cubic metre were added to the compost. Final potting and standing down was completed on 31 March 1994. Ronstar 2G (oxadiazon) herbicide granules were applied at 20 g m^{-2} after standing down. Water usage and rainfall data were recorded daily and nitrate analysis was carried out weekly, as was testing for the presence of *Phytophthora* and *Pythium.* Gloquat (trimethylammonium chloride) was applied at the rate of 20 ml $litre^{-1}$ to the Efford capillary bed and the water recycled capillary bed on 30 March 1994.

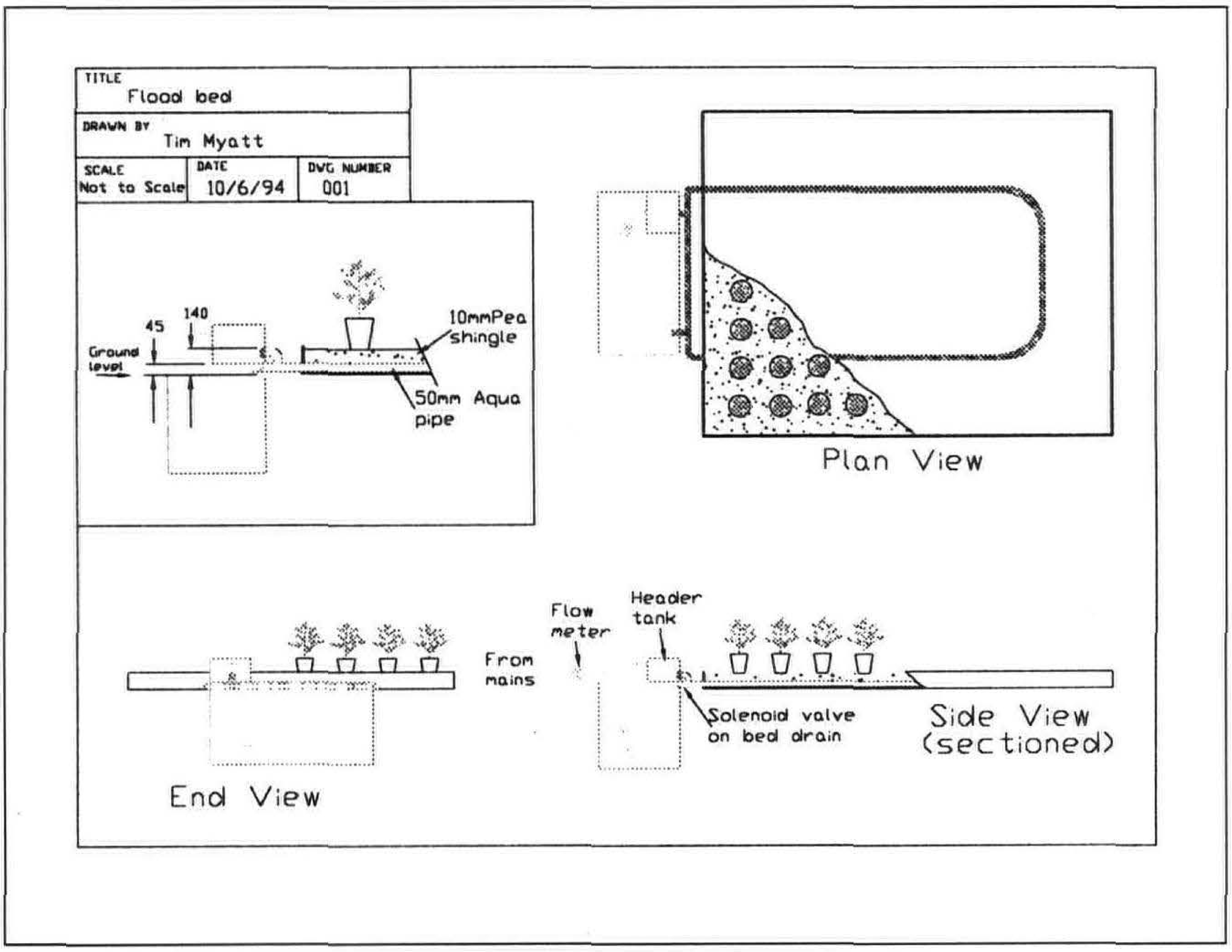

Figure 5. Details of the flood bed (ebb and flow system) with recycled water.

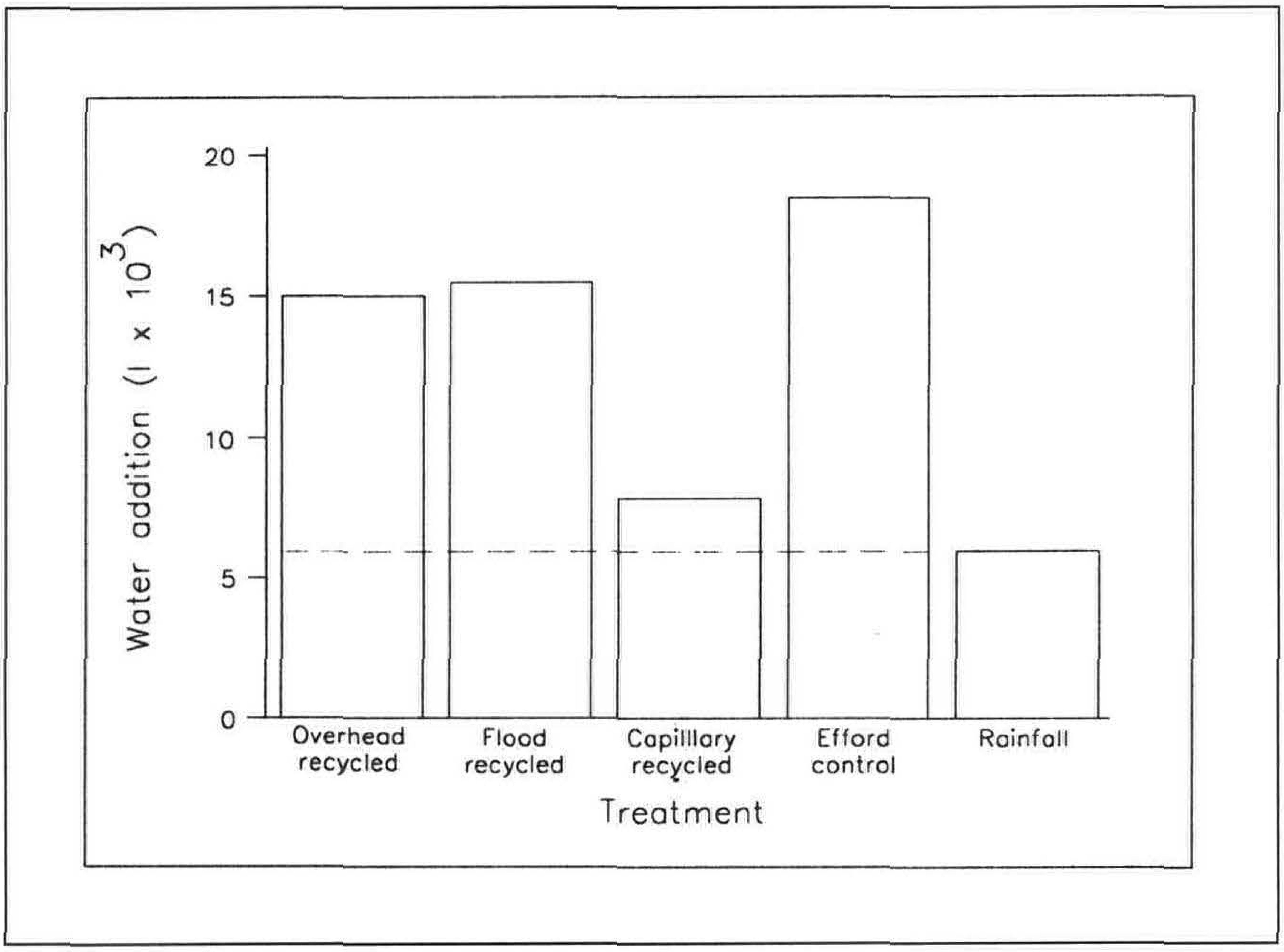

Figure 6. Cumulative water added to the plots during 1994 (1×10^3).

RESULTS

Table 1 shows the comparative performance of the four treatments in terms of fresh weight of plant, plant colour, rooting through, and pot cleanliness. The values represent the means from the trial data. The classifications for the last three parameters are:

- Plant colour, assessed from "0"— having a pale leaf colour unacceptable to the trade, to "5"— being above market standard for both colour and gloss.
- Rooting through, assessed from "0"— no rooting through, to "5"— severe rooting through with a majority of roots in excess of 200 mm long.
- Pot cleanliness, assessed from "0"— exterior of the pot free from potting media or substrate, to "5"— material adhering to the pot around full circumference.

Table 1. Table of the means of the results from the four test beds.

Pyracantha 'Orange Glow'

	Overhead recycled	Flooded recycled	Capillary recycled	Efford capillary
Weight (g)	58.78	61.78	57.3	73.42
Colour (0-5)	3.5	3.17	3	3.83
Rooting through (0-5)	0.83	1.33	2.5	1.5
Pot cleanliness	Clean	Clean	Very dirty	Dirty

Pyracantha rogersiana

	Overhead recycled	Flooded recycled	Capillary recycled	Efford capillary
Weight (g)	74.25	85.27	73.42	95.61
Colour (0-5)	4.17	4	3.83	4.17
Rooting through (0-5)	1.5	1.17	1.5	1.67
Pot cleanliness	Clean	Clean	Very dirty	Dirty

Figure 6 shows the quantity of metered mains water required by the different treatments. These quantities are shown in addition to rainfall collected by recycling, which was approximately 6 m^3. The control bed did not collect the rainfall which was allowed to run to waste.

Figure 7 shows the change in N levels for the four treatments (ppm) as monitored on a weekly basis during the irrigation season.

DISCUSSION

Effects on Plant Growth and Appearance. Analysis of the results in Table 1 show that there was no significant difference in plant growth or colour between the treatments, thus it can be safely assumed that there is no detrimental effect in using recycled water for irrigation. The degree of rooting through varied predominantly with the bed substrate material rather than the method of water application and was found to be severe in both the sand capillary beds and negligible in the gravel beds. The substrate also influenced pot cleanliness. Pots from the gravel beds could have been sold to the retail trade without the need for a pot-cleaning operation, those from the sand beds had sand from rainfall splash adhering around the lower section of the pots.

Water Usage. The mains water used by the treatments varied from 2 m^3 to 12.8 m^3 with the recycled capillary bed using the least. This variation may be accounted for in two ways. The difference between the recycled beds and the control bed reflects the amount of drainage water (from rainfall or excess irrigation) collected and re-used rather than run to waste, thus reducing the volume of mains water required to meet the plant's water demand and evaporation. The variation between treatments may, in part, be accounted for by wind drift from the overhead sprinklers and direct evaporation from the free water surface in the flood bed during its flood cycle. It is also accepted that any leakage due to imperfect sealing of the beds would be greater in the flood bed due to the greater head and mass of water in the bed, whereas in the capillary bed, water is held under tension within the substrate matrix and is slower to drain. Consideration of the total volumes of water used clearly indicates the water savings that can be made.

Water Nitrate Levels. An initially high nitrate level drops off very rapidly then slowly increases during the season (Fig. 7). The trend in nitrate levels is similar for all treatments. These high values are thought to be a result of nitrate from the initial residues in the compost being flushed out of the system, and because this was during the start-up phase of the trial, the addition of quantities of mains water to the systems reduced the nitrate concentration rapidly as the total stored volume increased. The gradual increase in nitrate during the season is thought to be a result of two combined factors. The first is the increase of nitrate levels in the incoming mains water, such a change is accepted as normal by the local water supplier. The second is the Osmocote, which is designed to give an increased release of nitrate as temperatures increase during the season, thus making more nitrate available for leaching through the potting media to gradually build up in the water. There are also some peaks in the nitrate levels (e.g., 13 May, 1 July) and as these occurred after periods of rainfall it is suggested that these peaks are a result of a thorough flushing of the potting media. The capillary bed was the system least subject to these peaks. This is thought to be due to the salts having been concentrated in the upper layers of the sand through capillary rise and evaporation thus requiring a greater amount of rain to flush them out of the bed.

Water savings can obviously be made by recycling rain/irrigation without the build-up of nitrate, pests, and disease to levels detrimental to the plants. This could

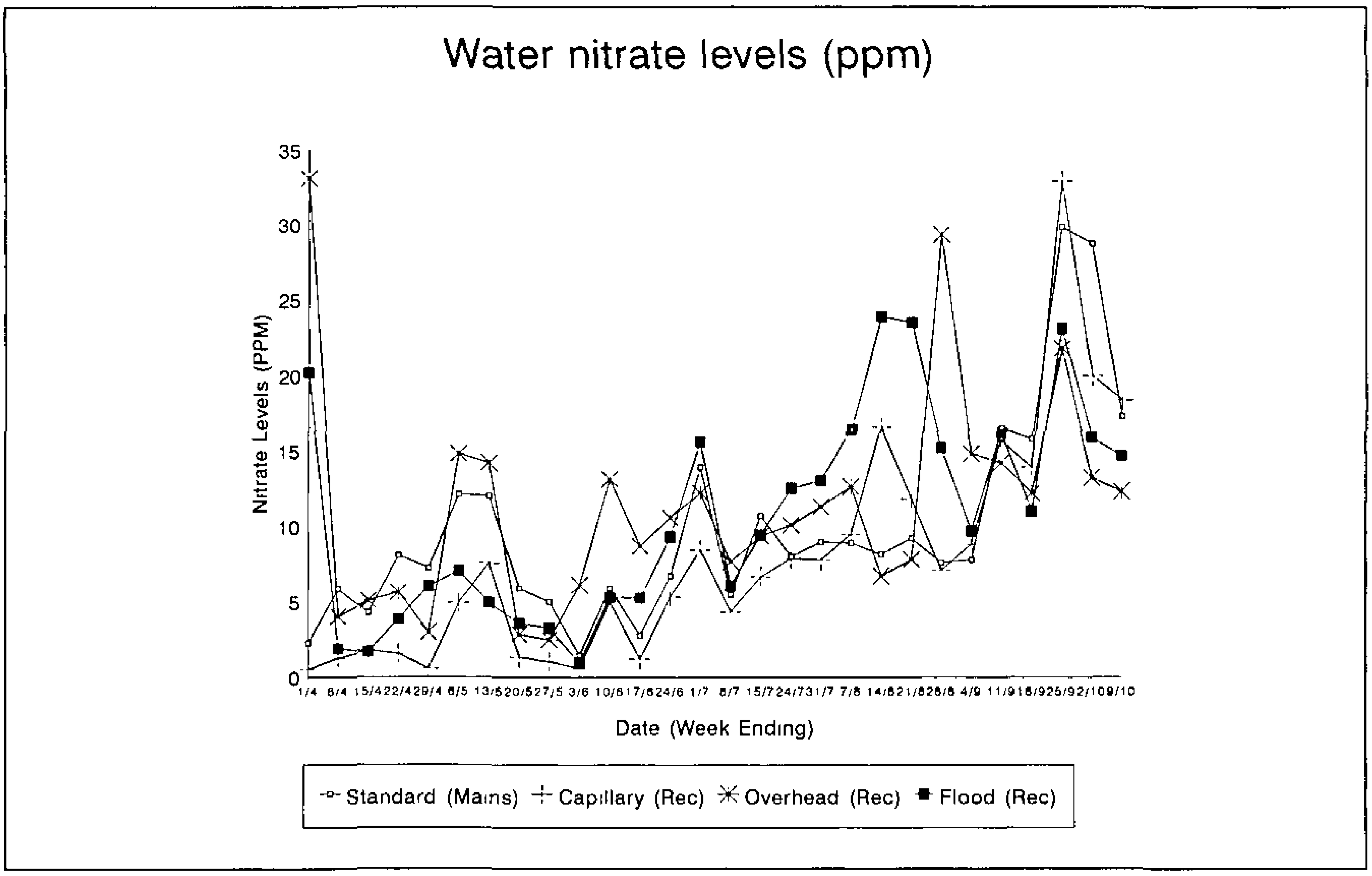

Figure 7. Water nitrate levels during 1994.

suggest that sterilisation is not always necessary. The reuse of the nitrate-laden water also offers the potential to save money through reduced nitrate losses and the costs associated with nitrate discharges to a watercourse. The work will continue at Writtle in 1995, with beds planted to an increased density and trials to attempt to limit rooting through into the sand beds. A commercial scale nursery has expressed an interest in installing a large flood bed system and this will also be monitored.

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Environmental Aspects of Fertilizing Container Plants

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INTRODUCTION

The quality of drinking water has been reducing throughout Central Europe for many years. The main source of water pollution is seen as agriculture. The widespread use of pesticides, artificial fertilizers, and very intensive meat production units are causing much damage to water resources. Tree and shrub nurseries represent only a fraction of the land used agriculturally. However, because of the intensive production methods and the large concentration of nurseries in a few areas they are coming under more and more pressure to adopt environmentally acceptable production methods. Lower Saxony has become the first state in Germany to require building permission for container plant production units—others will follow. Water authorities are already monitoring the run-off from some container areas. To date they have been concentrating on the nutrients nitrogen and phosphorus.

A literature review by Alt (1990) showed that the yearly uptake of nitrogen by plants growing in the open ground is relatively small. The range for one-year-old seedlings, for example, ranged from 39 kg for *Acer campestre* (650 thousand plants per ha) to 116 kg for *Fagus sylvatica* (1.2 million plants per ha). Two-year-old *Picea abies* took up on average 32 kg N per year (12 million plants per ha). In his

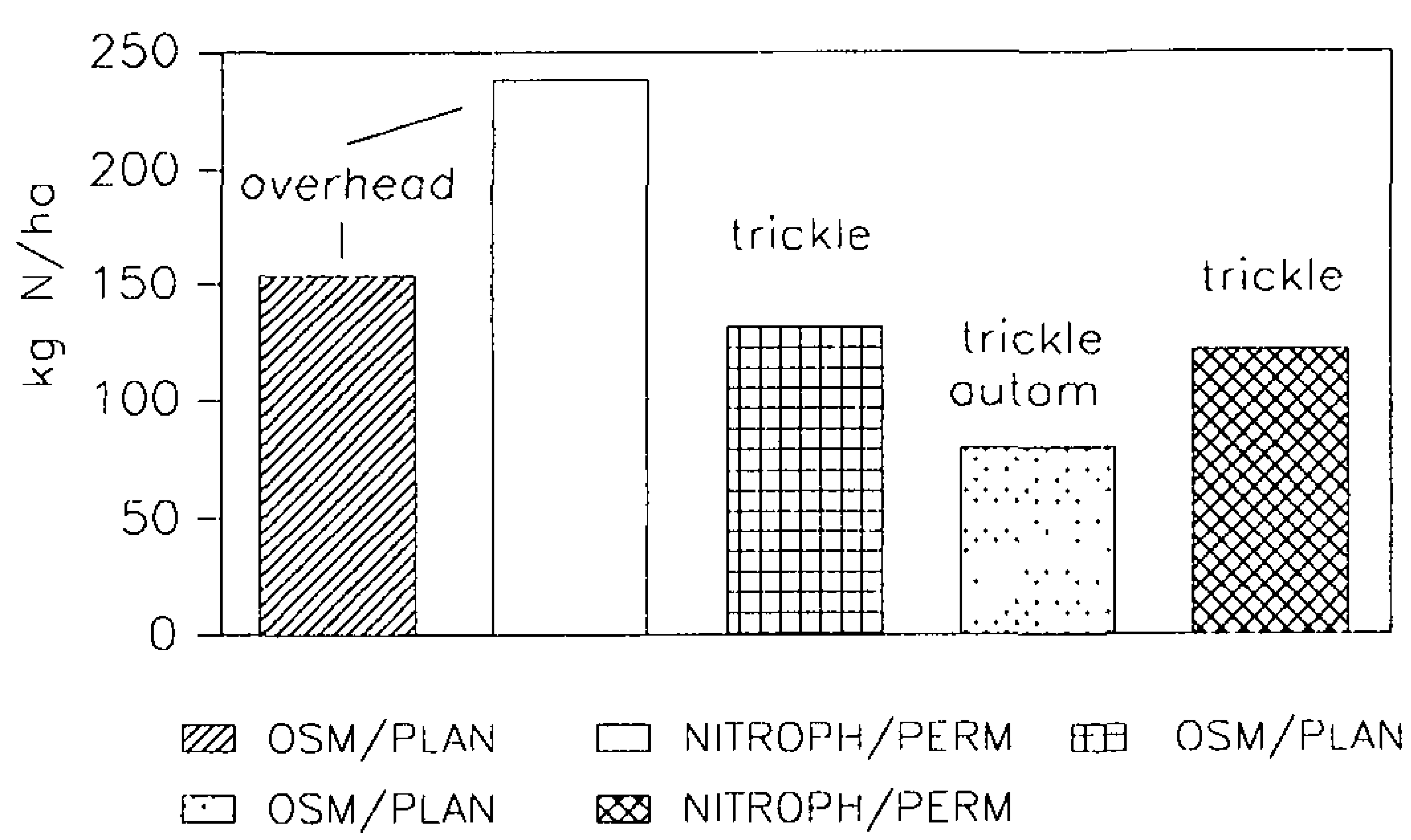

Figure 1. Influence of watering system (overhead, trickle, and trickle automatically controlled with a tensioswitch) and fertilizer type (1 = 3 g Osmocote 8-9 month and 1 g Plantosan, 2 = 2.25 g Nitrophoska Permanent (ca. 1/3 condensed urea) in base dressing and 2.25 g Nitrophoska Permanent as a top dressing, 3 = 1, 4 = 1, and 5 = 2) in container plant production.

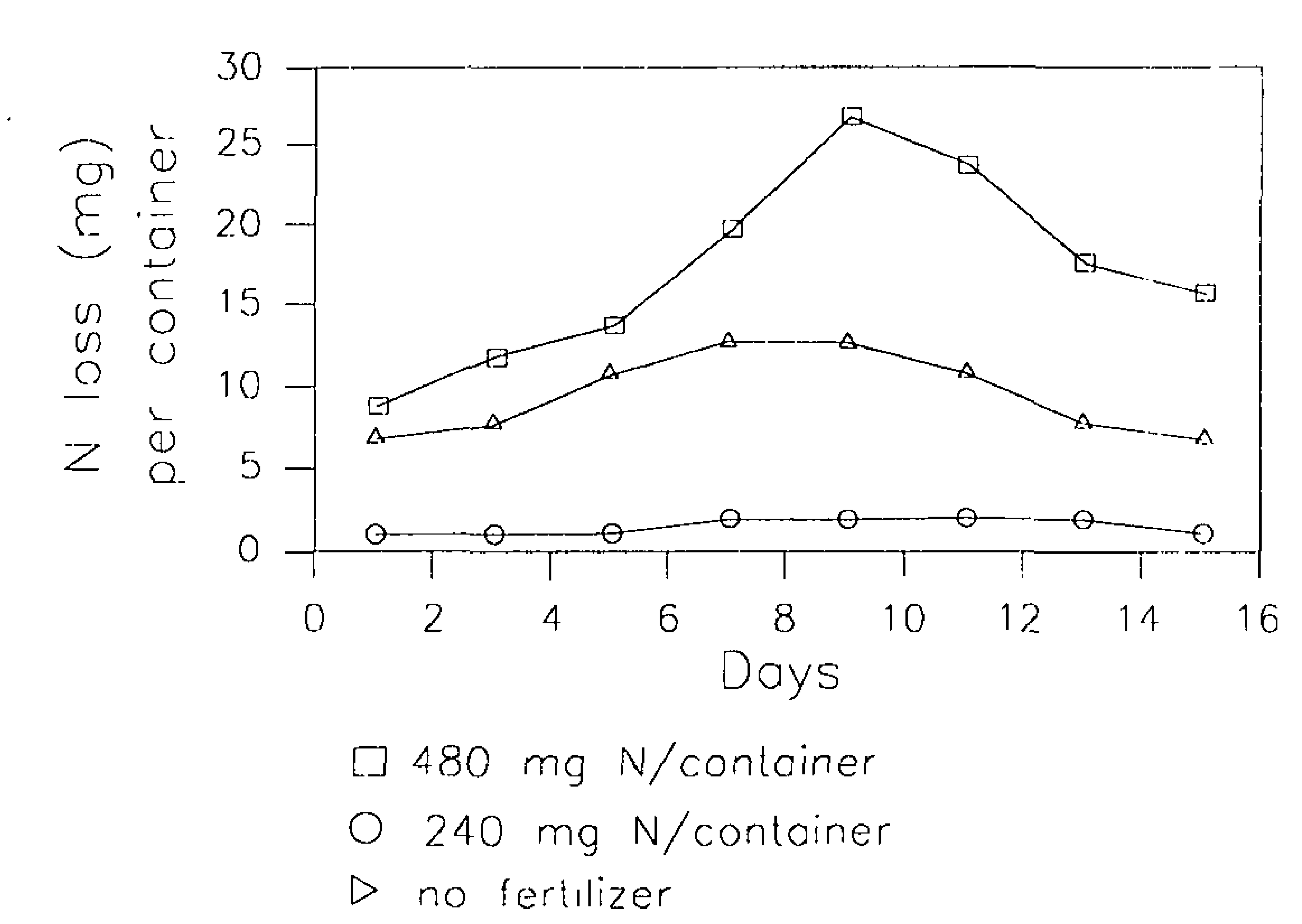

Figure 2. Nitrogen losses in mg/container from container-grown plants during a 15-day period after potting. The growing medium contained 240 or 480 mg in each container. Each day the equivalent of 9 mm rain was applied.

investigations he showed that for a very wide range of plants of different ages the uptake of N seldom reached 100 kg per year. In 80 % of the investigated cases the value was under 75 kg per year. Most plants cultivated in containers are fertilized with slow-release fertilizers. The quantity of nitrogen (N) given is often around 400 kg N per ha or more. Investigations in Germany have shown that using overhead irrigation, up to 150 kg N per ha is lost from the container growing area. Only 70 kg N per ha was lost using tensioswitch-controlled trickle irrigation (Fig. 1). Some N is also lost through denitrification. In this article, an attempt is made to suggest the most environmentally acceptable methods of fertilizing container plants by describing the different types of fertilizers and their uses in central European nurseries.

SALT FERTILIZERS

These are the common fertilizers used in agriculture, such as ammonium nitrate, potassium sulphate, and so on. Nearly all proprietary growing media contain 1 or 2 g of these fertilizers per litre. They are considered to be necessary to give the plants a quick start. They may also compensate for a wide C : N balance, as can be the case with media of high bark content. Many nurseries add them to growing media they make up themselves. However, they are easily leached. Figure 2 shows that nitrogen loss peaks after about 9 days given a daily rainfall of only 9 mm. An 18-mm average daily rainfall (a heavy thunder shower) leads to a peak N loss after 5 days (not shown). In Fig. 3 the cumulative loss as related to the average daily water application is shown. For example, around 150 mg of the total 240 mg applied

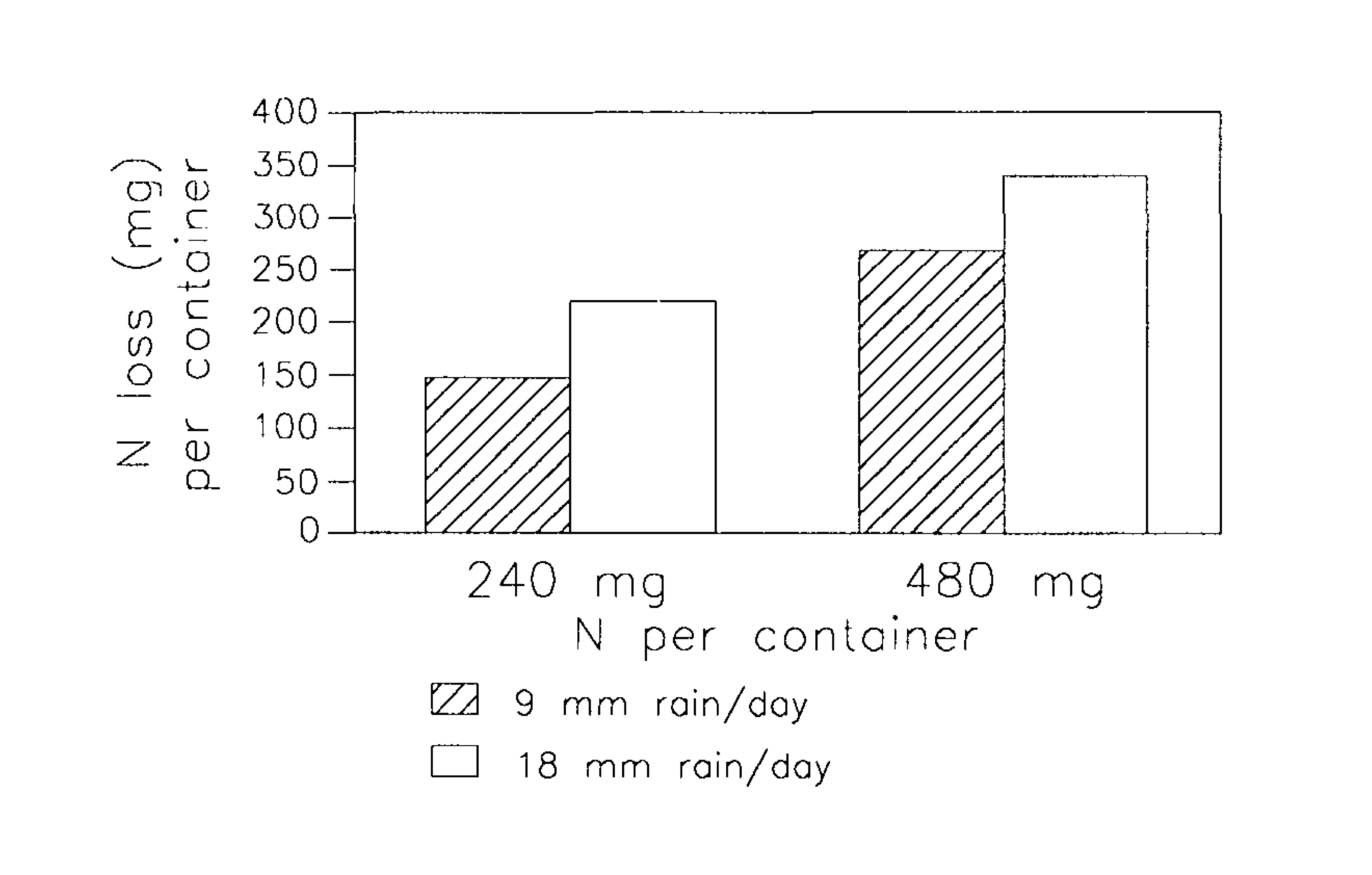

Figure 3. Total nitrogen losses over a 15-day period after potting and simulating a 9 or 18 mm rainfall per day. There was either 240 or 480 N mg per day.

nitrogen is lost within 15 days after a daily shower of 9 mm and 220 mg after a daily shower of 18 mm (Piringer, 1993). Therefore, these fertilizers should not be used, especially in early potting, if the water from the growing area can run into surface or ground water. Furthermore, the plants do not tend to make a lot of roots if there is a large quantity of N in the medium. It is probably better to have a substrate with a low level of nutrition for the first few weeks after potting to obtain faster root growth. A liquid feed for liners a few weeks before potting could be helpful to get root growth started in spring.

A few nurseries broadcast salt fertilizer as a top dressing. This method must be rejected in the future because only a small percentage of the nutrient is actually taken up by the plants, the rest is washed out of the growing medium or falls between the containers.

Salt Fertilizers for Drench and Foliar Feeding. These salt fertilizers are mixed with water. Examples used in central Europe are Alkrisal, Flory, and Hakophos. Plants react very quickly to their application. Foliar application can still be recommended for a quick improvement of the leaf colour but overhead application through the watering system cannot because of large nutrient losses. On the other hand use in trickle irrigation systems can be considered because it is possible to react to the growth pattern of the plant, thereby optimizing the nutrient uptake. During periods of rainy weather, however, the concentration of the nutrient solution must be increased and some losses occur.

Liquid Fertilizers and Suspensions. Examples of liquid fertilizers used in central Europe are Wuxal, Kamasol, and Basfoliar. They are generally used to treat deficiency symptoms, especially of trace elements. They are also used to give the leaves of evergreen plants a good colour. The amounts used are generally so low that any losses are negligible. They are also very suitable for trickle irrigation systems.

Non-Coated Slow-Release Fertilizers. Nitrophoska Permanent, Plantosan, Triabon, and Manadur are examples of this type of fertilizer. One part is quick acting (equivalent to salt fertilizers), and up to 70% of the total nutrient content can be in this category, and the rest is slowly released through microbiological breakdown. They are effective for 2 to 3 months. A standard mixture in Germany is 3 to 5 g of coated fertilizer and 1 to 2 g of non-coated slow-release fertiliser for a "start effect" at the time of potting. This is certainly better than using salt fertilizers for this effect. However, it is better to use these fertilizers for top dressing: they are very effective in this use and nutrient losses should not be high if the irrigation system is good. If these fertilizers are chosen as part of the base dressing then it is important to use a type with a high content of the slow-release material.

Coated Slow-Release Fertilizers. The best known representatives of this group are Plantacote, Osmocote, and Nutricote (Ficote). In general, reports on nutrient loss are low. The rate of loss is, however, dependent on temperature and watering system. Mac Carthaig et al. (1992) showed that the rate of nitrogen loss could be reduced from around 150 kg N per ha by overhead irrigation to around 70 kg N per ha by a tensioswitch-controlled trickle irrigation system. Rathier and Frink (1989) found that some 14% of the applied N was found in the plants, between 20% and 42% was found in the run-off water and often more than 50% simply could not be accounted for.

THE FUTURE FOR FERTILIZING METHODS IN CONTAINER NURSERIES

It is difficult to say how future legislation will change the way container plants are grown. At present in Germany (1994) many nurseries are changing to capillary watering systems because nutrient losses are low. The most common system is capillary matting, and application is controlled by tensioswitch. A number of nurseries are developing closed systems in which the water is collected and recycled. It is very likely that these systems will eventually be enforced by law. According to Behrens (1990) a water storage capacity of 1,000 to 3,000 m^3 ha^{-1} is necessary. Recycled water does not have a high salt concentration and disease problems have not so far been a problem. In the case of trickle irrigation it should be possible to reduce nutrient loss significantly by using a nutrient solution. Growers can increase fertilization when growth is strong or when buds are developing for the coming year in plants with predetermined growth such as *Euonymus alatus* or *Aesculus hippocastanum*. There is little experience of using liquid feeding on hardy nursery stock in Germany. The research centre in Boskoop, Netherlands, has made recommendations (Anon., 1992).

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A Manufacturer's View of the Problems and Opportunities for the Crop Protection Industry Caused by the Green Movement

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Crop protection is a major target of environmental campaigners resulting in many new regulations and controls. This has resulted in the withdrawal of many products and recommendations which has a particularly large effect on horticulture. Development of biological control methods has accelerated as a result, together with new products, new pesticide formulations, and new application technology. The U.K. horticultural industry must work hard to maintain "off label" approvals within the new European registration scheme.

INTRODUCTION

"The Green Movement" covers many areas and aspects of daily life and it has many ramifications, not least upon the crop protection industry. A simple definition of the movement is suggested as: "individuals and organisations who seek to improve the environment and the quality of life." Methods of achieving this include: conservation; the reduction of consumption by the use of recycling and renewable resources; and the reduction of pollution.

Crop protection products, herbicides, insecticides, fungicides, plant growth regulators, etc., have been accused of causing pollution since the publication of *Silent Spring* by Rachel Carson more than 30 years ago. While often exaggerated, distorted, or untrue, the concept that crop protection products cause pollution has and is having very direct effects on farmers and growers including growers of ornamentals and nursery stock. In the U.K., for example, the banning of the insecticide aldrin has led to problems controlling vine weevil. A future threat to growers will, if introduced, be the requirement to avoid polluting waterways by recycling water within the nursery.

THE SCALE OF ENVIRONMENTAL INTEREST

Membership of the Royal Society for the Protection of Birds, one of the most popular environmental organisations in the U.K., grew by 288% between 1973 and 1987 (Aitkin, 1988). Similar organisations have experienced similar growth. With this growth has come demands for controls on industry, agriculture, and crop protection.

MORI (Market Opinion Research Institute) surveys (British Agrochemicals Association, 1994) show that between 1985 and 1994 the proportion of the U.K. population expressing concern about the environment grew from 54% to 70%. This level is fairly even between males and females and between age groups and social classes.

Environmental issues that cause concern have changed, however. Between 1990 and 1994 concern over exhaust fumes rose from 11% to 21% of the population to make it the issue of most concern. Other issues of growing concern include pollution of waterways, loss of countryside, and industrial pollution. Concern over crop spraying/pesticides declined over the same period, from 10% in 1990 to 6% in 1994, suggesting perhaps that the vigorous campaign of public education mounted by the BAA in recent years is having an effect.

The sheer scale of the green movement through the vast number of organisations involved and with the majority of the population concerned about environmental issues and thus sympathetic to all but the most extreme organisations, has resulted in tremendous influence being wielded. Government, the European Union, educationalists, the media, supermarket chains, and industry have all been and continue to be influenced by the green movement.

EFFECTS OF THE GREEN MOVEMENT ON THE CROP PROTECTION INDUSTRY

Campaign groups have raised awareness of pesticides during the past two decades. Much of this has been through scare stories which the media have responded to and while hard scientific data has often been missing at the time or has subsequently exonerated the product concerned, images of "danger", "pollution", "residues", etc., have become associated with crop protection products. The effects caused by this raised awareness are:

- Legislation and controls imposed by the U.K. government.
- Directives and controls imposed by the EU.
- Supermarkets and other organisations involved in the processing, packaging, and distribution of crops, particularly fresh produce, now monitoring and direct producers.

The greatest effect of the green movement is in lobbying for legislation to control the research and development, manufacture, sale, distribution, storage, use, and disposal of crop protection products. Thirty acts and sets of regulations now control the crop protection industry of which 17 have been introduced during the last 10 years (British Agrochemicals Association, 1994). Whilst some of this legislation also covers other industries, e.g., The Environmental Protection Act, 1990, others are specific to the crop protection industry, e.g., Control of Pesticides Regulations, 1986.

Many of the regulations are complex and there are constant amendments and updates, thus product labels and instructions have to be frequently updated and reprinted. The continuing changes have necessitated an average of six label reprints for each Hortichem product during the past 10 years.

Similarly, there have been requirements for packaging to be changed and modified resulting in much wastage. From 1995 all packaging of crop protection products sold in the U.K. will have to comply to United Nations standards.

The green movement has also been very effective in influencing the European Union and thus there are many directives which affect crop protection products. Many of the directives parallel U.K. legislation so there is now an ongoing process of harmonising U.K. legislation with that of other member states. Inevitably, this adds to the complexity and costs of interpreting and implementing the legislation.

Some of the European directives are extreme and arguably impossible to implement. For example, the European Drinking Water Directive limits pesticide residues to 0.01 ppb. For many substances there are no methods of detecting such low levels and many members states do not possess the facilities or qualified people necessary to run such tests. Even so, farmers and growers will have to install water recirculation systems to avoid the risk of contaminated water entering waterways.

The supermarket chains have embraced those aspects of the green movement which enhance their public image. To quote a leaflet on pesticides recently issued by Sainsburys: "Along with farming organisations, Sainsburys is encouraging its suppliers to go further down the green road." Many of the leading British supermarket chains have formed a partnership with the National Farmers Union and with inputs from other bodies, e.g., The Ministry of Agriculture, have issued protocols for individual fruit and vegetables crops for growers to adhere to. These emphasise "reducing whenever possible" the use of chemical pesticides. Undoubtedly protocols for cut flowers, pot plants, etc., will be issued in due course.

Supermarkets also monitor produce for residues using the Pesticides (Maximum Residue Levels in Food) Regulations 1988 as standard. This is now being replaced the EU Maximum Residues in Foodstuffs Directive.

THE CONTROL OF PESTICIDE REGULATIONS

An examination of all of the legislation that affects the U.K. crop protection industry is outside the scope of this paper but the Control of Pesticides Regulations 1986 (COPR) which implemented part (iii) of the Food and Environment Protection Act 1985 does warrant comment since the regulations have had such profound effects.

Prior to 1986, registration and approval of crop protection products in the U.K. was controlled by two voluntary schemes which were relatively simple and inexpensive. The requirements of COPR have greatly increased the amount of toxicology data and other data required for registration which is extremely expensive to generate. It is also necessary to submit data on the efficacy of a product submitted for registration. The effects of COPR are summarised in Table 1.

Table 1. Effects of COPR 1986.

Action	Results
Withdrawal of clearance of certain old products	Loss of products
Review of clearance of older products	Loss of products Loss of horticultural recommendations for retained products
Extra data requirements to maintain existing products	Loss of horticultural recommendations
Extensive and expensive data requirements to register new products	Few new products for horticulture

As can be seen, the registrations of certain old crop protection products have been withdrawn which has meant sales of these products has been discontinued. Often, these withdrawals, e.g., DDT or mercury-based products, were at the instigation of the EU.

The Ministry of Agriculture's Pesticides Safety Directorate (PSD) which implements COPR has a programme to review the registrations of all retained old products. If there are deficiencies in the data, e.g., efficacy trials, the product will be refused registration unless the manufacturer is prepared to generate new data. The effects of this are the continuing loss of older small volume products and the loss of minor uses e.g., horticultural recommendations of those products which are re-registered. Similarly, maintaining registrations of younger products or adding new minor horticultural uses has become very expensive and thus minor uses are lost or are not even applied for. The cost of registration is now so expensive that for a completely new product it is only a commercially viable proposition for the major agricultural crops.

Commercial horticulture in the U.K. has had to accept that it is losing products and that there is an absence of replacements. This is demonstrated by an examination of weed control in U.K. horticulture (Atkins and Burn, 1991).

Table 2. Increases in UK registration costs 1989 to 1994.

Service	1989 £	1990 £	1991 £	1992 £	1993 £	1994 £	Increase (%) 89-94
Experimental permit	50	250	1000	1550	1600	1600	3,200%
Normal stream	250	750	1700	2250	2300	2300	920%
Evaluation fee[1]	7000	30,000	33,000	49,000	54,000	60,000	857%
Off label	50	250	450	450	460	460	920%
Levy on sales	0.68%	0.96%	1.63%	1.85%	1.81%	?	292% (88 to 93)
Annual rate of inflation	7.8%	9.5%	5.9%	3.7%	1.6%	2.5% (est.)	35%
Price of 5 litre pack of Childion[2]	28.13	28.13	32.01	34.15	36.90	36.90	31.2%

[1] Evaluation fee refers to evaluation of new compounds.

[2] Price of Childion is given as an example of pricing of a typical commercial horticulture product over the period. Prices are distributor list prices. During the 1987-92 period, three statutory label changes for Childion have been implemented.

Direct registration costs, i.e., the PSD fees, are very high in the U.K. since the PSD mandate is to operate a policy of complete cost recovery. Table 2 gives examples of some of the fees charged and how they have increased over the period 1987 to 1994. A comparison with registration costs in other European states is given in Table 3. The U.K. has the highest costs for any European state and together with Denmark, is the only state to impose a levy on manufacturers sales. With direct costs of registration in the U.K. about 100 times more expensive than say France, it is perhaps not surprising that very few new products or new recommendations are introduced for horticultural crops.

In recognition of the problems of COPR, the PSD introduced the Off-Label Scheme. Essentially, it allows, at the users own risk, the use of registered products

Table 3. European registration costs compared—1992 (Value in £ 1992)[1].

	GB[2]	F	D	DK	N	GR	P	CH	I	IRL
New registration	53,000	545	6180	0[3]	582	210	60	8455	455	910
Re-registration	0	545	1090	0	870	64	0	0	0	682
Annual renewal fee	0	0	0	45	0	0	365	0	0	90
Minor amendment	600	0	1090	0	290	64	18	0	455	90
Major amendment	2250	100	2270	0	0	0	0	0	455	180
Trials clearance	1550	1000	NA	0	0	2770	590	0	455	180
Other fees	0	0	2730	0	870	64	0	0	0	0
Levy %	1.85	0	0	3	0	0	0	0	0	0
Market value £m (home sales 1991)	416	1251	651	133	118	68	59	53	500	32
Total cost (£m) of Registration scheme	10.4	NA	NA	3.5	NA	NA	NA	NA	NA	6

1 Notes: (1) New registration fee for the U.K. includes a sift fee of 4000.
(2) The most recent comparison of registration fees was issued by the European Commission in July 1992.
2 GB=United Kingdom, F=France, D=Germany, DK=Denmark, N=The Netherlands, P=Portugal, CH=Switzerland, I=Italy, IRL=Ireland.
3 0 = No fee applicable, NA = No information available sources BAA/ECPA.

on non-edible crops. It also allows the use of products registered for significant crops on botanically similar minor crops. Growers and growers organisations can also apply for specific off-label approvals provided that the necessary residue and efficacy data is generated and submitted.

While the Off-Label Scheme has been a lifeline to commercial horticulture and other minor markets, there are problems:

- The fee for a specific off-label registration has risen significantly since the scheme was introduced.
- The data requirements for specific off-label submissions have increased and are expensive to generate.
- The scheme is only valid for products registered for major crops. It does not help in the registration of new products.

Hopefully the Off-Label Scheme will be retained when the U.K. registration scheme is harmonised with the pan European registration scheme. Without the Off-Label Scheme, there would be serious consequences for U.K. producers of horticultural and minor crops. The horticultural industry must not miss the *opportunity to fight for the retention or improvement of the Off-Label Scheme* while European harmonisation is taking place.

OPPORTUNITIES BROUGHT ABOUT BY THE GREEN MOVEMENT

There have been some positive effects of the green movement on the crop protection industry:

- **Registration Protection**. Because of the cost and complexity of registering a product, once obtained the product and thus the manufacturer is protected, i.e., even when the product is out of patent a competitor cannot easily introduce an identical product.
- **Biological Control**. Research and development of biological-control products has been stimulated, thus products like pheromone traps for pests have been introduced and new products based on naturally occurring bacteria, fungi, etc., which affect specific weeds or pests, are likely to be introduced shortly. So-called natural predators and parasites, i.e., insects which are harmless to crops but which attack those insects which are crop pests, have become widely used, particularly in protected crops and new businesses have been created to produce and distribute these natural predators.
- **Integrated Pest Management (IPM)**. Where naturally occurring beneficial insects are encouraged, a new lease of life has been given to some older insecticides which have a narrower spectrum of activity than some of the more modern insecticides.
- **New Formulations**. The banning of persistent insecticides like aldrin has encouraged the development of novel formulations of modern short-persistence insecticides so that the release of product is controlled and extended. SusCon Green (chlorpyrifos) for controlling vine weevil in growing media is a good example. Development of formulations which are easier and safer to handle than conventional liquids and powders has been encouraged, particularly by the legislation governing the safe handling of pesticides.
- **Application equipment**. Applicators which reduce drift and wastage of products have been developed in recent years whilst the closed fill systems, i.e., systems which allow a product to be added to a sprayer tank and sprayed without any direct contact with the product being necessary are becoming more viable.
- **New products.** Agriculture at least is still benefitting from a flow of new crop protection products. Many of these new products are characterised by being very active and thus are used at very low doses, often grams per hectare, and of being very specific in action. This trend of new products which better fit environmental requirements looks likely to continue.

CONCLUSIONS

The green movement has caused, by skillful lobbying and publicity, restriction and control of the crop protection industry through the regulations and directives that have been introduced. The accession of the Nordic states to the EU will probably add to the green pressure on Brussels. While in recent years, manufacturers, through their trade organisations, have helped to moderate the effects of the green movement and have achieved a better understanding by the general public and a less hysterical reaction to crop protection, much counter-lobbying and education will still be necessary. In the U.K., the slavish devotion by officialdom to the directives emanating from Brussels, compared to the more relaxed and sympathetic approach of officialdom in countries such as France, together with the lack of any government subsidy of the U.K. registration scheme has had a particularly serious effect on the availability of crop protection products for minor crop areas including horticulture.

It is respectfully suggested that organisations such as the I.P.P.S., which have achieved a reputation for the encouragement of horticultural technology and the dissemination of this technology, should seek more understanding and take more note of the threats to the horticultural industry and become more politically active. Failure to do so could lead to the loss of essential products on the propagation bench like IBA and NAA.

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Pests and Diseases at Garden Centres

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Research carried out for Gardening Which? found a wide range of pests and diseases on hardy nursery stock for sale in retail garden centres. Fruit trees, ornamental trees and roses were the worst affected plant types, while alpines and conifers were relatively problem free. Apple scab, downy mildew on hebes, rust on roses, bacterial canker on *Prunus*, and aphids on a wide range of stock were the most common problems. The research and ideas for improvement are detailed.

METHOD

Sixty garden centres, all selling a wide range of plants, were selected to represent the retail trade throughout the country. Each garden centre was visited anonymously in the last week of June or first week of July 1993 by one of a number of professional hardy nursery stock specialists, briefed by Gardening Which?. Plants were assessed by type, in seven groups, as shown in Table 1. Each group was rated on a 5-point scale for overall health, and separately checked and rated for aphids, spider mites and, as appropriate, the specific pests and diseases detailed in Table 2. Inspectors were also asked to comment on any other plant pests or diseases they encountered, and to note any other problems with plants on sale, such as weedy pots or dry compost.

RESULTS

General. There was considerable variation in the quality of plants on sale, both between one garden centre and another, and between different groups of plants in the same garden centre. A selection of inspectors' comments gives a flavour of the range of quality encountered:

- "Very well stocked, generally very good condition" (Norwich)
- "Overall quality and presentation to a high standard, stock levels appropriate to the season" (Somerset)
- "Shabby, lack of attention to detail, impression of a once good centre that has run down. Shrubs suffering nutrient deficiencies, poor watering, physical damage, and slugs. Plants remaining in compost far too long, and look hard and starved. Many plants on offer should not be put on sale." (Devon)
- "Bad shrub damage on deciduous and evergreen shrubs, both showing iron chlorosis, poorly managed with no quality control." (Wiltshire)
- "Promotional stock healthy and well cared for, problems with older shrubs and trees, especially fruit." (Gloucestershire)
- "Large centre with large range of plants and large range of disorders. Plant care and maintenance very variable." (West Midlands)

Table 1. Overall rating for each plant type, plus incidence of aphids and spider mite, shown as a percentage of garden centres inspected.

	Overall					Aphids		Spider mite	
	Very poor	Poor	OK	Good	Very good	Severe[1]	Some[2]	Severe	Some
Alpines	0	3	8	33	56	0	5	0	0
Climbers	0	11	30	27	33	0	17	0	24
Conifers	0	8	25	25	42	0	18	0	0
Deciduous shrubs	0	13	43	32	12	0	41	0	37
Evergreen shrubs	0	7	38	38	17	0	25	0	20
Fruit	10	23	38	17	12	0	32	3	38
Herbaceous perennials	0	8	27	42	23	0	24	0	12
Ornamental trees	5	15	37	18	25	5	34	0	20

1 Severe = one-fourth or more of plants on sale seriously affected.
2 Some = up to one-fourth of plants affected.

There was no significant difference overall between members of the Garden Centre Association and non-members, nor was there any difference in overall performance between independent garden centres and members of garden centre chains. (Do-it-yourself superstores with garden centres attached were not included in the survey.)

Table 1 shows the percentage of garden centres receiving each quality rating for each plant type. For example, 3% of garden centres inspected were rated "poor" for alpines, whereas 56% were rated "very good". Overall our inspectors found far more good plants than poor ones. However, there were clearly some problems, most notably with fruit plants, where the overall quality was judged unacceptable at one in three of the garden centres. Typical comments were "Top fruit abysmal, very neglected", "Very old, overgrown, unsaleable", and "Leaf loss and nutrient deficiency". Ornamental trees were another poor area, unacceptable at one in five garden centres. Maintenance was a particular problem, as shown by these comments: "Poorly set out, falling over", "Wind damage to trees" and "Too close together for too long, poor shape."

Deciduous shrubs are by far the largest group at most garden centres, and were at least acceptable at the majority though only a few (12%) were rated very good. Most problems were confined to a few plant types, most notably roses. Other problems are detailed in the next section. Alpines as a group suffered fewest problems and were judged good or very good at over half the garden centres visited.

Table 1 also shows the incidence of aphids and spider mites on all plant types. Many garden centres are to be congratulated for high standards in this area, over 90% of alpines, 80% of conifers, and 70% of climbers were free of these pests when checked. On the other hand, at over 30% of garden centres one or both of these pests were found on deciduous trees, shrubs, and fruit, and 5% of garden centres had severe aphid problems on their trees.

Specific Disease Problems. These are detailed in Table 2. The incidence of pests and diseases which were routinely checked for at each garden centre varied considerably. For example, bacterial canker on *Prunus* was found at a total of 55% of garden centres, and at 8% of these was judged to be severe, i.e., at least one-fourth of the plants on sale were seriously affected. On the other hand, verticillium wilt on *Acer* was rare, with only 7% of garden centres having any plants showing symptoms of infection.

The most widespread disease was scab on apple trees, found at a total of 87% of garden centres—and serious at over one-fourth of them. Other common problems were downy mildew on *Hebe*, leaf spots on evergreens, and rust on *Rosa*. In addition to the 14 pests and diseases listed in Tables 1 and 2, the inspectors noted a total of 74 other specific plant disorders. Of these, the most widespread were blackspot on roses; downy mildew, particularly on roses; eelworm, particularly on *Weigela*; powdery mildew, particularly on *Lonicera*, *Rosa* and *Spiraea*; slug and snail damage; and adult vine weevil damage, particularly on *Rhododendron*. Although not widespread, there were several instances of fire blight, mostly on *Cotoneaster*.

Other Problems. Many garden centres were found to have problems with weed infestation—particularly bittercress and liverworts—in some plant containers, or on holding areas. Generally this is an indication of poor management, and often means that plants have been in the same container for too long. Comments included: "Weed

Table 2. Occurrence of specific pests and diseases, shown as a percentage of garden centres inspected.

Pests/diseases	Severe[1]	Some[2]
Bacterial canker on ornamental *Prunus*	8	47
Clematis wilt	0	22
Downy mildew on *Hebe*	7	60
Eelworm on *Buddleja*	0	19
Leaf blemishes e.g., shothole on evergreens	0	58
Phytophthora root rot on *Chamaecyparis lawsoniana* 'Ellwoodii'	0	9
Powdery mildew on *Rhododendron*	0	31
Rust on *Hypericum calycinum*	14	14
Rust on *Rosa*	5	55
Scab on apples	27	60
Verticillium wilt on *Acer*	0	7
Adult vine weevil on *Pieris*	0	18

1 Severe = one-fourth or more of plants on sale seriously affected
2 Some = up to one-fourth of plants affected.

control very variable, with some weeds larger than the plants"; "Weeds a problem in both pots and beds, especially bitter cress, willow herb, and pearlwort"; and "Moss and liverworts widespread, compounding watering problems". Watering proved a serious problem at a few garden centres, both too much and too little, as these comments show: "Irrigation variable, both root rot and leaf scorch in evidence"; and "Very dry compost leading to leaf loss and dead branches on trees and fruit but roses and climbers standing in water." Even when not directly related to the incidence of pests and diseases, plants under stress are going to be more susceptible to these problems than those which are weed-free and correctly watered.

DISCUSSION

Under the Sale of Goods Act 1979, goods bought by consumers must, amongst other things, be "of merchantable quality", and "fit for their purpose". Clearly, plants suffering from pests and diseases are unlikely to meet these criteria, and should not, therefore, be on sale. If they are sold, purchasers are not only receiving an inferior product but, in many instances, they risk introducing troublesome pests or diseases to other plants in their gardens.

Although pests and diseases can, of course, strike at any time, it was clear from inspectors' comments in this survey that the majority of infections and infestations were associated with plants which had been on sale for too long, and that more regular checking and elimination of old stock would remove many of the problems. More time-consuming measures such as pesticide spray programmes could then be concentrated on plants that really need them.

Suggestions for Action. Good garden centres with very low incidences of pest or disease problems show what can be achieved with good management. Gardening Which? believes that attention to the following points would lead to significant improvement in the health of hardy plants on sale at garden centres and, consequently, to improved customer satisfaction:

- Inspecting all stock on arrival and rejecting substandard plants.
- Reducing stress-causing factors, such as inadequate feeding or watering, overcrowding, and weed competition.
- Ensuring plants are withdrawn from sale as soon as they are past their best.
- Training staff in appropriate treatment in advance of the problems actually occurring, so that prompt action can be taken. Treatment may consist of an appropriate pesticide spray, but pruning or other non-chemical treatment may be equally effective.
- Establishing routine examination for pests and diseases and ensuring that appropriate action is always taken.
- Buying in, and where necessary promoting, more disease-resistant plants. This could lead to a significant reduction in disease problems on, for example, roses and apples.

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Benefits of Water Recycling in Nursery Stock Production

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INTRODUCTION

The horticulture industry worldwide is under pressure to comply with new environmental standards and regulations. These vary from state to state but in most cases the issues at stake are common. The following paper reviews the approachs that different organisations are making towards tackling the problems. Observations are mainly taken from the U.S.A. and Germany where legislation has been enforced more rigourously and for longer than in the U.K..

GROUNDWATER CONTAMINATION

The majority of the U.S.A. and parts of Europe now have laws to protect the quality of groundwater, drinking water sources, and the quality of waste water that enters natural water courses. As a result, container nurseries are having to address fertiliser and water management to ensure that they fall within the law.

In the U.K. at present there is no legislation requiring runoff to be controlled. However, the pressure to introduce such legislation, and to harmonise the situation across Europe, is mounting and it would be naive of growers in the U.K. to ignore the issue.

Unlike in North America, where liquid feeding plays a predominant role in the nutrition of crops, U.K. production relies heavily on controlled-release fertilizers, which offer more control over the nitrogen content of run-off water. Pesticide contamination of water is relatively uncommon unless concentrated spillage occurs. The breakdown of pesticides prior to water contamination is attributed to the development of more environmentally friendly products and the filtration of residues by the soil.

Many North American nurseries are now recycling their run-off water, not only to reduce their potential liability but also to make their products more economical and businesses more profitable. I believe that the British industry should consider this approach for a number of reasons:

1) To prepare for future laws that will control the quality of the water that leaves nurseries.

2) To provide an independent water supply to enable close control over quantity and quality of supply.

3) To reduce the cost of water.

I believe that the last two points offer enough cost benefits for growers to start recycling water. This is particularly relevant at a time when water costs are escalating and the granting of extraction licences becomes more tightly controlled. There are too many different practical approaches to water recycling to propose one single, detailed implementation plan that would suit every nursery. However, there are a number of basic considerations a grower should address in formulating a plan.

If growers simply need to reduce the volume of water used when irrigating, either because of high cost of water supply or because of restricted availability of water, this can be achieved through attention to choice of application method and application management. However, if water is to be collected, either for recycling onto crops or for safe disposal, then a more complex system has to be developed.

IRRIGATION TECHNIQUES

The method of water application and the refinement of irrigation practice will determine the amount of water that runs off growing beds which is available for collection and recycling. Considerable savings in water run-off can be made by optimising the use of water by the crops—that is, ensuring only sufficient water is applied to satisfy the plants' needs. This approach has been called "pulsing" in North America and is used extensively as a first step towards water recycling, where it has often reduced the volume of water applied by up to 40%.

For example, water usage for a crop receiving two applications per day for 20 min might be 1000 gal of water, including some run-off, compared to only 750 gal if applied in shorter bursts three times per day, and runoff may be reduced. Timing of water application should also be considered in any assessment of water usage.

In order to capture run-off water from container beds, the system must be partially or completely closed. Capillary sand beds provide the most commercially viable closed system, although initial investment cost is high. Water savings are made through the elimination of sprinkler drift and the maintenance of a low-level reservoir in the bed at all times. Considerable advances are being made in Germany in the use of capillary mats on flat and sloping applications which should offer a cheaper alternative for some crops. However, most trials have been carried out on *Erica gracilis*, which is sold as an autumn crop, and there is concern that the majority of crops may need more effective winter drainage than matting can offer. The design of capillary beds should allow all water running off the beds to be collected in a central drain or collection point, from where it can be taken for storage and treatment.

The application of water by overhead sprinklers will almost always result in some drift and waste, therefore conservation and recycling of water must come as a result of the design of a recycling system if an overhead sprinkler system is to be used.

RUNOFF WATER COLLECTION SYSTEMS

U.K. nurseries need to consider how to collect run-off water from growing beds to ensure they fall within possible future EEC legislation. Laws in North America and Europe generally relate to the contamination of water courses such as rivers, streams, and ponds by nitrates and chemical residues—and consider the soil as an adequate natural filter for groundwater reservoirs. Therefore, growers should concentrate on how surface run-off water can be contained.

Most American nurseries have developed a twin-bed system that shares a central collection drain. Beds are laid to slope slightly towards the drain (approximately 5 degrees of slope) to ensure water does not sit on the surface, while polythene or ground-cover fabric may be used to reduce loss of water to the soil. While this layout keeps run-off water off the roadways, it reduces efficiency by preventing machinery from working across the entire width of the bed. Water from the bed drains is channeled to a collection pool. Large collection drains ideally need to be strengthened to ensure that erosion damage does not occur in heavy rains. This is the same reason why many growers do not favour the use of roads as water collection conduits.

WATER TREATMENT

Where the availability and cost of water is not an issue, growers may be satisfied with regularly checking water quality in the collection pool to ensure it is within required standards, then allowing it to flow into the local water course rather than recycling it onto the crop. In the event of any water contamination the collection pool should be able to be isolated.

The natural filtration of waste water with bog plants such as*Phragmites australis* is becoming increasingly popular in Germany where similar techniques are used for the treatment of domestic sewage and industrial waste. This also allows the collection pond to be used as a site of environmental benefit. Many German growers are now relying on the filtration of water in this way before directly reapplying the water onto the crops. There is evidence that available nitrate levels can be reduced in this way and trials are in the process to establish whether the technique offers any disease control.

Approaches to water treatment vary considerably between North America and Europe. The majority of North American nurseries that recycle and treat their water use either chlorine, ozone, or ultraviolet radiation to ensure that all potential pathogens are killed. Treatment of this type can only take place after considerable mechanical filtration to remove larger solids and will still not remove chemical residues. Herbicide build-up in recycled water was a problem for a couple of American growers I visited. They had been recycling their water for more than 10 years and charcoal filters are now used to remove them. Recycled water was rarely reapplied to crops without blending it with at least 50% fresh water and even blended water was not used in propagation or liner production. The cost of such treatment and monitoring systems is very high and only cost effective on larger nurseries.

In contrast, Dutch researchers and nurseries have been using sand filters for cleaning recycled water. Results indicate that this technique will remove both pathogens such as *Pythium* and *Phytophthora* and small solids. This system can be operated at a fraction of the cost of the more elaborate North American systems and would appear a good option for smaller nurseries or nurseries that do not suffer from pathogens in their water supply. In combination with reed-bed treatment, sand filters would appear to offer growers a cost-effective approach to water treatment.

CONCLUSIONS

Within existing laws it is unlikely that the majority of U.K. nurserymen will be considering the issue of water recycling. This is because of the high initial investment in collection systems and treatment equipment. However, there are considerable cost benefits to those growers who do recycle their run-off water, even if this is restricted initially to the collection of water from glasshouse and polytunnel roofs which should require no treatment.

With customers and the public becoming increasingly environmentally aware we can no longer expect our products to carry our environmental front. Growers must have forward-thinking environmental policies in order to compete in the future marketplace or the industry as a whole will suffer as a result of reduced public confidence and hence reduced consumption of plants.

Water Quality

Finn Knoblauch

INTRODUCTION

Good water quality is a must in container production and propagation. In Denmark, there has been, and still is, ample water resources available. However, the quality of this water can vary considerably even within a small district. Since 1970, I have advised over 200 nurseries on the use of their water resources.

ARTESIAN WATER

Artesian water is rain water that over time has percolated down to the artesian water level. It is illegal to use surface water from streams and lakes, and collected rainwater is only used to a lesser extend because of uncontrollable levels of contaminating substances. The majority of water used in nurseries is, therefore, Artesian well water.

Chemically pure water does not exist in nature since even rainwater has absorbed nitrogen, oxygen, carbon dioxide, sulphur, etc., with ions from costal regions such as chloride, sodium, and magnesium added in. Rain water on its way through the soil absorbs additional carbon dioxide from the soil. Additionally when water becomes a weak acid, it is able to solubilize calcium carbonate, sodium, manganese, etc., and these are carried along as the water moves downward through the soil.

Water Reserves. Denmark's yearly rainfall varies from 500 to 800 mm and supplies the artesian water reserves with between 1 and 4 million litre per ha. (Fig. 1). The flow of water and the possibilities for pumping artesian water are greatly influenced by the physical conditions of the soil.

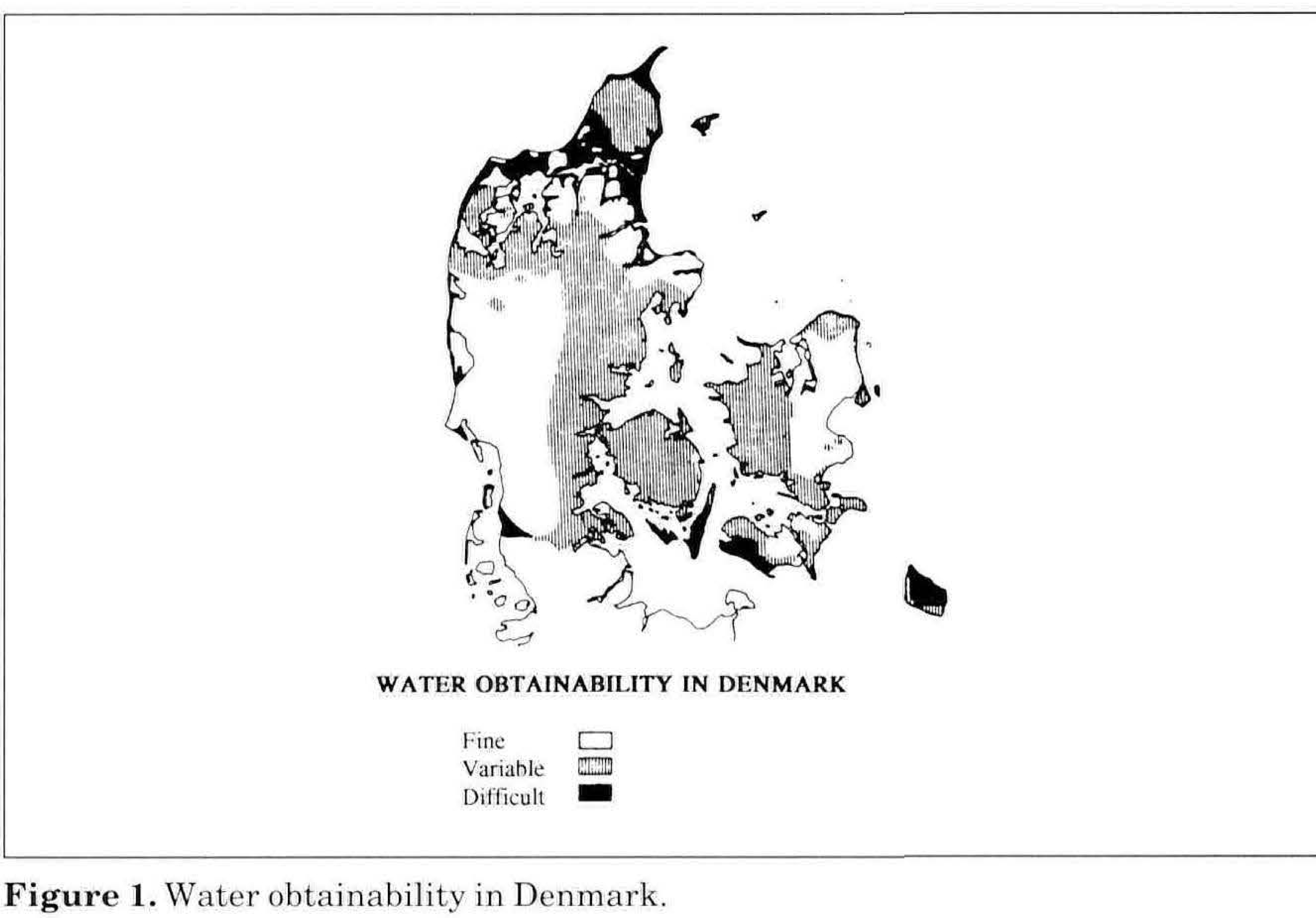

Figure 1. Water obtainability in Denmark.

Quality. Most of the ions dissolved in artesian water have a supplementary effect when liquid fertilizer is added. Calcium and magnesium, as well as micronutrients, are often present at high levels in addition to unwanted ions, such as chloride and sodium. Sodium bicarbonate functions as a buffer in the soil water, however, it can increase pH to a toxic level (Table 1, Nutrient location number 3). It is sometimes necessary to inject acid to reduce the pH. Table 1 shows examples of water quality at eight different locations in Denmark. Locations 4 and 7 have the best artesian water, whereas locations 1, 2, and 3 have a poor quality.

Water Analysis. Artesian water must be analyzed in order to optimize liquid fertilizer use. In the beginning, 25 years ago, water was analyzed by the same standards as drinking water. Today, supplementary analyses for boron, copper, zinc, and sometimes molybdenum are conducted. The composition of the added nutrient elements is determined in accordance with the water analyses, and pH is regulated by sulfuric acid, phosphoric acid, or nitric acid injection. The relationship between nitrate and ammonium nitrogen can also influence pH—nitrate increases pH, whereas ammonium causes pH to decrease during the growing period.

Water Purification. A high salt level in artesian water may cause growing disorders as well as technical problems. Ion exchange is widely used in laboratories, but is not used in nurseries. Reverse osmosis is the preferred method in nurseries. With reverse osmosis, water quality becomes equal to distilled water. Water treated by reverse osmosis is ideal for mist and fog propagation.

CONCLUSION

It is a must that water quality and mineral nutrition be optimized in an up-to-date production nursery. High quality water used in irrigation and ebb and flow systems is composed of artesian water supplemented with an optimal nutrient composition designed for the crop in production. Carbonates and pH may be controlled by acids, and the proportion between ammonia and nitrate will insure a stable pH during the growing period. When a nursery is able to control these parameters, water conservation and recycling will be a natural part of plant production.

Table 1. Comparison of artesian water quality in relation to a full nutrient solution. Levels of mineral nutrient is given as mg per litre (=ppm), pH, hydrogen carbonate, and chloride. ND = not determined.

Nutrient Location	N	K	Mg	Ca	Na	Fe	Mn	B	Cu	Zn	HCO_3	SO_4	Cl	$NaHCO_3$	pH
1. Amager	0	14	50	106	640	1.09	0	0 56	0.002	0.03	449	310	1108	0	7.8
2. East Zealand	0	6	92	280	43	8.00	0.14	0.07	0.12	0.22	433	604	72	0	7.5
3. Central Zealand	0	3	3	7	259	0.34	0	1.52	0.03	0.10	566	0	19	684	8 4
4. Central Fyn	0	2	10	78	17	0	0	0	0	0.06	210	49	40	0	7.6
5. Central Jylland	2	1	4	4	17	11.76	0	0.01	0.005	0.09	32	10	30	0	6.0
6. West Jylland	29	11	19	25	36	0.23	1.69	0.08	0.037	0.54	18	79	62	0	4.8
7. Hornum Exp.Sta.	0	0	5	47	9	1.00	0	0.02	0.005	0.15	154	0	16	0	7.6
8. Liq. nutrition	182	146	30	0	0	1.80	0.56	0.16	0.100	0.09	0	16	0	0	ND
9. Toxic level	ND	ND	100	150	50	5.00	1.00	0.25	0.20	0.25	>100	>100	50-100	100	ND

Water and Plant Growth

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INTRODUCTION

It is well known that maximum plant growth is dependent on an optimum water supply. Large amounts of water are passing through a plant, most of which is used for temperature regulation. It is generally accepted that 97% of the water taken up is transpired. This leaves 3% for other uses, and nearly all of this water is used in the growth process, whereas extremely little is utilized in chemical processes. The total amount of water used may be 350 litre (100 gal) per kg (2 lb) dry matter produced. Of the 350 litres of water, only 10 liters is used for growth, leaving 340 litres to be transpired. Small restrictions of water flow to the plant over a short time period would be harmless, if it only affected the water transpired. However, a decreased water supply quickly affects growth rate. Several factors are known to influence water availability.

Humidity. Under most growing conditions, the forces pulling water out of the leaf are so strong that transpiration has first priority causing even small levels of water depletion to affect plant growth more than expected. Each time a water molecule is transpired, a new molecule has to replace it to prevent water stress from occurring. Leaf growth decreases dramatically when well-watered plants are transferred from humid to arid conditions (i.e., a decrease in humidity from 85% to 50%) (Nagarajah and Schulze, 1983). Therefore, transpiration may limit growth even if the root system is well watered.

Water availability. Most of the water is taken up by the very tip of the root in the root hair zone. Just a few millimeters further up the root, and the ability of water to penetrate the root surface becomes difficult. Only a growing root is continuously making new cells where water uptake takes place. The implication of this is that, when a root experiences drought, the capability for water uptake diminishes, making it even more difficult for the plant to maintain its growth rate.

Temperature. When the temperature decreases, the viscosity of a liquid increases. This is also true not only for soil water, but also for the lipids in the cell membranes. When plants acclimatize to cooler temperatures, cell membranes change to minimize the effect on transport of ions, etc. through the membrane. However, in subtropical species, such as citrus, these membrane changes are not as pronounced as in subalpine species such as Engelmann spruce (*Picea engelmannii*) (Kaufmann, 1975). The consequence of this is that, at low soil temperatures, water uptake is restricted by high resistance in the roots and the resistance is higher in subtropical species.

Nutrition. The existence of a close relationship between plant growth and the nutritional status in the growing media is a well established fact. However, it is more surprising that there also may be a direct relationship between phosphorus levels and root resistance to water uptake. Radin and Edinboch (1984) have demonstrated such a relationship in young cotton plants. Under water stress conditions water flow through the roots of phosphorus-deficient plants was only one-third of control plants.

MATERIAL AND METHOD

Hibiscus cuttings (*Hibiscus rosa-sinensis*) were rooted hydroponically, and grown for an additional month in a full nutrient solution as described by Bertram (1991). The plants were grown at 20C. When plant roots were about 15 cm long, the apical 10 cm was cut off and placed in a Clark-type oxygen electrode and respiratory oxygen uptake determined at temperatures ranging from 5 to 35C. Fresh weight of the root was determined after the experiment was conducted.

RESULTS

Root respiration is strongly dependent on the temperature. At 30C, 0.3 ml oxygen per g fresh wt per hour was taken up, whereas at 5C this value had decreased to 1/10 (Fig. 1). The decreased respiratory oxygen uptake at 35C is most likely caused by a heat shock effect.

DISCUSSION

To ensure optimal plant growth, it is commonly accepted that growing media must have optimal air/water properties. However, this alone may not secure a good water uptake by the roots. When a drought situation has occurred, either because of natural causes in the field or by a failure in the watering system, excess watering

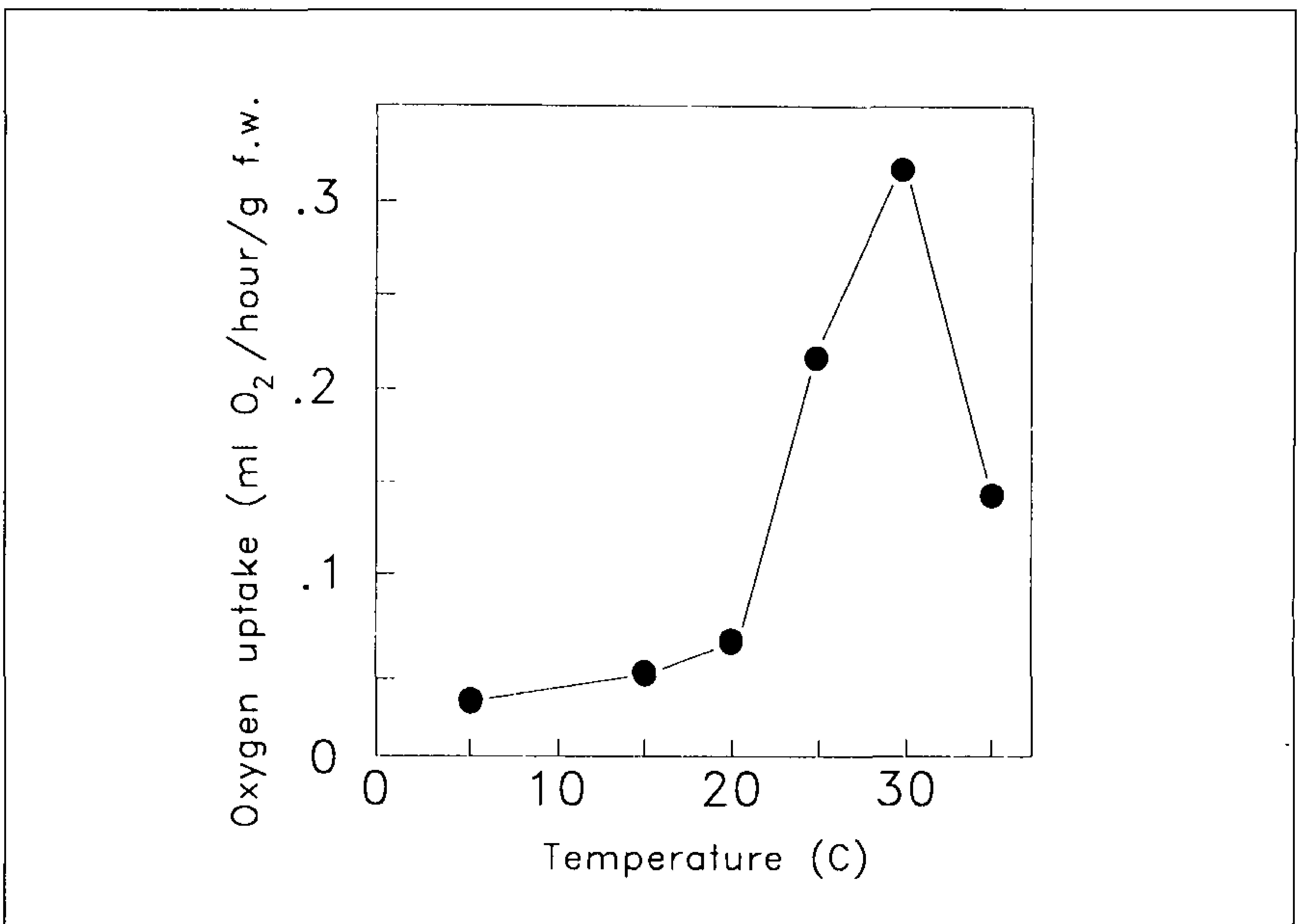

Figure 1. Temperature-dependent oxygen uptake in roots of*Hibiscus rosa-sinensis*. The plants were grown hydroponically at 20C until used for measurements.

is commonly observed afterwards. The plants therefore first experiences a drought which is followed by a flooding situation. On a smaller scale, this is also what occurs in greenhouse production, where ebb and flow tables are used. Under such conditions suffocation of the roots might be a possibility. In Denmark these conditions may be experienced during fall in the field. Under poor drainage conditions, the respiring roots will use up all the oxygen, and anaerobic conditions occur. This situation occurs 10 times faster at 30C compared to 5C. If uncontrolled watering occurs after a drought period, not only is the capability to take up water diminished, but anaerobic conditions may occur causing the young root tips to die, further constricting the water-uptake capability of the plant.

CONCLUSION

Water uptake of a plant is affected by a range of factors. To ensure optimal water conditions in the plant, it is not enough just to examine the water relations in the growing media, because factors such as a previously experienced drought, relative humidity soil temperature, and phosphate level greatly influence the ability of the plant to take up water.

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Recycling of Water in a Container Nursery

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INTRODUCTION

When I sat down to put this paper together, I asked myself: "What is it I want to get across to this group of propagators and growers?" I think the answer is:

- It can be done
- It is done
- It works
- It grows great plants
- It is economically feasible

So, I shall strive to do so.

BACKGROUND

Our nursery, Midwest Groundcovers, is a propagation and container nursery. It is located on the Western edge of the Chicago metropolitan area in northern Illinois. The climate is typically continental with hot summers and cold winters, so it would be much more like Moscow than Denmark or southern Sweden.

We grow groundcovers and perennials by the millions, but also large quantities of shrubs and evergreens. We are growers and wholesalers, and supply landscapers, garden centers, and nurseries in a six-state area in the Midwest of the United States. This area would be similar in size to Denmark, southern Norway and Sweden, and the northern half of Germany.

All propagation and growing is done in flats or containers using soilless media consisting of peat moss, sand, spent mushroom compost, perlite, and pine bark, in various formulations.

All fertilization is done by liquid injection through the irrigation water.

DISCUSSION

Our experience growing plants with recycled water really goes back to our early start on five acres (2 ha) of land. The land had a low area in the middle where the surrounding areas naturally drained. This low area was dug out and became our irrigation pond. We did have a well, but it was not big enough and considerable irrigation water was pumped from the pond. In those days we did not even know this was called recycling!

As we developed our main nursery a few miles away, we were more concerned about growing, selling, and surviving than with recycling.

About 10 years ago, when we started a new large expansion project, we were aware of recycling and problems caused by runoff in some areas of the country. We thought we should do something about runoff before the government told us it was necessary. At that this time greenhouse growers in Europe were utilizing totally enclosed recycling systems—the so-called ebb and flow systems and certain other types.

The dumbest thing many nurserymen have ever done was to think they were better or smarter than the greenhouse growers and that they should protect their secrets. We tried not to be quite so bad and set out to learn from the greenhouse growers, and then developed the many modifications necessary for using their principles in an outdoor environment.

The following are a few basics in recycling:

- Reuse the excess irrigation water (what the plants did not utilize)
- Supplemental water and fertilizer
- A growing area with some type of water distribution system (sprinklers, nozzles, drip, subirrigation)
- Drain back of excess irrigation water and rain
- Reservoir to hold the drain-back water
- Pumping and water treatment facilities

We have two large systems in operation relying wholly or partly on recycled water: 1) Our north propagation facility and 2) Our Hickory container growing and sales facility

The north propagation facility has about 25 acres (11 ha) of mainly outdoor propagation in quonset structures and some indoor propagation in plastic houses with limited heat. In this facility we mass produce the bulk of our groundcovers—cuttings are stuck and rooted directly in the selling flats.

Misting is done with good quality water from a deep well that is acid treated to lower the pH.

All irrigation with fertilizer injected is done with recycled water. The mist and irrigation lines are inside the quonset house. A drain tile between adjacent houses directs the excess water to spillways and then back to the reservoir.

There are two water lines—one with clear water for misting and the other with recycled water (with fertilizer) for the irrigation. For 10 years this facility has produced millions of excellent groundcover plants with no more diseases or other problems than we had with well water.

Our Hickory container growing facility was started 5 years ago and now consists of 50 acres (22 ha) of container growing areas as well as sales yards and staging areas. The growing areas are mostly producing plants in 5-gal (14 litre) containers, and all are laid out with drip irrigation. Most areas also have overhead sprinkler capacity. In the container growing area drain back is also through drain tiles between the quonset houses and open spillways to the reservoirs. Storm sewers in the sales yard, staging, and road areas also lead back to the reservoirs.

Since the Hickory area has large elevation differences, a system of four diked reservoirs was constructed. The reservoirs are interconnected so all water moves down to the lowest reservoir and pumping station. These reservoirs have a capacity of about 8 million gal (30 million litre or 30,000 m^3). This capacity gives us the ability to irrigate for several weeks without rain or supplemental water. The pumping station has three separate units, one for each specific growing area. The system is not permanently pressurized. Each unit consists of a small pump (40 gal/min = 150 litre/min), a larger pump (300 gal/min = 1100 litre/min), a sand filter to take out particles, an acid injector, and a fertilizer injector. The acid injector system monitors the pH and injects concentrated sulfuric acid to keep the pH at about 6.1. The fertilizer injector, a DGT-Volmatic electronic injector (type ELB), measures the EC and adds fertilizer if there is not enough in the drain-back water. Recycling has substantially reduced fertilizer consumption to 25% to 50% of what non-recycling systems use.

If rainfall is not adequate, supplemental water is supplied to the reservoirs from wells or from a stream.

CONCLUSION

The concerns about diseases being spread and rampaging through growing areas when using recycled water has not materialized. No additional fungicide applications were made to those areas utilizing recycled water. High quality plants are produced in a more cost-effective way. The cost of building a production facility using recycled water is higher than that of a non-recycling facility, but not that much when it is planned and done from the beginning.

Substantial savings on fertilizer expenses are realized and many more plants can be grown without procuring additional water. Last, but not least, we are husbanding Mother Earth's limited resources much better, polluting much less, and, hopefully, keeping the environmental authorities away from our nurseries.

The Super Nutrient Film Technique (NFT) System

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HISTORY AND PURPOSE

The nutrient film technique (NFT) system was first tried out in 1941 in Shanghai, China, in a nursery called The Chemical Garden. This system was in operation until 1944, when it closed down because of the war. Its inventor stated that there were nutrient problems and that NFT was uneconomical. In 1956 the technique was again used in Sweden by a chemical firm but abandoned 2 years later because of nutrient solution problems. In 1964 BV Hydro Systems developed a system in Denmark for orchids and in the 1970s a large number of experiments were conducted. However, no really important developments occurred before 1972, when Alan Cooper in England conducted the first commercial experiments with NFT. Since then, a large number of people in different countries have attempted to use NFT with a varying degrees of success. The original NFT system developed in England is—as the name implies—a thin nutrient film running down a gully or trough. The system is based on the capillary effect (hygroscopic conductance) of the root mat and, in principle, the plants are placed on a level surface with a longitudinal slope. This layout is covered to minimize evaporation, to eliminate the build up of excess heat which will damage root development, to exclude light from the roots, and to avoid algae growth in the nutrient solution. In this covered trench, the nutrient solution is delivered at one end and drained off at the other end. Due to the slope of the underlying surface, gravity will cause the solution to flow the length of the trench. Steepness of the slope, roughness of the surface, and gully width and length determine the speed with which the nutrient solution flows down the gully. The velocity of the nutrient solution in the gully should be greater that 10 cm/sec. The slope is generally 2.5%, the length of the gully not more than 4 to 5 m, and the width approximately 30 cm in order to assure that all root exudates are transported away from the root surface.

As the name NFT implies, the nutrient film is very thin and should not exceed 0.5 mm in order to allow the nutrient solution to flow underneath the root mat. If this is the case, capillary action of the root mat will transport the nutrient solution up through the root mat and be absorbed by the roots. At the same time oxygen will diffuse down between the single roots in the root mat to be absorbed by the roots. As the roots develop over time in a NFT system they form a very dense root mat. The increased root density reduces the oxygen diffusion coefficient because of the restricted movement of the nutrient solution in the root mat and resultant running of the nutrient solution on top of the roots. A NFT system, even if good in theory, gives practical problems in commercial installations because it requires very precise regulation of solution flow in the gully. The amount of solution will also have to be changed, as the plants grow and the volume of the root mat expands, in order to assure good oxygenation at all times. If a pot or substrate block is used, it will have to be elevated above the nutrient solution as soon as the roots have formed a mat; otherwise the roots under the pot or block will die and rot from anaerobic conditions. In addition, the flow pattern down stream of the block or pot will cause oxygen deficiency if not elevated.

THE SUPER NFT TECHNOLOGY

The Super NFT system was developed in 1992 for a project in Ukraine. The main objective was to create a NFT system that eliminated the common problems (i.e., root death) observed with ordinary nutrient film systems.

The Super NFT system was designed as a bareroot hydroponic system with a solution level of 1 to 2 cm and a distributed nutrient-feed system. This combined with a special gully geometry creates a nutrient-solution distribution pattern which in gully lengths up to 12 m gives a near perfect oxygen distribution to the plant roots. At the same time, root exudate removal becomes more efficient. Drain-off can be at the end or middle of the gully.

The fan-shaped flow pattern of the liquid further removes the majority of the used solution so that fresh solution always is available to the root system. The special tracks in the bottom of the gully also make it possible to place a pot or a rockwool cube either between them or on top of them. During the first 2 to 3 weeks the plant is placed between the tracks directly on the bottom of the gully. After a thin root mat has developed, the plant container is lifted and placed on top of the tracks. This allows the solution to flow under the pot or block and eliminates oxygen deficiency and root exudates build-up.

In conventional NFT systems long and narrow gullies—often with intermittent watering—have given growers many problems and the system a bad name. This has discouraged many growers from using such bareroot systems. It must be remembered that the system originally was designed with a very thin nutrient film (0.5 to 1 mm). In such a design, oxygenation was good but the removal of root exudates poor—this configuration resulted in constant problems. Later the systems came with a raised level of nutrient solution (0.5 to 2 cm) which gave better removal of root exudates but poor oxygenation especially under the rockwool cubes or peatmoss pots. It must be remembered that there is a close relationship between gully length, gully width, solution depth, flow rate, and flow pattern. If these parameters are not optimized the system will not function properly.

The idea behind the Super NFT system was to create a system that would conform to the simple hydraulic requirements presented above, give optimal growing conditions for the plant in culture, and at the same time make it possible to use a SPF (specific pathogen free) hydro system to eliminate diseases.

To fully understand the Super NFT technology it is important to realize the two main problems a plant culture encounters in a hydroponic system. The first one is lack of oxygen—most of today's systems do not supply adequate oxygen to the plant roots. The second problem encountered in hydroponic systems is high levels of COD and TOC. It is known that up to 25% of the photosynthetic products can be lost through roots. This loss creates phytotoxic problems in the root mass when these organic substances decompose consuming available oxygen in the process and at the same time serving as food for bacteria and fungi. In order to counteract this problem it is necessary to remove these substances either by frequent changes of the nutrient solution or by passing it through a biological filter.

This requires, however, that the amount of liquid supplied to each gully has to correspond to the amount of oxygen it is able to transport—this is usually between

4 and 10 liters/hour/plant. The exact amount depends on temperature and oxygenation efficiency of the solution. The removal of root exudates also requires a distributed feed system and a special flow pattern of the nutrient solution. In addition, the flow is furthermore balanced so that the hydraulic pressure created by the slope of the gully corresponds to the friction exerted on the liquid in the gully. Plant containers have to be placed in front (up hill) of the nutrient solution emitters in order to give maximum flow in the primary track. The Super NFT system is a pure hydroponic system. It can be fitted with spray emitters and will then act as a combined aeroponic and NFT system. In gully length up to 2.5 m and fitted with a special overflow valve, an ebb and flow nutrient system can be used. This requires that the gullies are mounted without slope. Figure 1 shows a Super NFT system in cross section.

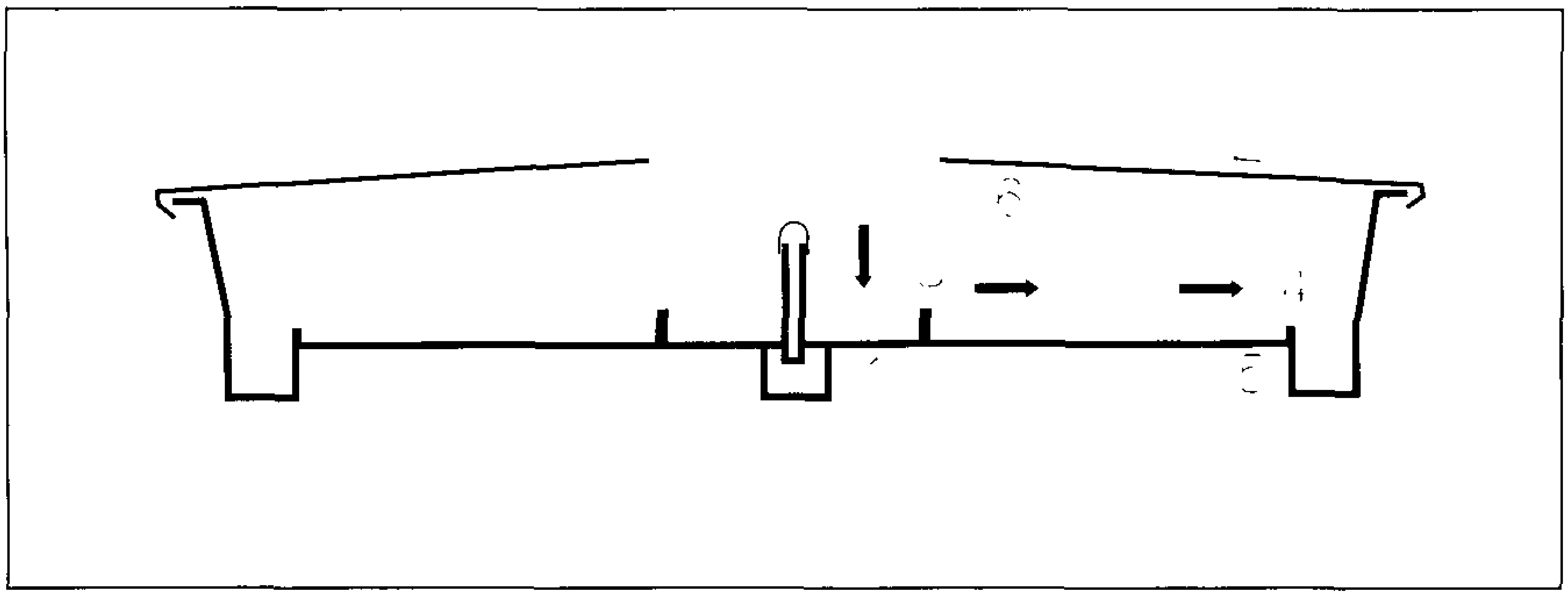

Figure 1. The Super NFT system with the feed tube (1), the nutrient solution emitter (2), the first track (3), the second track (4), the drain-off channel (5), and the lid (6).

Figure 2 shows the flow pattern in the gully with the plant containers placed on the gully bottom and on the top of the primary tracks. It illustrates how the development of the root mat forces the nutrient solution to flow from the primary tracks to the secondary and finally into the two drain channels in each side. It will be necessary to remove the roots which have grown into the main drainage system from time to time.

TOMATO GROWING IN SUPER NFT

The Super NFT system was specially developed for growing tomatoes. The following are recommendations on how to set a Super NFT system up for growing tomatoes. The gully should have a slope of 0.4% with a plant spacing of 33 cm. If plant spacing is 30 cm, the slope should be increased to 0.5%. Higher plant densities are not recommended. Nutrient solution flow should not be less than 4 liters/hour/plant and 5 liters/hour is recommended. The plants should be placed before the nutrient solution emitter (see drawing). If plants are grown in a region with poor winter light the water flow can be restricted the first 2 weeks to induce stress. The plants should then be placed between the tracks and the water turned on and off at intervals. Care must be taken not to let the plants dry to the point that the roots are damaged. If high conductivity is used to stress the plants, they should also be placed between the tracks on the bottom of the gully. When a thin root mat has developed in about 3 weeks, the plants are lifted out of the nutrient solution to allow the solution to flow

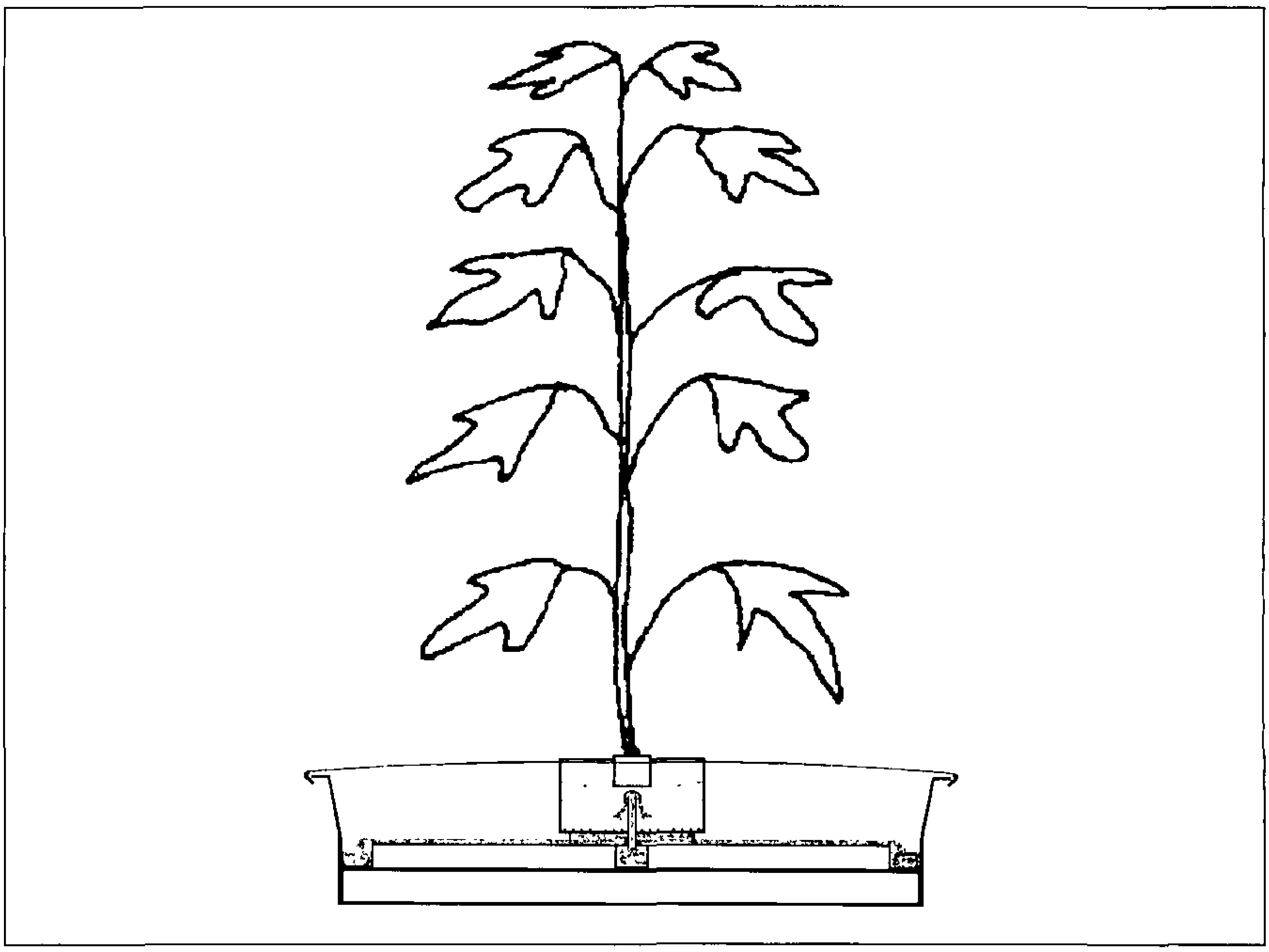

Figure 2. Flow patterns in the gully with the plant containers placed on the gully bottom and on the top of the primary tracks.

under the blocks or pots to remove the root exudates and aerate the roots.

This operation is best done by using an asymmetric block (e.g., 6 cm x 7 cm) and turning it 90 degrees so it rests on top of the two center tracks. If a smaller pot is used, it can be placed on one of the tracks. The roots will grow into the main drainage tube and must be removed manually at intervals (3 to 4 weeks).

CUCUMBERS IN SUPER NFT

Cucumbers grow more vigorously than tomatoes and need more space and oxygen. Therefore, a between-plant distance of 35 to 40 cm is recommended. The flow should be increased to minimum 8 liters/hour and in hot climates up to 10 liters/hour is recommended. With cucumber it is important to keep the root neck dry to avoid attack by fungi. This can be achieved by using a growth substrate with a high air to water ratio and making certain that the pot or block is well above the lip of the gully. While the growing block in a tomato culture can be as low as 5 cm it is recommended with cucumbers that blocks 5.5 to 10 cm in height be used. Further the top of the pot can be covered with white EPS shavings to create a dry surface.

OTHER CULTURES IN SUPER NFT

Other plants worth considering for cultivation in the Super NFT system include aubergines (eggplant), green peppers, melons, and other plants which have large root systems in culture and require distance between the plants.

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Laser-Based Measuring Equipment for the Analysis of Size and Velocity Distribution of Liquid Drops

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The Particle Dynamic Analyzer is a laser device based on the phase Doppler-Anemometry. The equipment is used for continuous measurements of size, velocity, and concentration of globular particles contained in the liquid jet from nozzles.

INTRODUCTION

The size and velocity of drops are significant factors in connection with pesticide spraying and plant irrigation.

The nozzle type used determines drop size, liquid volume, and liquid pressure. Drop diameter of fog will typically be below 15 µm, and for aerosols it will be below 50 µm. For fine, medium, and coarse sprays the drop diameter will be respectively 100 to 200 µm, 200 to 300 µm, and over 300 µm.

For pest control spraying the spray coverage of plants should be as high as possible. The smaller the drop size, the higher the spray coverage that can be achieved. However, because of environmental considerations—wind currents and workers inhaling the small particles—limits exist on how small the drops can be. Therefore, drop diameters of 200 to 400 µm are recommended.

A coarse atomization can be achieved using rain-drop nozzles. The drop must be sized so as not to harm the plants, and the drop size must be sized in proportion to the plant species being sprayed. Therefore, for field irrigation a drop diameter greater than 4000 µm should not be used.

MEASURING METHODS

The distribution of drop velocity and size from a liquid flow were measured by laser-based equipment.

The equipment consists of laser, beam splitter, Bragg cell section, adjustable prisms, and front lenses. Photo multiplier sections pick up the signals and transmit them via a signal processor to a computer for analysis.

Laser effects may be achieved from nearly all light-emitting materials. The laser equipment used is based on an argon-ion laser unit. The laser unit will emit laser light of different wavelengths and a laser line is selected by turning the prism to achieve the optimum intensification for the desired wavelength. A wavelength of 514.3 µm was chosen for this study.

In order to measure the particle size, the laser beam is split into two beams. One of the beams is transmitted through a Bragg cell in which the frequency shifts. The beams are transmitted through a front lens with a specific focal length. Where the beams intersect, interference fringes are created. The point of intersection serves as the measuring point. The laser frequency determines the intervals between the fringes.

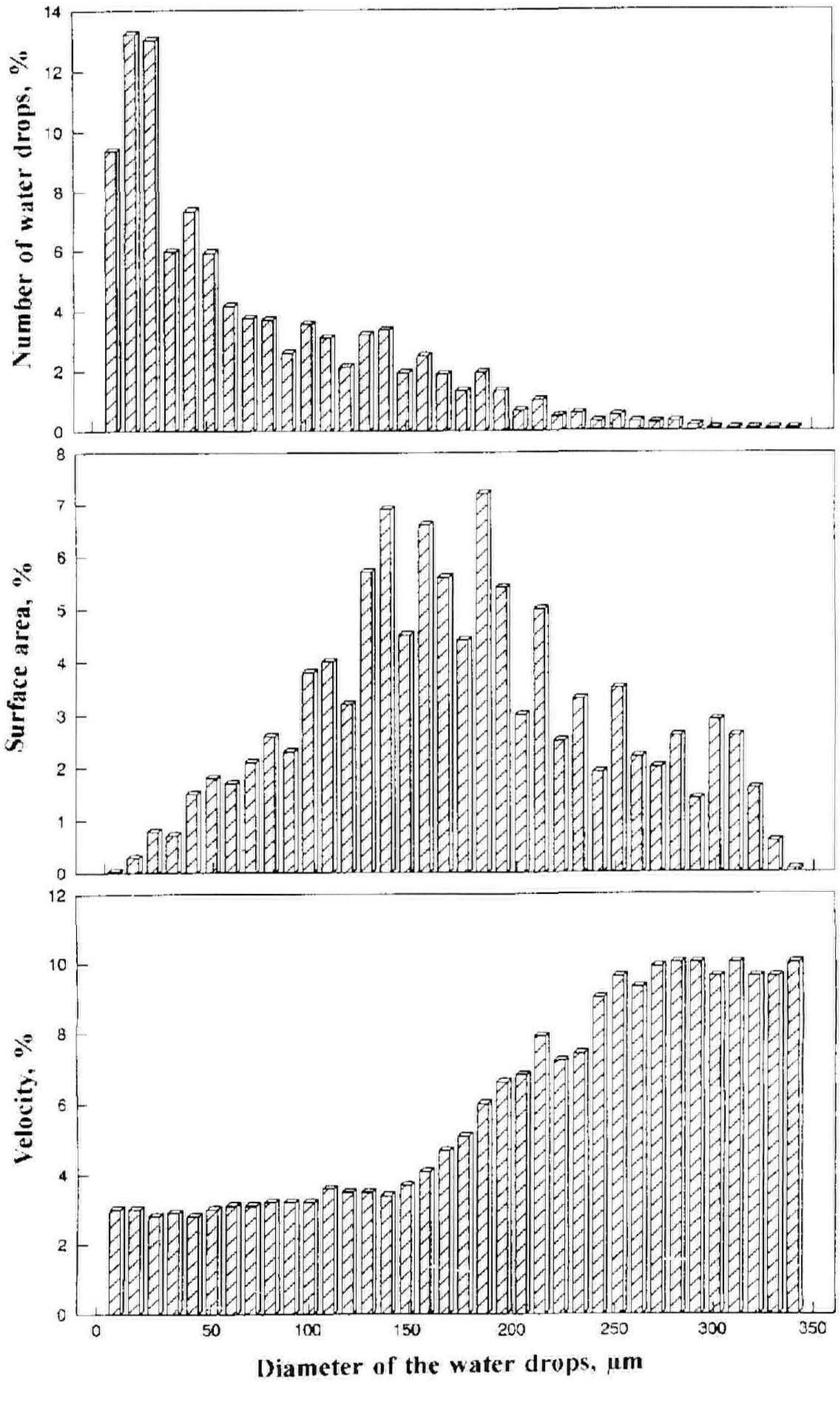

Figure 1. The distribution of velocity and size of the drops from a selected nozzle.

To measure the drop velocity a photo multiplier is used to pick up the pulsation of light occurring as the drops pass vertically through the horizontal parallel fringes.

The above-mentioned frequency is proportional to the drop velocity.

For measuring the drop diameter the equipment is fitted with two photo detectors for picking up light pulsations. The detectors are located so that they will both pick up the light pulsations at the same frequency, however, with a phase difference. The drop size is determinative of the difference in phases.

RESULTS

Figure 1 shows that the liquid spray contains a large number of drops with a small diameter. From the determination of the distribution in percentages of surface area of the drops according to size the large amount of drops with a small diameter is rather insignificant. It can furthermore be seen that the velocity increases with increasing drop diameter.

DISCUSSION

Other known drop analysis equipment will only measure drop sizes and distribution. The laser-based equipment will additionally measure drop velocities. This is essential when measuring wind deviation.

Irrigation Systems

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INTRODUCTION

Plants need water and fertilizer at the right time, in the right amount, and at the right pH level. The optimum fertilizer concentration and pH level differ by season, plant species, and plant age.

POSSIBILITIES FOR DISTRIBUTION OF LIQUID FERTILIZER

Liquid fertilizers can be distributed by the following methods:

1) **Water-driven pump**. This provides for direct injection of liquid fertilizer into the irrigation system and is a cheap solution.

2). **Mechanical mixers**. These provide the possibility of mixing more than one stock solution and for control of the fertilizer concentration.

3) **Computer-controlled mixer**. This provides the possibility of mixing more stock solutions and controls fertilizer concentration and acidity for each combination of stock solutions. Control of the acidity is important to ensure that the fertilizer components are available in a chemical form that plants can take up.

WHY USE COMPUTER-CONTROLLED FERTILIZATION

With an AMI fertilization computer it is possible to irrigate with eight different fertilizer compositions, with different EC values (= fertilizer concentrations) and eight different pH values.

Fertilizer Concentration. The EC value is important for the proper growth of plants. If the EC value is too low, plants do not get enough fertilizer, growth and the plant quality are reduced, and the resulting plants are more prone to attack by fungi and other pests.

If the value is too high, plants cannot absorb enough water for evaporation. This causes stomata (guard cells) closure which inhibits photosynthesis.

The optimum EC value changes during the day. When solar radiation is high, the EC value should be lowered. Computers have the facility to lower the EC value automatically in relation to solar radiation. The fertilizer composition stays the same but the level of the different fertilizers is lowered.

When irrigating outdoor plants, rainfall decreases the concentration of fertilizer in the soil water. Measurements in a Swedish forest nursery showed that a moderate rainfall, one that lasted half an hour, lowered the EC value from 3 to 1.5. Therefore, it is necessary to irrigate with a higher EC value in the water after a rainfall. It is therefore necessary to have a number of recipes where the pH value and fertilizer composition is the same but the EC value differs.

pH Value. The pH value indicates the acidity or alkalinity of the irrigation water. If pH becomes too low or too high, the uptake of many minerals decreases. Low pH (e.g., pH = 4.5) affects the uptake of ions, such as calcium, potassium, and molybdenum. A high pH (e.g., pH = 8.0) diminishes uptake of phosphorus, manganese, and boron. If the pH is too low or high, it is necessary to increase the amount of fertilizer to ensure that plants get all the nutrients they need. Therefore, correct pH values save fertilizer.

The optimum pH is generally between 5.5 and 7.0, with the optimum value varying from species to species. For example, tomatoes have an optimum pH of 5.8, whereas begonias have an optimum pH of 6.5.

Fertilizer Composition. When you grow different species at the same time, you need to be able to give each species the right fertilizer composition. Instead of either giving all plants the same fertilizer composition, or mixing as many different solutions as needed, you can mix a limited number of stock solutions and then instruct the computer how to mix these stock solutions so they fit the different plant species.

QUALITY AND QUANTITY

Plants must grow fast and steady to maintain a high level of quality and quantity. If plant growth is slowed because of either poor climate conditions or incorrect fertilization, both quality and quantity are influenced. The shape of the plants may be altered and flower number may be reduced or aborted. Delayed cropping time makes production more expensive and poor quality results in lower prices—therefore, profitability is reduced.

RECIRCULATION

When fertilization is computer controlled it is also possible to recirculate the water, which additionally saves fertilizer. Water recirculation research has shown a 30% savings in irrigation water and 50% of the fertilizers used.

It is possible to have different irrigation solutions separated. The computer can then automatically take the recirculated water from the proper basin and mix with fresh water and fertilizer needed for each of the irrigation solutions.

LABOUR REDUCTION

The AMI computer saves labour. The computer starts automatically when needed based on weather information. Different plant species may require different conditions and once these conditions are determined, the computer will control irrigation of each plant type. The AMI computer can be used for all types of irrigation—drip watering, benches, sprinklers, etc—and all types of media—rockwool or grodan, perlite, NFT, etc., including normal soil.

With a personal computer connected to the AMI computer, it is possible to obtain surveys of all the irrigation settings and collect data on each irrigation cycle.

Production of Specimen *Ilex* Species in Virginia, U.S.A.

John Machen Sr.
Mobjack Nurseries, Inc., Box 322, Mobjack, Virginia 23118 U S.A.

The holly cultivars we produce at Mobjack Nurseries have been selected for: 1) popularity in the U.S. mid-Atlantic states, 2) cold hardiness in this market area, and 3) cultural requirements that our production system can fulfill.

We are constantly searching for new hollies to meet these criteria. The following taxa are currently being produced:

- *Ilex* 'Nellie R. Stevens', a putative hybrid between *I. aquifolium* and *I. cornuta*, is a large dark-green evergreen shrub or small pyramidal tree 5 to 8 m high. It is hardy in areas which normally experience winter temperatures as low as -23C. This holly was introduced by G.A. Van Lennep, Jr. of St. Michael, Maryland, U.S.A., in 1954 (Dirr, 1983).
- *Ilex* 'Edward J. Stevens', is a large male clone useful for pollinating 'Nellie R. Stevens'. It is more narrow in growth habit but essentially similar.
- *Ilex* ×*attenuata* 'Foster's Number 2' is one of a group of five interspecific hybrids of *I. cassine* and *I. opaca*. It has a compact, narrow growth habit to 10 m, is heavily fruited with small red berries, and is hardy to -23C. This plant was selected by E.E. Foster of Bessemer, Alabama, U.S.A. (Dirr, 1983).
- *Ilex* ×*attenuata* 'Foster Brilliant' a selected seedling of 'Foster's No. 2' is more compact but grows more rapidly than its parent. The leaves have an olive green color and the bright red fruit is larger. It was selected by Charles Shreckhise of Weyers Cave, Virginia, U.S.A. It is as cold hardy as 'Foster's Number 2'.
- *Ilex* 'Doctor Kassab', is a beautiful dark green evergreen of broad pyramidal form that will reach 7 m. This hybrid between *I. cornuta* and *I. pernyi* is hardy to -28C and was introduced by Dr. Kassab, a gardener from Philadelphia, Pennsylvania, U.S.A. (Dirr, 1983).
- *Ilex* ×*koehneana* 'San Jose' is one of a group of interspecific hybrids between *I. aquifolium* and *I. latifolia*. *Ilex* ×*koehneana* is the grex name for a group of vigorous evergreen hollies. Named and introduced in 1919, these outstanding hollies have been overlooked (Dirr, 1983).
- *Ilex* ×*aquipernyi* 'meschik' Dragon Lady® holly, is a dense pyramidal shrub to 4 m with shiny dark green jagged-edged foliage. Large bright red berries show well on this holly which is hardy to -23C.
- *Ilex opaca* 'Miss Helen', a selected culitvar of *I. opaca*, native to North America, is an excellent broadleaf evergreen growing rapidly to 15 m. Introduced in 1944 by Steward H. McLean, U.S.A., this holly is hardy to -28C (Poore, 1984).

- *Ilex pedunculosa*, one of the hardiest of the evergreen hollies, has smooth dark green leaves and long stalked bright red berries. Introduced into England from the orient in 1893, it is hardy to -29C (Poore, 1984).

PROPAGATION

The *Ilex* cultivars we grow can be propagated from cuttings during most of the summer, fall, or winter months, so we take cuttings when we have time and space available. The bottom leaves are removed and the cuttings are bound together with rubber bands as they are taken in the field. After immersion in a fungicide solution they receive a basal dip of 10,000 ppm aqueous solution of the potassium salt of indolebutyric acid. The cuttings are stuck into flats of 75-mm peat pots containing a medium of 3 milled pine bark : 1 perlite (v/v). These flats are set under a mist system in warm weather or over bottom heat with mist in cool weather. By spring the cuttings have enough roots to be planted into 150-mm (2.8 litre) plastic pots.

Our growing medium is 6 milled pine bark : 1 washed concrete sand (v/v) with approximately 1 kg of finely ground dolomitic limestone and 500 g of urea (43:0:0) added per cubic meter. These pots are filled and set into our growing areas during late fall and early winter (off season). The cuttings will usually flush new growth so they receive one trimming before planting out in mid to late April. They are dibbled by hand into the pots at this time.

CULTIVATION

Liners for field planting are grown in 1-gal pots for one year. They are sheared flat to produce a dense branched base. After the land is prepared and limed with 4500 kg of dolomitic limestone per ha, the hollies are planted out into rows 2.1 to 2.4. m wide on 1.5-m centers. Irrigation is provided by 16-mm tubing with in-line emitters 600 mm apart, which delivers approximately 2 litre/h/emitter. A preventative spray program using Orthene, either Benlate or Bravo, and a miticide is applied every 2 to 3 weeks as needed with a mist blower type sprayer.

Cultivation between the rows is not used. Instead, red fescue and perennial white clover are fall planted in the alleyways and mowed as needed during the summer. Herbicides, pre-emergence and post-emergence, are applied through low-volume nozzles using a small narrow-gauge farm tractor. Weeds which escape control are treated with backpack applications of Roundup. Fertilizer is applied by hand three times per year. The first application is of 10 : 10 : 10 in early spring, the second is of 43 : 0 : 0 after the spring flush, and the last application is applied after frost.

Our hollies are shaped by one of two methods. Those not listed for spring sales are heavily sheared to a narrow pyramidal form during the winter or early spring. Those listed for sale are trimmed lightly to assure uniform size and shape. After the spring flush the plants not scheduled for summer sales are sheared again to a fairly tight pyramidal form. During the rest of the summer our hollies are given a light clipping to maintain shape, to keep tops narrow and tight and to encourage continued growth.

HARVESTING

Virtually all of our field-grown plants are harvested with a hydraulic tree spade. A plant after digging is brought in the spade to the head of the row and put into a wire basket lined with burlap on a low farm wagon. The burlap sack is secured around the trunk, the top of the basket is laced and drawn tight around the trunk with poly twine, and any loose wires are twisted with a hook to tighten them. The size of the ball can be adjusted to the size of the plant by lowering or raising the tree spade with the adjustable legs. An operator and three workers can produce 75 to 100 trees per day on wagons ready for loading into semitrailers.

LOADING

Our semitrailers are equipped with steel racks along the sides which support 50 mm by 250 mm pine shelving. Field-grown plants are loaded horizontally on the floor and container plants are then loaded onto the shelves. Our farm wagons are backed up to the semi-trailer and a ramp is made using shelving boards. The plants are then pulled up the ramp into the trailer. We feel this method is far safer than the use of loading equipment by unskilled workers.

CONCLUSIONS

We endeavor at the nursery to keep the plant's environment weed free and to protect them from insect pests. A sandy loam soil to grow in, sufficient moisture, and the adequate supply of nutrients are just the basic requirements. The single factor which is the strongest contributor to our plant quality is timing. The proper timing of both shearing and feeding enables us to induce the maximum amount of growth where it is most needed during the development of the plant.

We have learned that root elongation and nutrient uptake is highest when shoot elongation is at its lowest during the growing season. We try to ensure that nutrient availability is highest just before the plants begin to grow. In late spring we attempt to stop growth with our heavy shearing and again feed heavily. We shear just before our hollies would normally finish their growth cycle. During the second growth in mid-summer we trim very slightly to maintain shape and to encourage multiple breaks on new shoots where needed.

These procedures have enabled us to produce specimen hollies of very high quality which command the best price in our marketplace as well as being a lot of fun to grow.

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Poore, J.M., (ed). 1984. Plants That Merit Attention. Vol. 1 - Trees. Timber Press, Beaverton, Oregon.

Opening Address of the Inaugural Meeting of IPPS - Japan, Potential Region—Scope of I.P.P.S. Japan

Satoshi Yamaguchi
National Research Institute of Vegetables, Ornamental Plants, and Tea, Kanaya, Shizuoka, 428

I.P.P.S. Japan is aiming to bring together practical nurserymen, scientific researchers, farmers, and consumers under the motto of "SEEK AND SHARE".

When I joined I.P.P.S., just 8 years ago, I was the only Japanese member of the Society.

During my extensive work with micropropagation, a number of projects were accomplished and shared with others, i.e., micropropagation of *Rhododendron*, *Haemanthus*, a new yellow garden *Camellia*, and *Cyclamen*. I was pleased seeing these results and feeling a little proud of my work. I had fulfilled my duty, namely, "SEEK AND SHARE".

I sincerely hope this new I.P.P.S. Japan will play an important role to bring together various researchers, nurserymen, farmers, and consumers, and will develop into a true "SEEK AND SHARE" society.

Expanding Flower Colour Variation in *Gladiolus* Through Mutation Breeding and Tissue Culture

M. Kasumi, H. Tomotsune, Y.Takatsu, and F. Sakuma
Ibaraki Biotechnical Institute, Ago-3165-1, Iwamacho, Nishi-ibarakigun, Ibaraki Pref. 319-02

S. Iida
Institute of Radiation Breeding, NIAR, Kamimurata 2425, Ohmiyamachi, Nakagun, Ibaraki Pref. 319-22

To expand flower colour variation in *Gladiolus* mutation breeding using gamma radiation was adopted. By using radiation with a strength of 100 GY on bulbuls of *Gladiolus*, six times more colour variation was observed. All variants showed pink or white chimeric features in their flower stalks. The ovaries of chimeric plants were cultured in vitro on an agar medium with NAA and BAP added. After callus induction, they were transferred to a regeneration medium, supplemented with BAP (Fig. 1). Uniform flower colour was achieved by regeneration of ovary callus from chimeric parts (Fig. 2).

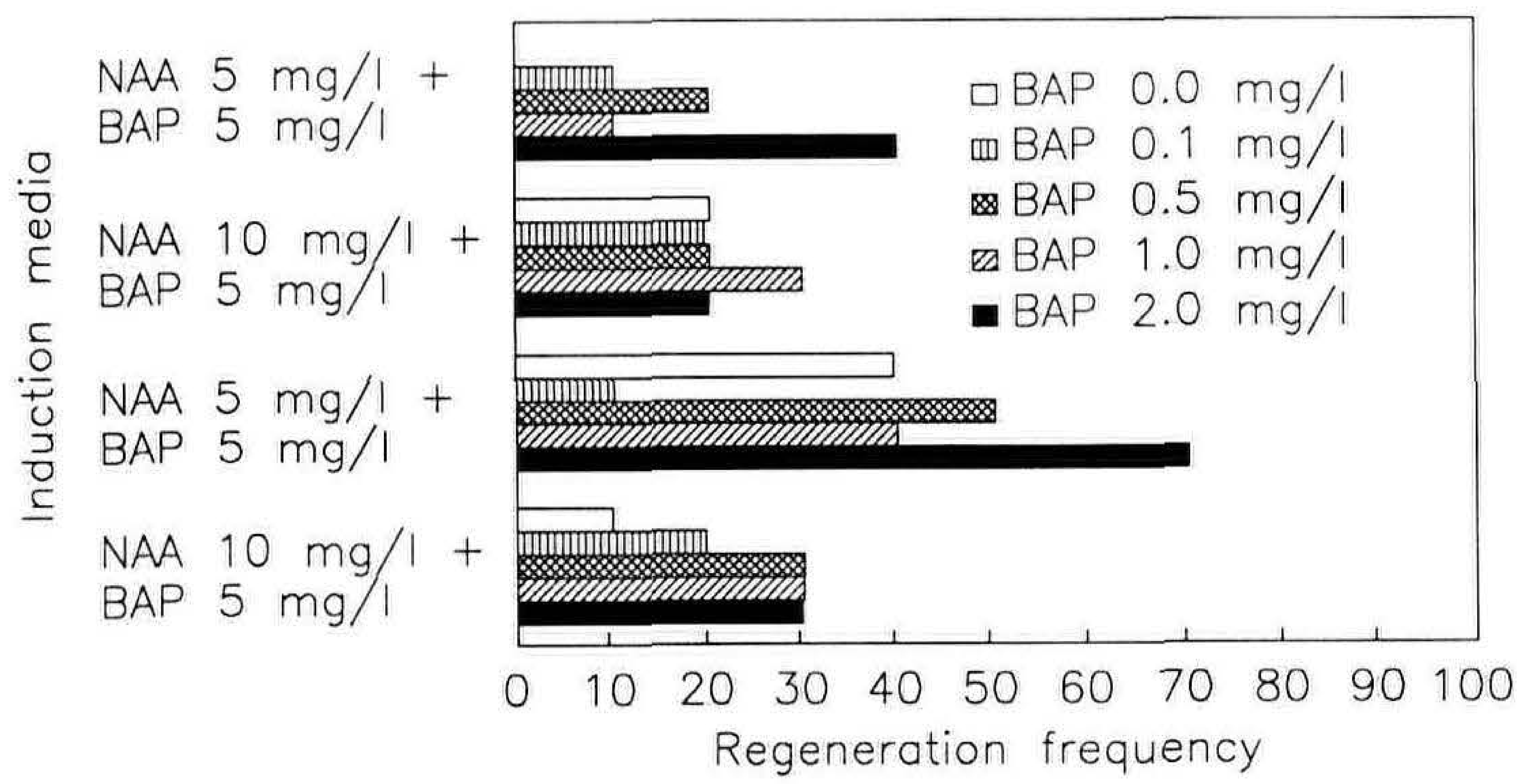

Figure l. Effect of the condition of callus induction and BAP concentration on the regeneration frequency in tissue culture of ovaries from young flower buds of *Gladiolus*.

Figure 2. Regeneration of young shoots from ovary-derived callus.

New Cultivars of *Cyclamen*, Kage-Yellow and Golden Boy

T. Kage and S. Kage
Kage Shinkouen Nursery, Tsunemochi-894, Kurume City, Fukuoka Pref. 859-38

My home town, Kurume City, is located in the southwest of Fukuoka Prefecture in Kyushu. Producers of *Cyclamen* in this city number 30.

In Japan, in recent years, production of *Cyclamen* has been gradually increasing with consumers wanting cheaper plants and larger flower colour choice.

To meet these trends in demand for new *Cyclamen*, our nursery set up a tissue culture laboratory and began a breeding project to develop new types of cyclamen. Now, we are very pleased to show our new elite cultivars, Kage-Yellow and Golden Boy, both with yellow flowers. Older cyclamen cultivars lacked yellow flowers. We succeeded in producing yellow-flower-colored types.

Outline of Breeding. Our breeding work started with finding yellow-flowered mutants among many seedlings of Kage's strain of 'Pure White'. The flower of 'Kage-Yellow' is medium-sized with a yellow colour at the bud stage and pale cream when open. Its colour becomes deep yellow at lower temperatures (around 15C) and under full sunlight. 'Golden Boy' is an improvement on 'Kage-Yellow' with deeper colour. We will be releasing a true yellow cultivar in the very near future.

Application of Plug-cell Stock Plant Production System for Orchidaceae Plants

K. Yoshino
Create Az Ltd., Togamicho-147-2, Utsunomiya City, Tochigi Pref. 320

The common stock type of orchid is flask stock or CP stock. However, a low rate of plants are established during acclimatization. Improvement in the number of good plants acclimatized is important. Plug-cell stock production was tested as a means of improving acclimatization on *Phalaenopsis* flask plants grown from seed. Organic compost combined with a hydroponic culture system was most effective for the establishment of flask plants.

Application of Tissue Culture Technique in Nursery Stock Production of Fruit Trees

H. Hara
Sanyo-Noen Nursery, Itsukaichi-215, Sanyocho, Akaiwagun, Okayama Pref. 709-08

Twenty years have passed since the tissue culture technique was introduced into nursery stock production on a commercial basis. It was somewhat of a fashion for nursery companies to adopt this new technique. But, at present, there are only a few companies producing plants on a profitable basis. Today, many businesses in

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the nursery industry are finding it hard to maintain their economic viability. This paper presents the current status of Sanyo-Noen Nursery's micropropagation of virus-free understocks of fruit trees.

Sanyo-Noen Nursery set up a micropropagation laboratory in 1984. Since then, it has concentrated on the micropropagation of virus-free stocks of fruit trees. The major product of our company is grafting understocks for sweet cherry and peach. The understock plants are 'Dandy Chair' and 'Meteor' introduced from New Zealand. Both are useful dwarfing understock cultivars in Japan because they show good summer heat tolerance. Each year, 10,000 to 20,000 plants of both cultivars are produced by meristem culture. At present, a steady pace of production and sales is planned. However, there are still serious production problems remaining.

One problem is the need for improvement in the rate of acclimatization. The solution to this problem is to improve the quality of the young plants while in vitro. If good root production occurs in culture, young plants will establish freely at the acclimatisation stage. We have improved the soil in the acclimatisation bed, but there are several more modifications needed in the mixture ratio of composts.

Apart from fruit trees, another 30 flowering plants and vegetables are under study for their rapid mass production in tissue culture.

A second research area is the breeding of elite grape cultivars. The main target is to produce a seedless triploid cultivar. Several trial crosses have been made of diploid and tetraploid cultivars.

In summary, our company, Sanyo-Noen Nursery, utilizes micropropagation to produce fruit trees. However, the usage of micropropagated stocks is still only a small proportion of the production of such plants in Japan. Japanese agriculture will change dramatically in the near future and along with these changes, fruit tree understock production using micropropagation techniques will play an important role and be of great benefit in the future.

Large-Scale Production of Yama-udo (*Aralia cordata*) Using Adventitious Embryo Culture

S. Nishimiya and M.Kubota
Ibaraki Biotechnical Institute, Ago-3165-1, Iwamacho, Nishi-ibarakigun, Ibaraki Pref. 319-02

Today, natural foods such as Japanese native herbal vegetables are fashionable. Accompanying this trend, the more aromatic yama-udo (*Aralia cordata*) is more popular than the common udo. Propagation is done by seed rather than division because it requires less labour. However, seed stocks are variable in sprouting, growth, and quality. Several aspects of tissue culture of yama-udo were examined in an attempt to produce uniform stocks.

The application of 2,4-D at 1 mg litre^{-1} was most effective for inducing adventitious embryos (induction frequency was 90%); BAP suppressed embryo formation.

Induction frequency was observed to be different between strains. Strain No.7 was the most prolific in embryo production. To save labour in isolating the small embryos, a simple protocol was established. This protocol involved mashing the

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At present, inspection of in vitro micropropagated plants has shown uniform traits of sprouting time, stalk colour, internode length, and flowering time.

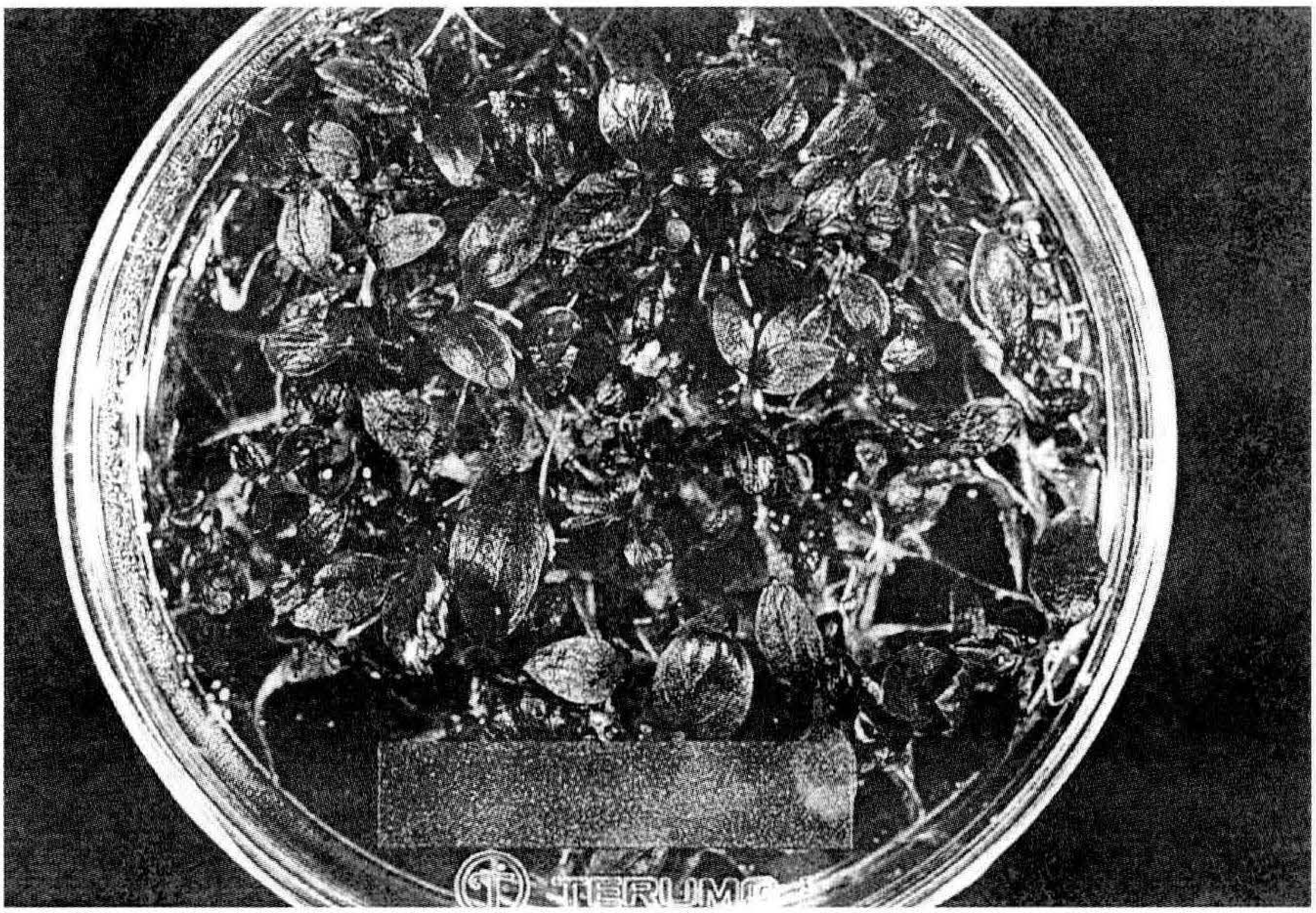

Figure 1. Young plantlets of yama-udo (*Aralia cordata*) regenerated from tiny embryos sown on the MS medium in vitro.

Changes in the Rooting Response of Two Miniature Roses During Micropropagation.

H. Sugiyama, H. Fukui, and M. Nakamura
Gifu University, 1, Yanagido-1-ban, Gifu City, Gifu Pref. 501-11

T. Ohnishi
Central Rose Nursery, 772-4, Ichinostsubo, Itonuki-cho, Motosu-gun, Gifu Pref. 501-04

The rooting ability of a number of difficult-to-root woody plant species has been markedly increased by repeated in vitro subculturing. This phenomenon is referred to as "rejuvenation by in vitro culture." In the present study, the relationship between the degree of rooting ability and "rejuvenation" is discussed with in vitro cultured miniature roses.

Rejuvenation efficiency was evaluated by percent rooting, number of roots, percentage of elongated lateral shoots, and flowering in vitro. Only the rooting results are presented.

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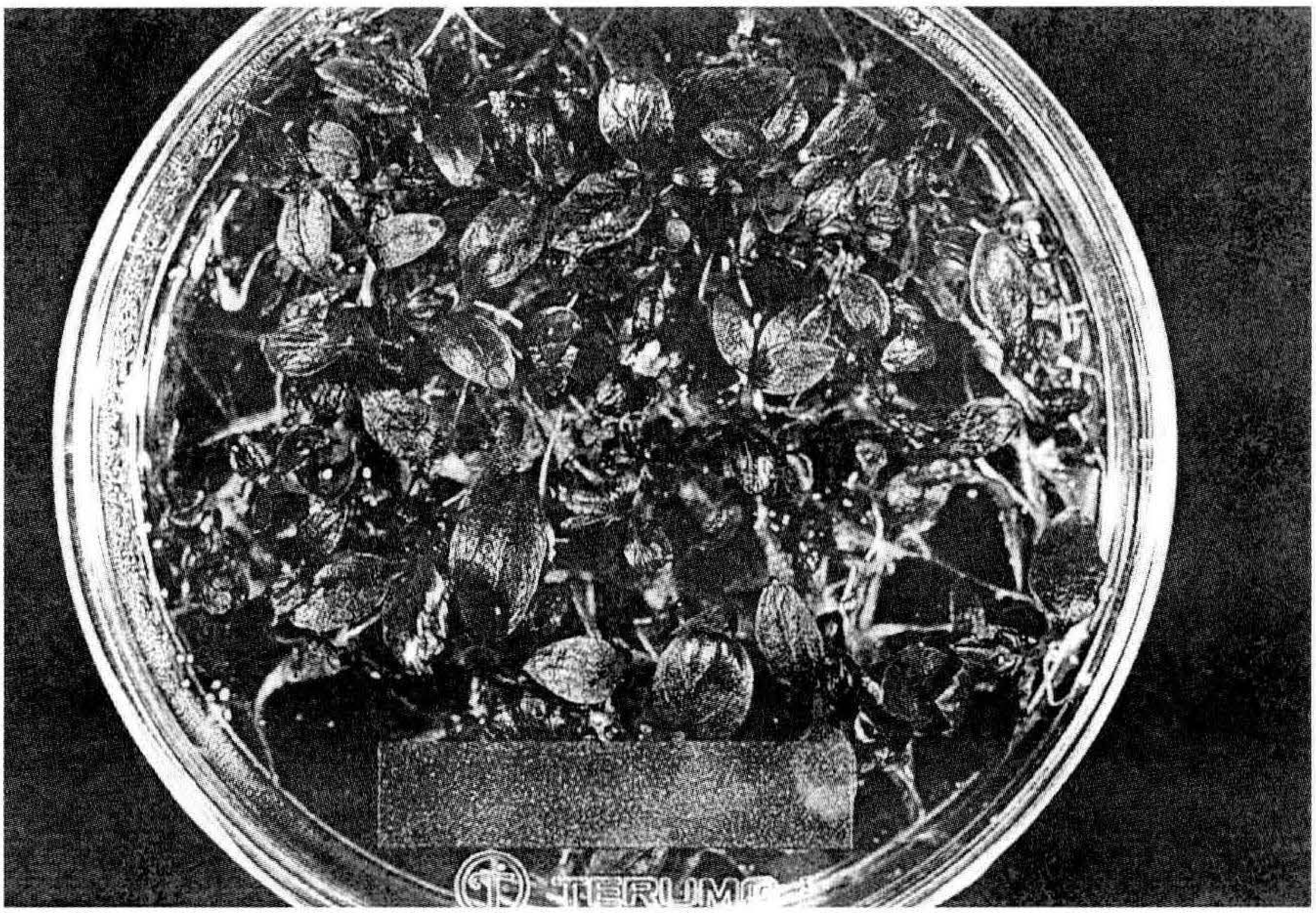

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In the cultivar Fashion Parade, the ease of rooting was the highest at five times subculturing and declined after five subcultures (Figs. 1 and 2). This suggested that the shoots may be aging. In contrast, with the cultivar Alba Meillandina, the ease of rooting was the highest at six times subculturing (Figs 3 and 4). Therefore, there were cultivar differences in "rejuvenation."

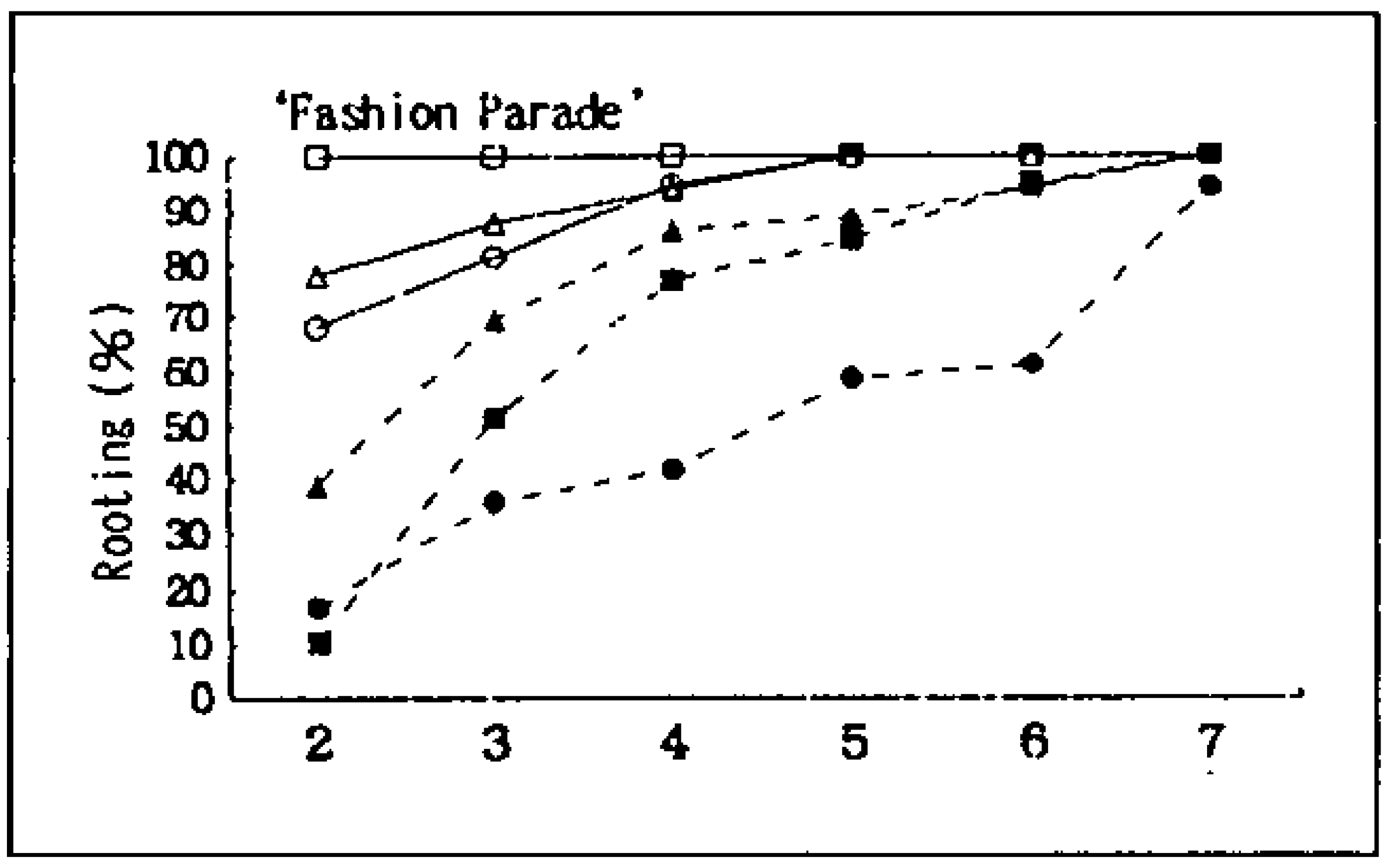

Figure 1. Change in rooting rate after rooting induction treatment.

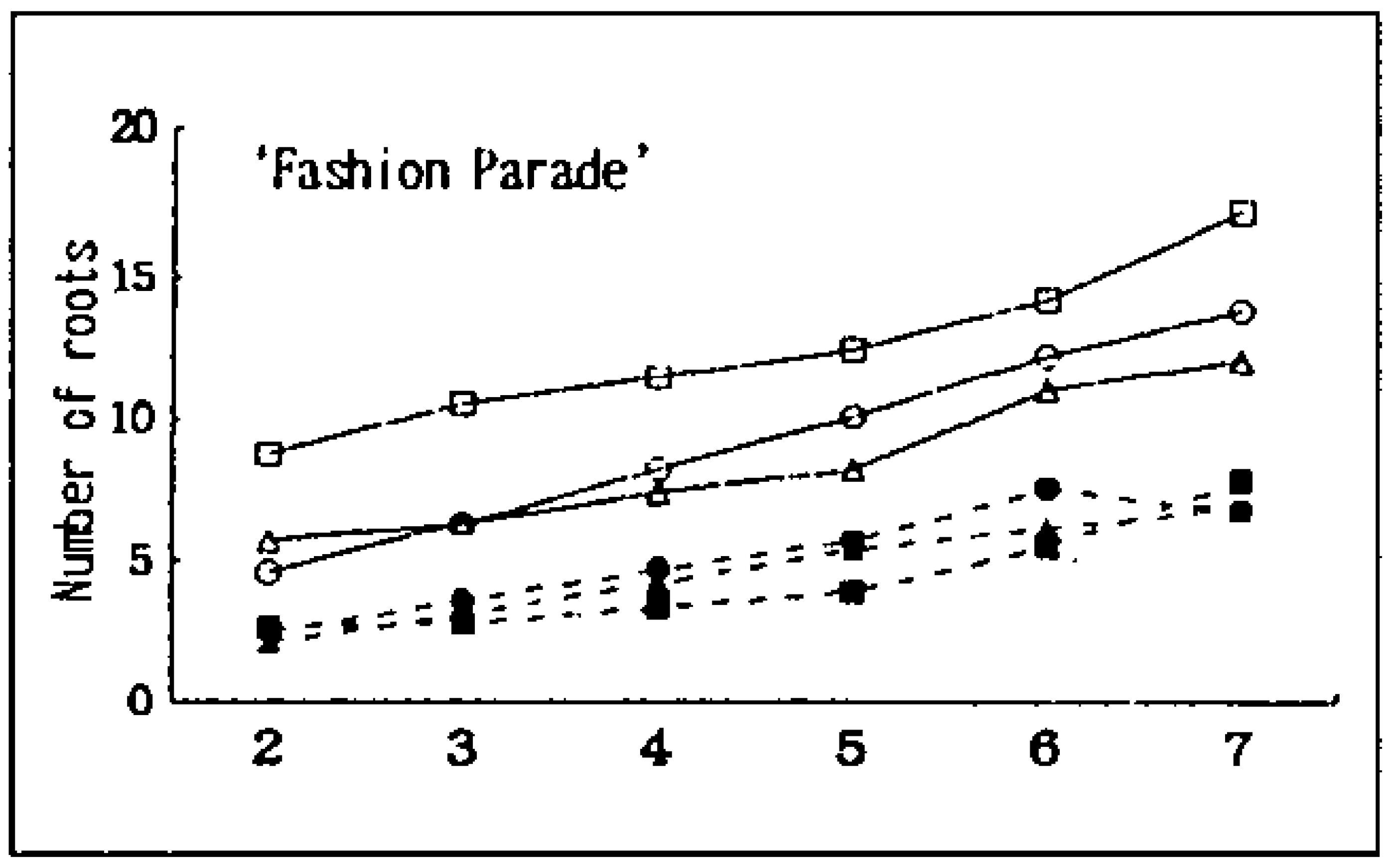

Figure 2. Change in number of roots after rooting induction treatment.

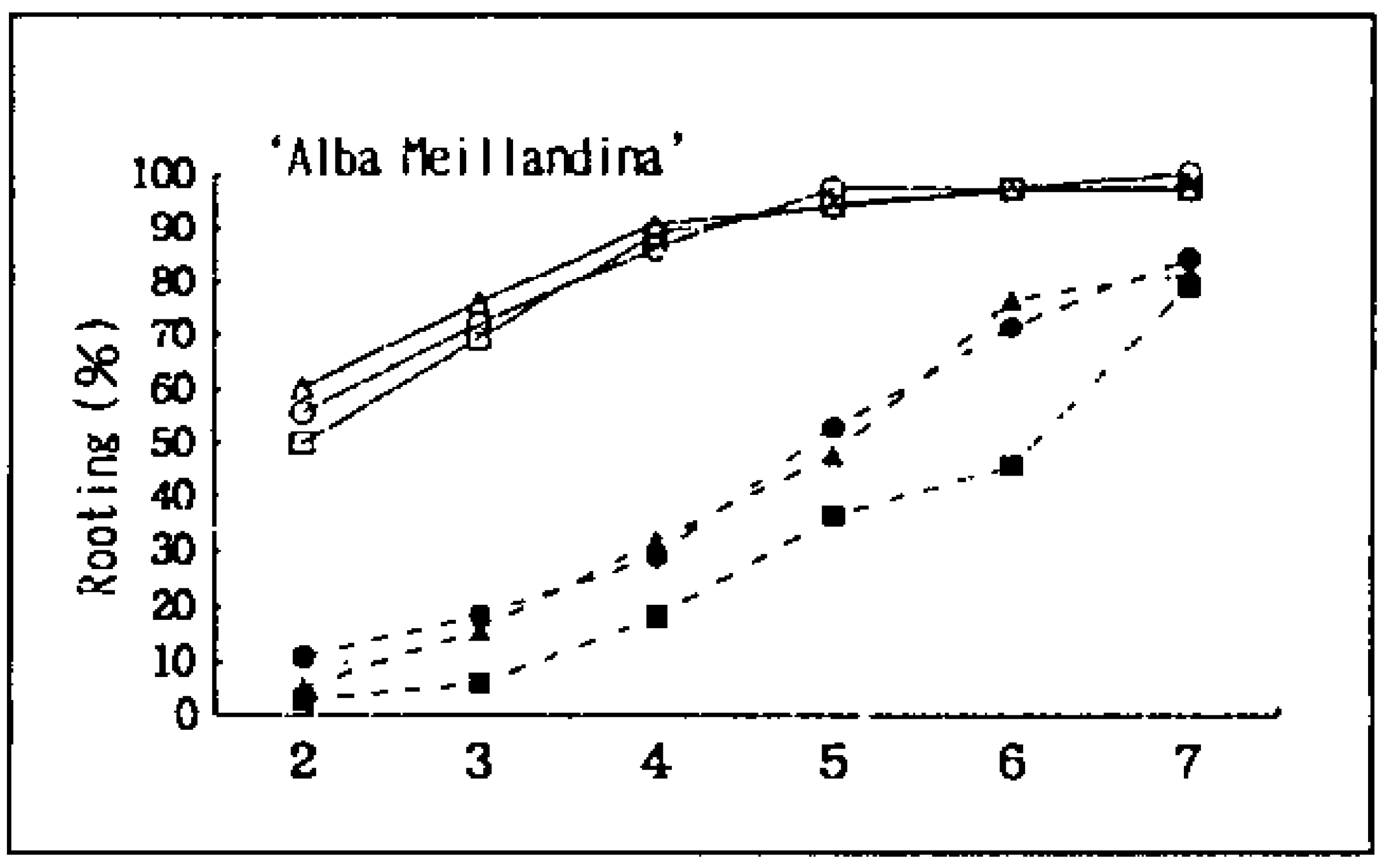

Figure 3. Change in rooting rate after rooting induction treatment.

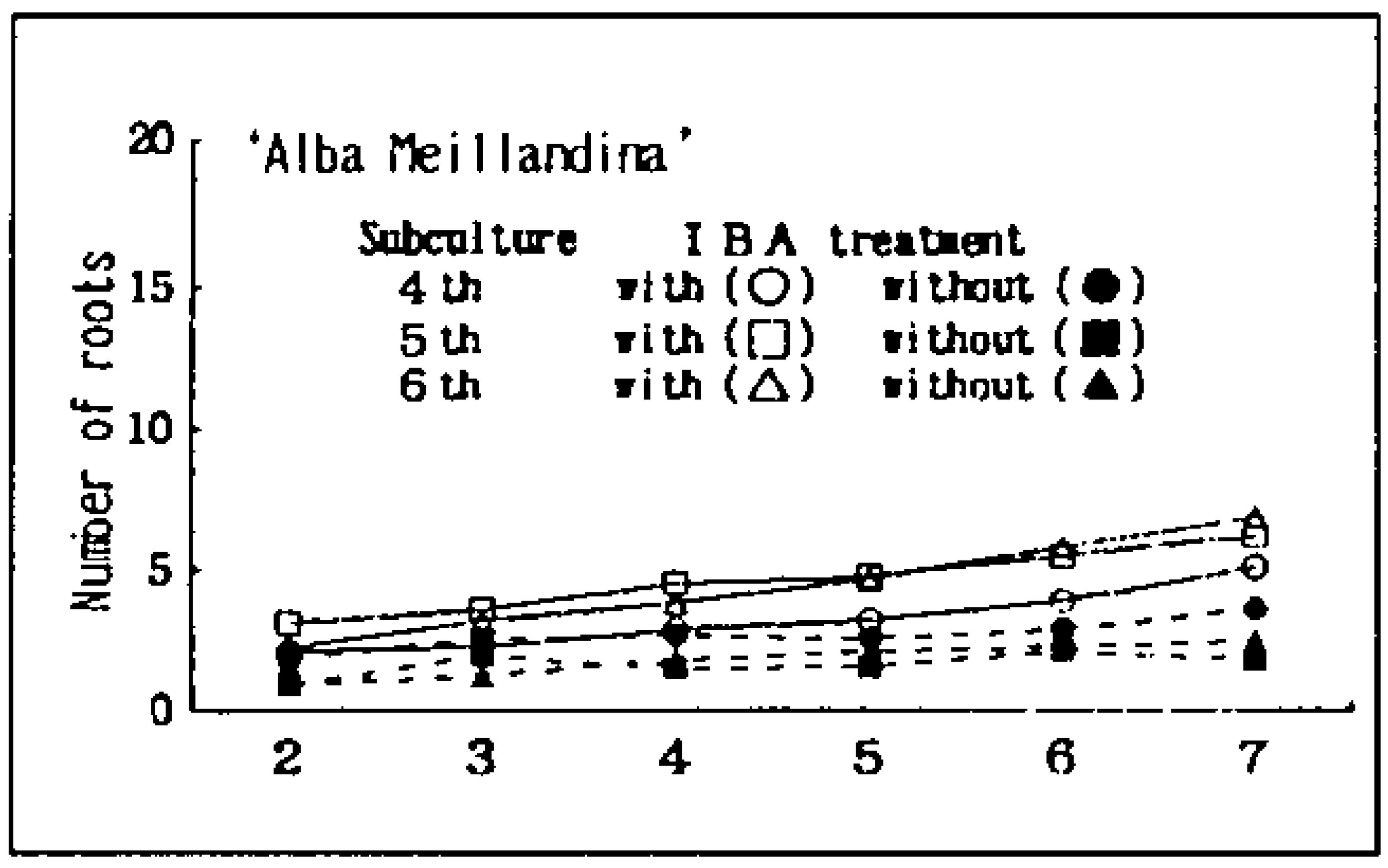

Figure 4. Change in number of roots after rooting induction treatment.

Biological Control of Fusarium Wilt of Carnation by Application of Nonpathogenic *Fusarium oxysporum*

H. Mizuno, T. Komatsu, Y. Fukano and Y. Asakura
Japan Tobacco Inc., Applied Plant Research Laboratory, 1900 Idei, Oyama, Tochigi, 323

***Fusarium* species isolated from the root tissue of carnation were screened for biocontrol activity to fusarium wilt of carnation caused by *Fusarium oxysporum* f. sp. *dianthi.* Some isolates showed suppression of fusarium wilt in carnations. The most effective isolate, No 108, was identified as *Fusarium oxysporum,* and is nonpathogenic to major crops such as tomato, radish, eggplant, and cucumber. No 108 isolate showed a 70% reduction in disease severity 16 weeks after transplanting in field trials. Pre-inoculation with No 108 isolate is considered to be a practical biocontrol agent of fusarium wilt of carnations because it is effective in field trials and nonpathogenic to major crops. Moreover, it showed protective effect when it was inoculated not only just before transplanting, but also at the cutting rooting stage.**

INTRODUCTION

Fusarium wilt caused by *Fusarium oxysporum* f. sp. *dianthi* is one of the most serious diseases worldwide in carnation culture (Garibaldi, 1979). Steam disinfection and chemical fumigants, such as chlorpicrin, are commonly used to protect against this disease. But these methods are somewhat unreliable, eliminate the antagonistic microflora that normally inhibit this pathogen, and excess application of chemical fumigants causes soil and air pollution. The application of antagonistic microorganisms was examined to develop a new control system in harmony with the natural environment.

MATERIALS AND METHODS

Isolation of *Fusarium* Species and Screening in Pot Tests. Isolates of *Fusarium* species, isolated from carnation roots using Komada medium (Komada and Ogawa, 1980), were screened for biocontrol activity to fusarium wilt of carnation, by dipping the roots of rooted cuttings (cv. Lena) into the bud-cell suspension (10^7 bud-cells ml^{-1}) of each isolate just before transplanting. Rooted cuttings pre-inoculated with tested *Fusarium* species were transplanted into 18-cm-diameter pots containing soil infested with the pathogen (10^4 spores per g dried soil). Five plants were transplanted into each pot and grown in a glasshouse at 28C. Control plants were dipped in distilled water. Twenty plants were examined for each treatment. The plants were examined for symptoms of fusarium wilt every 7 days after transplanting.

The index of symptoms was recorded as follows: 0, no external symptoms; 1, chlorotic leaves or crooked neck shoots; 2, widespread light wilting or partially severe wilting; 3, widespread severe wilting; and 4, complete wilting (death).

$$\text{Disease severity} = \frac{\text{Sum of index value (0-4)}}{\text{Number of tested plants} \times 4} \times 100$$

$$\text{Protective value} = \frac{\text{(Disease severity in untreated control)} - \text{(Disease severity in pre-inoculated with tested isolates)}}{\text{(Disease severity in untreated control)}} \times 100$$

Field Trial. A field trial was conducted in the soil bed of a glasshouse with the same No 108 isolate utilized in the pot test. The same method and inoculation concentration were used as in the pot test. The carnation cultivar and pathogen infestation level were also the same as in the pot test. The trial was carried out over 6 months from May to November.

Effect of Inoculation at Cutting Sticking Stage. The bud-cell suspension of No. 108 isolate was sprayed on cuttings prior to rooting. They were rooted, stored at cool conditions (0 to 1C) for 2 weeks, and then transplanted into pots containing pathogen-infested soil. Plants were cultivated in a glasshouse at 28C.

RESULTS AND DISCUSSION

Selection of Effective Isolate to Fusarium Wilt of Carnation. The protective use of *Fusarium* species against fusarium wilt has been widely reported (Garibaldi, 1987; Ogawa 1984; Tezuka, 1991). In this experiment, more than 100 isolates of *Fusarium* species were isolated and tested for their biocontrol activity on fusarium wilt of carnations. Some isolates showed biocontrol activity. The patterns of protective effect in tested isolates were classified into three groups:

1) The isolates in which the effect was maintained for a long time;
2) The isolates in which the effect was shown for only a short time;
3) The isolates in which no protective effect was shown (Fig. 1).

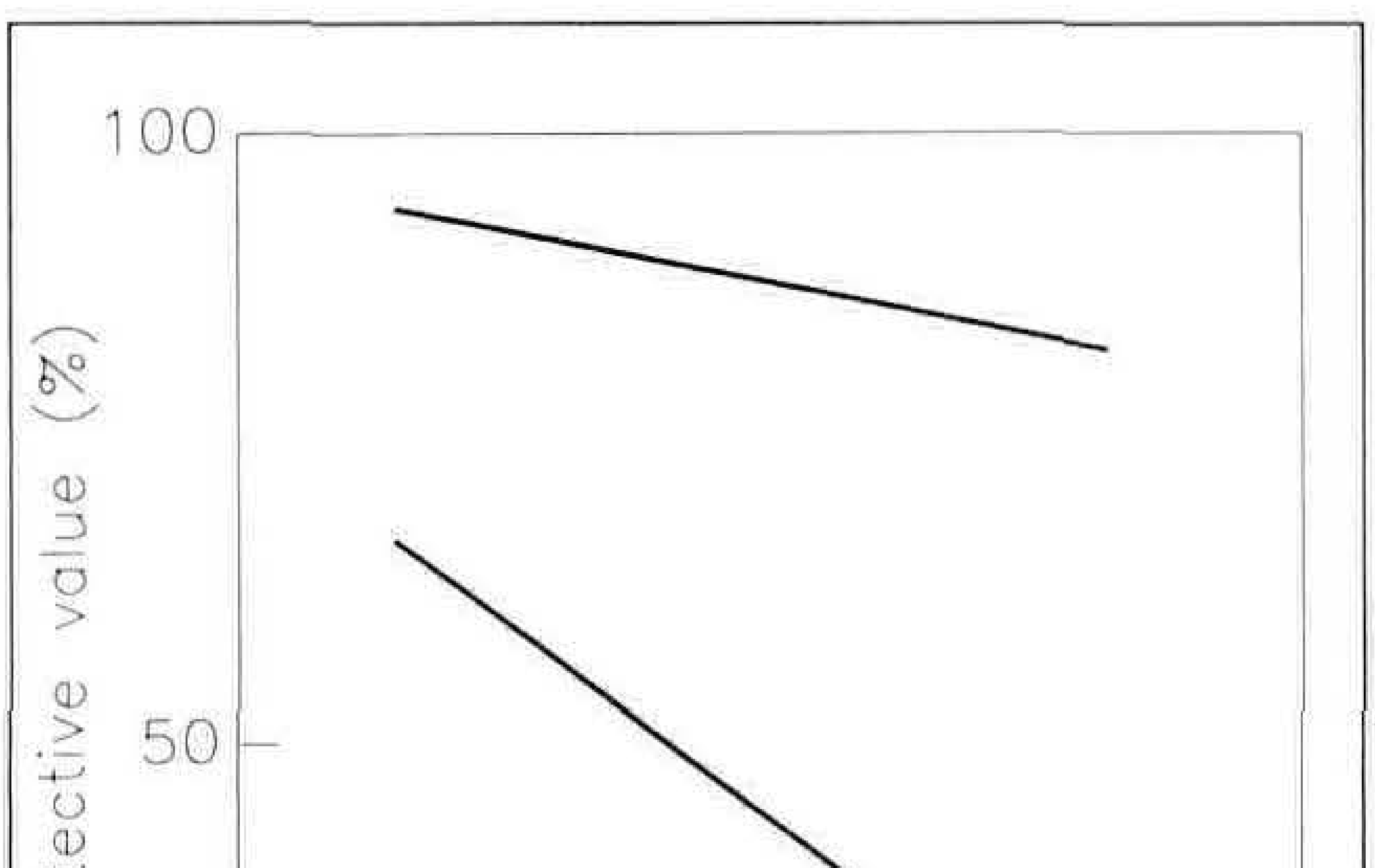

Figure 1. Three patterns of protective effects with tested isolates.

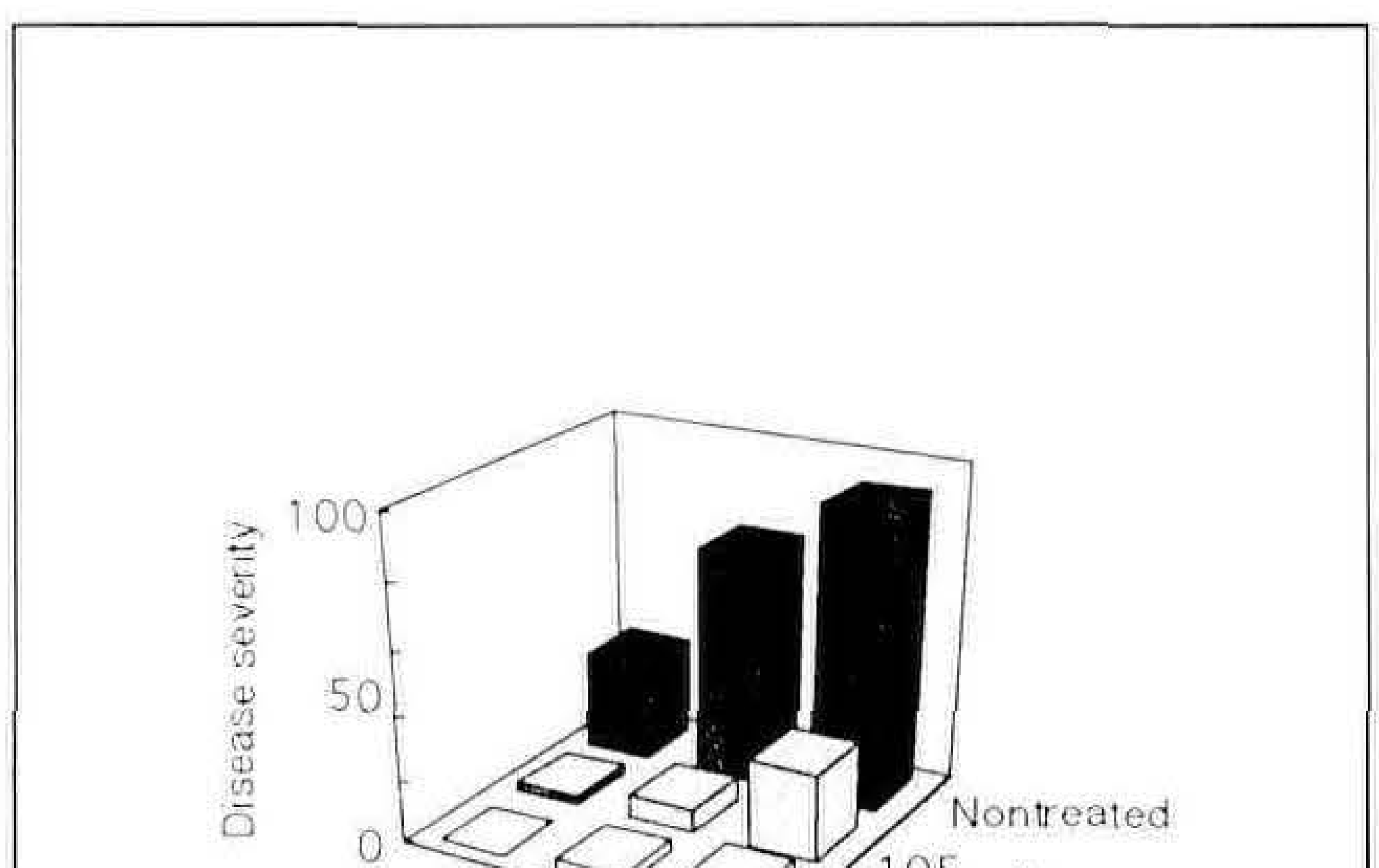

Figure 2. The effects of selected isolates in pot tests.

The most effective isolate, No. 108, showed 80% protection even 15 weeks after transplanting in a pot test (Fig. 2). No. 108 isolate was identified as *F. oxysporum* by microscopic test, and confirmed by inoculation tests to be nonpathogenic to major crops (such as tomato, radish, eggplant, and cucumber).

Field Trial. The effect of the No.108 isolate was examined in a glasshouse under near normal growing conditions. In control plants, 100% of the tested plants showed disease symptoms, and disease severity reached 60 at 10 weeks after transplanting. In contrast, in pre-inoculated plants with No.108 isolate, only 20% of tested plants showed disease symptoms and disease severity was low. The protective value of No.108 isolate was maintained for a long time and registered 70% at 16 weeks after transplanting (Figs. 3 and4). Therefore, it may be concluded that No. 108 isolate is able to be applied in practical conditions as a biocontrol agent.

Effect of Inoculation at Cutting Rooting Stage. No. 108 isolate showed a protective effect when it was inoculated not only just before transplanting, but also at cutting stage (Table 1). In the future, rooted carnation cuttings resistant to fusarium wilt may be pre-inoculated with No. 108 isolate at cutting sticking stage. An examination of the effect of application at cutting rooting stage in field trials will be needed for practical use.

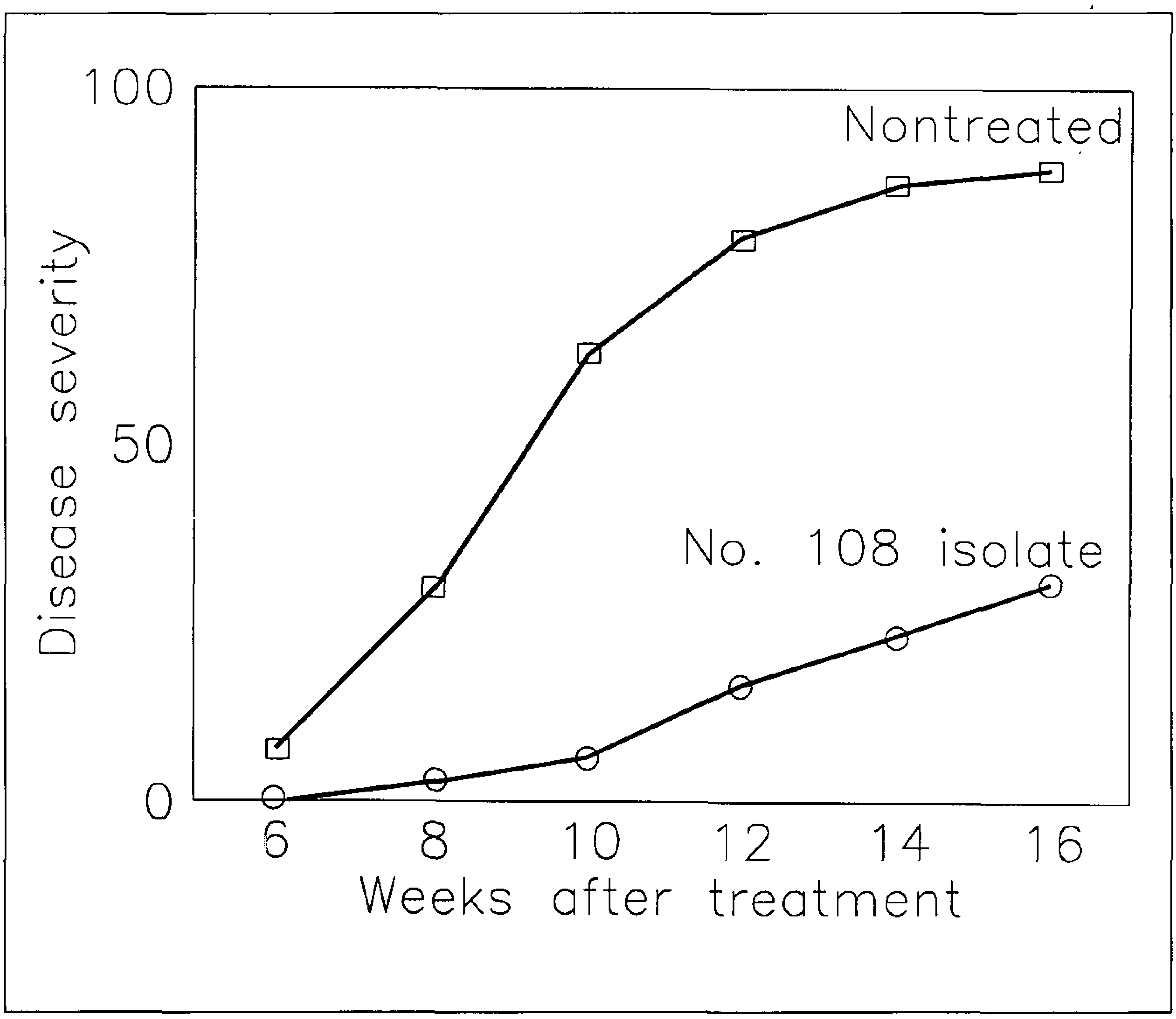

Figure 3. The effect of No. 108 isolate in a field trial.

Figure 4. The effect of pre-inoculation with No. 108 isolate in a field trial 10 weeks after transplanting (left: pre-inoculation with No. 108; right: control).

Table 1. The effect of isolate No. 108 on disease severity of carnation cuttings inoculated at pre and post rooting stages.

Time of treatment	No. of tested plants	No. of diseased plants	Diseased plants (%)[z]	Disease severity	Protective value (%)
Cutting sticking[x]	15	4	26.7	10.0	88.5
Cutting rooted[y]	12	2	16.7	10.4	88.0
Non-treated	15	14	93.3	86.7	NIL

[x] 2 liters of bud cell suspension (10^6 bud cells ml^{-1}) was sprayed on 100 rooted cuttings.
[y] The roots of the rooted cuttings were dipped in the bud cell suspension (10^6 bud cells ml^{-1}) for 30 min.
[z] Values represent the results 12 weeks after transplanting.

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Propagation of *Gladiolus* by Somatic Embryogenesis

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Suspension callus was induced from gladiolus cormels after sprouting under aseptic conditions. Suspension callus was induced on a culture medium containing NAA with the best results obtained using a medium with NAA at 10 mg litre-1. A good rate of regeneration was obtained from suspension callus induced in culture medium containing 5 mg litre-1 NAA when regenerated in a hormone-free culture medium and also with suspension callus induced in a culture medium containing 10 mg litre-1 NAA and regenerated in a culture medium containing 0.1 mg litre-1 BA. Suspension callus was subcultured for more than a year and maintained its embryogenic ability.

INTRODUCTION

Gladiolus is an iridaceous plant grown for ornamental and cut flower uses. In the "old days" selective breeding was done by hobbyists. Now new plant cultivars are introduced by seed companies. Propagation by peduncle, lateral bud, cormel apex, a leaf piece, ovary, virus-free explants, and cormel cultivation has been reported (Ziv et al., 1970; Simonsen et al., 1971; Hussey, 1975; Hussey, 1977; Takatsu, 1982; Logan et al., 1985; Sutter, 1986; Dantu et al. 1987; De Bruyn and Ferreira 1992). However, regeneration by suspension callus has not been reported. We report on the development of a suspension callus micropropagation method of high regeneration ability with gladiolus. This programme is effective for the propagation of plants following induced somatic cell variation.

MATERIAL AND METHODS

Plant Material. Explants were obtained from cormels of *Gladiolus* 'Traveller'. The cormels were sterilized with 70% ethanol for several sec after the dry papery covering of the cormel was peeled away with tweezers. These were next sterilized in Antiformin solution of 1% chlorine for 20 min, and then washed in sterile water three times for 5 min each time. Explants were placed on Murashige and Skoog (MS) (1962) culture medium containing 3 g litre^{-1} sucrose and 2 g litre^{-1} Gelan Gum. The medium was adjusted to pH 5.8 before autoclaving. Cultures were incubated at 25C, and light was provided by warm white fluorescent tubes for 16 h daily at 4000 lux. Any cormel whose leaves grew 5 to 10 cm was used for suspension callus induction.

Induction of Suspension Callus. The suspension-callus induction medium consisted of MS basal salts and vitamins supplemented with 3 g litre^{-1} sucrose and 0, 5, 10, 15, or 20 mg litre^{-1} NAA. The medium was adjusted to pH 5.8 before autoclaving. For each cormel explant the leaf was cut 1 cm above the cormel and the cormel halved horizontally (Fig. 1). The upper parts of the cut cormels were put in flasks containing 30 ml of medium with one explant per flask and incubated on a shaker at 120 rpm at 25C. Light was provided by warm white fluorescent tubes for 16 h daily at 4000 lux. They were incubated for 8 weeks.

Regeneration Condition. Quantities of suspension callus tissue equivalent to 0.1 ml packed cell volume were placed uniformly on sterilized filter paper (55 mm in diameter). The medium consisted of MS basal salts and vitamins supplemented with 3 g $litre^{-1}$ sucrose and 0 to 1.0 mg $litre^{-1}$ BA. The medium was adjusted to pH 5.8 before autoclaving. The filter paper with suspension callus was placed on the medium in disposable petri dishes. These were incubated at 25C, and light was provided by warm white fluorescent tubes for 16 h daily (4000 lux).

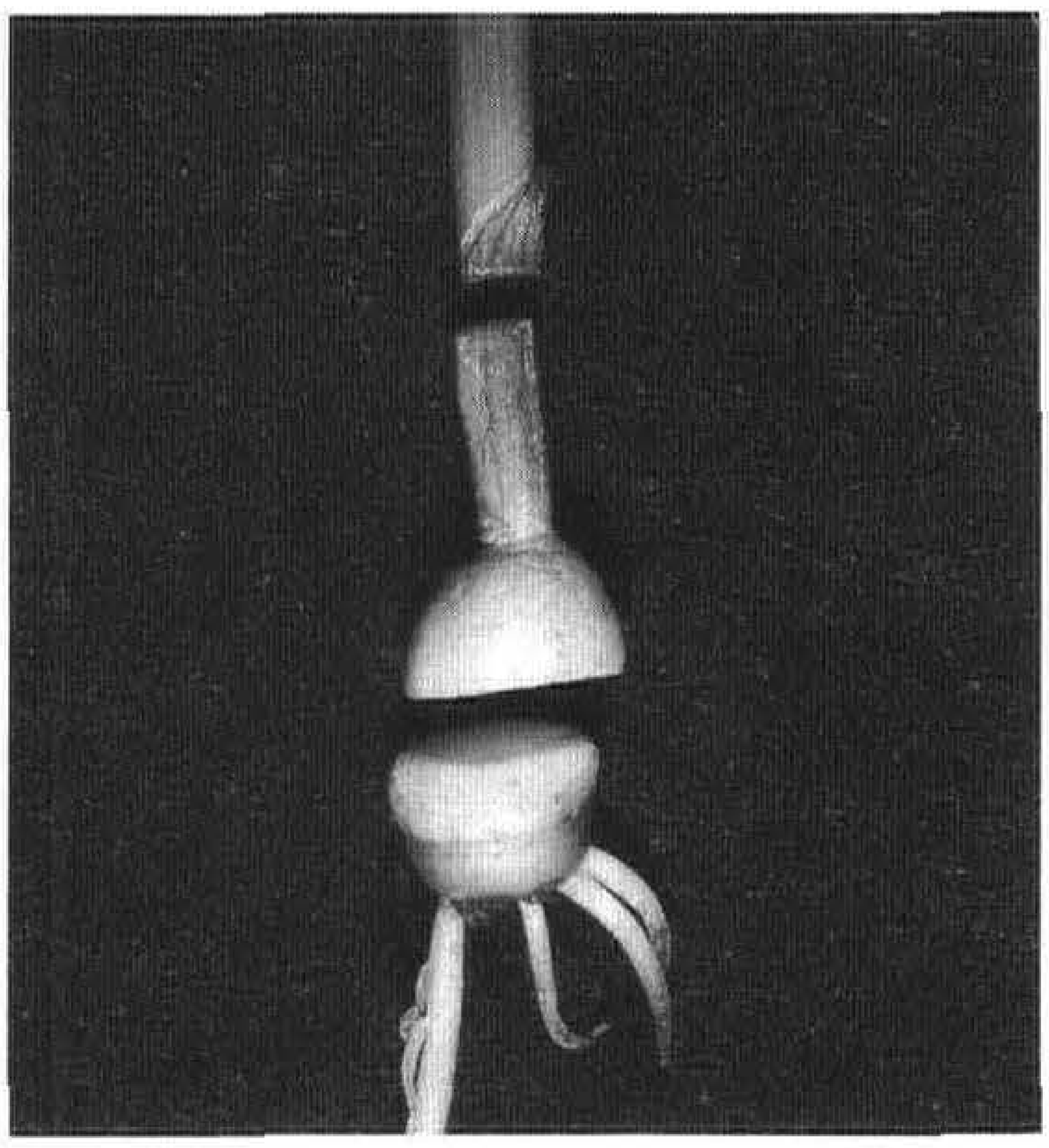

Figure 1. Explant preparation for callus induction.

Examination of Subculture. Suspension callus was washed in new induction medium. Flasks containing 30 ml of medium with 0.1 to 0.5 g of suspension callus were incubated on a shaker at 120 rpm at 25C. Light was provided by warm white fluorescent tubes for 16 h daily (4000 lux). These were investigated regularly for signs of increase.

RESULTS AND DISCUSSION

Suspension callus was induced at the apex of the cormel, at the junction of cormel and leaf (Fig. 2). The greatest amount of suspension callus induced was on the

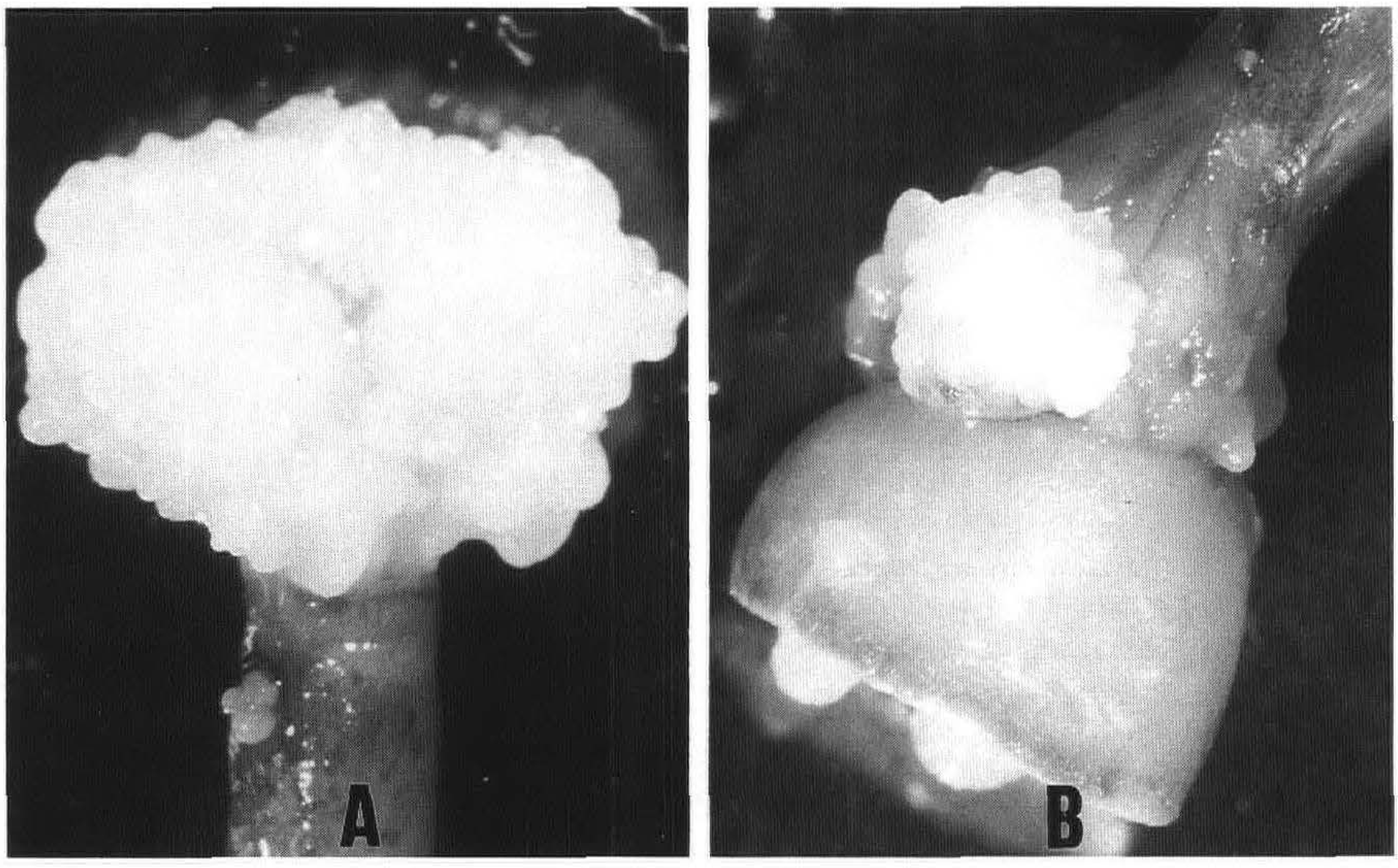

Figure 2. Development of callus on explant: (A) Callus induced in the region of the leaf; (B) Callus induction in the leaf stem and cormel region.

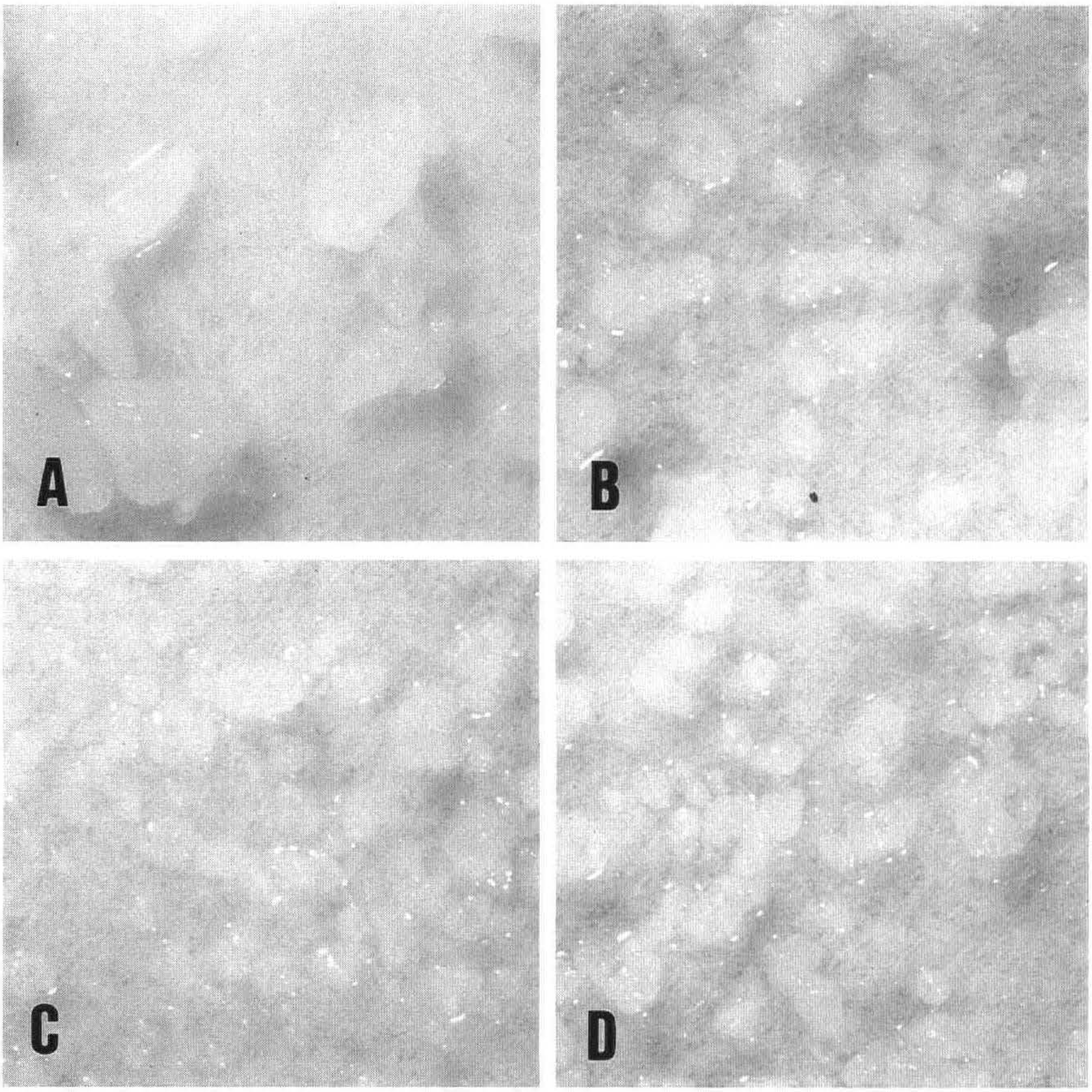

Figure 3. Suspension callus induced on media containing: (A) 5 mg litre^{-1} NAA; (B) 10 mg litre^{-1} NAA; (C) 15 mg litre^{-1} NAA; and (D) 20 mg litre^{-1} NAA.

medium with 10 mg litre^{-1} NAA (Table 1). The medium with 20 mg litre^{-1} NAA produced an uneven rate of increase. Suspension callus induced in the culture medium with 5 mg litre^{-1} NAA was largest in amount, with suspension callus induced in culture medium with 10 and 20 mg litre^{-1} NAA smaller (Table 1, Fig. 3). In the culture medium without added hormone, there was no suspension callus produced and rooting of the apical bud was noted. Suspension callus was regenerated in all regeneration culture medium. Regeneration was obtained through somatic embryos like those described by Stefaniak (1994) (Fig. 4). Good rates of regeneration of the suspension callus were obtained from the induction culture medium containing 5 mg litre^{-1} NAA and regenerated on medium with no hormone in the regeneration medium. Good rates were also achieved in the culture medium containing 10 mg litre^{-1} NAA and regeneration culture medium containing 0.1 mg litre^{-1} BA (Table 2). The rate of increase of suspension callus when 0.1 g was used as the cell mass produced the best results (Table 3). When a cell mass of 0.5 g was subcultured, it turned brown. Suspension callus was subcultured in this way for more than a year and maintained its regeneration ability.

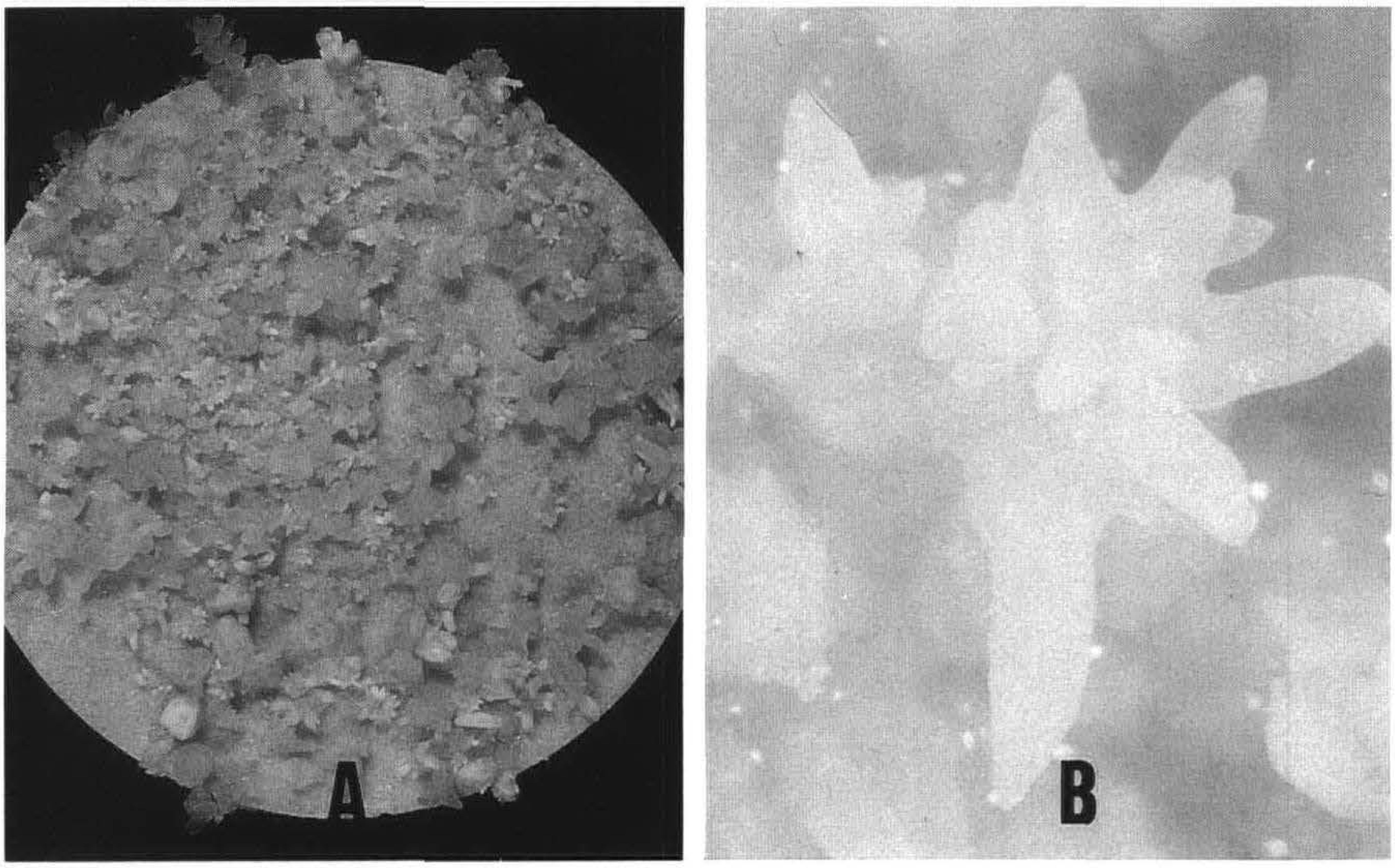

Figure 4. Regeneration of suspension callus: (A) After 3 weeks on regeneration culture medium; (B) Closeup of embryo formation.

Table 1. Effect of NAA concentration on induction of suspension callus from cormel explants[a].

NAA (mg litre^{-1})	Weight of suspension callus (g per flask)	Average size of suspension callus (mm)	Note
0	0.00	-	Rooting of apical bud
5	1.08	2.31	
10	1.49	0.87	
15	1.23	0.67	
20	0.75	0.99	

[a] 100 ml flask, medium 30 ml, 8 weeks after culture.

Table 2. The effect of NAA concentration in the induction medium and BA concentration of regeneration culture medium on somatic embryogenesis[a].

Induction medium NAA(mg litre^{-1})	Regeneration medium BA(mg litre^{-1})	Somatic embryos per g
5	0	224.1
	0.1	120.0
	0.5	102.0
	1.0	132.0
10	0	102.0
	0.1	198.0
	0.5	156.0
	1.0	111.0
15	0	88.9
	0.1	104.2
	0.5	110.9
	1.0	49.0
20	0	60.0
	0.1	90.0
	0.5	60.0
	1.0	60.0

[a] 3 weeks after culture on regeneration medium.

Table 3. Effect of suspension callus inoculation amount on suspension callus production 3 weeks after subculture[a].

Suspension callus inoculum (g)	Weight of suspension callus 3 weeks after subculture (g)	Increase rate (b/a)
0.1	1.61	161
0.3	2.97	99
0.5	3.40	68

[a] Inoculum from MS + 10 mg/l NAA, medium 30 ml per flask (100 ml), suspension callus induced from corm with MS +10 mg litre^{-1} NAA.

ACKNOWLEDGMENTS

I am profoundly grateful for all who have helped with advice for this study, and the assistance given by the staff of the research laboratory with these experiments.

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Low Temperature Storage of In Vitro Shoots of Japanese Persimmon (*Diospyros khaki*)

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In vitro storage at low temperatures was applied to the shoot segments of Japanese persimmon (cultivars Fuyu and Nishimurawase) that were proliferated through shoot tip culture. At 2C storage temperature, preconditioning of the shoot segments on a medium of 60 g litre-1 sucrose showed high viability. In the case of 10C storage, however, preconditioning on a medium of 15 g litre-1 sucrose maintained the best viability. The shoot segments of 'Nishimurawase' survived for 30 weeks at 10C, while those of 'Fuyu' lived for 12 weeks at the same storage temperature. The results of this work establish the possibility of an in vitro gene bank for Japanese persimmon.

INTRODUCTION

The maintenance of valuable plant genotypes of woody fruit trees in an orchard is costly and involves a considerable investment in labour, land area, and materials. The use of in vitro repositories for the maintenance of valuable plant genotypes offers a number of advantages but subculturing can be costly. The use of low temperatures for long-term storage of cell and organ cultures has been applied successfully to a number of species (Mullin and Schlegel, 1976; Monette, 1986; Borkowska; 1990) and reduces the cost of subculturing. Using in vitro techniques we have established and proliferated 102 cultivars (Fukui et al., 1990) of Japanese persimmon (*Diospyros khaki*). The objective of the present study was to determine the suitability of storage at low temperatures on cultures of Japanese persimmon.

MATERIALS AND METHODS

Shoot segments of Japanese persimmon (cultivars Fuyu and Nishimurawase), produced by shoot-tip culture (Fukui et al., 1989) on a modified MS medium (½ N, 1 μM zeatin, 30 g litre^{-1} sucrose, 8 g litre^{-1} agar), were used in the following experiments.

Experiment 1: Effects of Preconditioning on the Viability of Shoot Segments After Cold Storage. For preconditioning, the shoot segments of 'Fuyu' were cultured on a basal medium (½ N, 1 μM zeatin, 8 g litre^{-1} agar) containing 15, 30, or 60 g litre^{-1} sucrose for 6 weeks at 25C with a 16 h photoperiod under 3000 lx. Shoot segments cut from the preconditioned shoots were placed on the basal medium containing 15 or 30 g litre^{-1} sucrose, and were stored for 6 weeks at 2 or 10C in the dark. Upon removal from storage the explants were transferred onto the basal medium with 30 g litre^{-1} sucrose, and were examined for viability by culturing them for 6 weeks at 25C with a 16 h photoperiod under 3000 lx.

Experiment 2: Low Temperature Storage of Shoot Segments. Shoot segments of 'Fuyu' and 'Nishimurawase' were preconditioned for 6 weeks at

25C with a 16-h photoperiod under 3000 lx on the basal medium with 15 g $litre^{-1}$ sucrose. The preconditioned shoot segments were placed on the basal medium with 30 g $litre^{-1}$ sucrose and stored for 42 weeks at 10C in the dark. After 6, 12, 18, 30, and 42 weeks of cold storage, the shoot segments were removed and cultured at 25C with a 16-h photoperiod under 3000 lx and checked for viability after 6 weeks.

RESULTS

Effect of Preconditioning on Viability During Cold Storage. Table 1 shows the effect of preconditioning on viability after cold storage. The number of elongated shoot explants after storage at 2C increased with increasing sucrose concentration during preconditioning. The number of brown or dead explants decreased as the sucrose concentration was increased. Therefore, the viability in storage at 2C increased as the sucrose concentration increased. However, after storage at 10C, the presence of a high sucrose concentration for preconditioning was an inhibiting factor because it increased the number of explants without growth. Therefore, while a sucrose concentration of 30 g $litre^{-1}$ during storage at 2C enhanced the viability of explants as compared with the 15 g $litre^{-1}$ sucrose concentration, there was no effect under 10C storage. The explants preconditioned at a 15 g $litre^{-1}$ sucrose concentration and stored at 10C on the media with 15 or 30 g $litre^{-1}$ sucrose showed the least mortality and highest viability.

Table 1. Effect of preconditioning on viability after cold storage.

Storage temp. (°C)	Sucrose conc. (g $litre^{-1}$) Precondi-tioning	Storage	No. of shoot elongated explants	No. of explants without growth	No. of browning or dead explants	Shoot length (mm)
2	15	15	3	0	17	12.0[1]
		30	5	1	14	12.2
	30	15	9	0	11	10.6
		30	12	2	6	8.8
	60	15	12	1	7	10.9
		30	18	1	1	13.7
10	15	15	19	0	1	11.3
		30	19	0	1	12.8
	30	15	14	2	4	9.5
		30	17	3	0	7.1
	60	15	15	4	1	9.2
		30	12	5	3	7.6

[1] Average length of elongated shoot from viable explant.

Low Temperature Storage. With 'Nishimurawase', all of the stored explants survived for up to 18 weeks. The survival of the shoots declined substantially after storage for 30 weeks and fell to 15% after 48 weeks of storage. Survivals with 'Fuyu' was 100% up to 6 weeks of storage; declined to about 80% during 12, 18, and 30 weeks in storage; and eventually fell to 15% after 48-weeks storage.

Storage duration had a marked effect on the growth of shoots. Figure 1 shows the viability after culture for 6 weeks at 25C followed by 0, 6, 12, 18, 30, and 42 weeks in storage. The viability of 'Nishimurawase' explants was higher than that of ' Fuyu'. The shoot length after 12 weeks of storage was 19 mm in 'Nishimurawase', which was almost the same as the shoot length from non-stored explants. The viability after 18-weeks storage declined gradually and the explants after 42 weeks of storage had no viability. The shoot length of 'Fuyu' declined with longer storage, and explants stored over 18 weeks had no viability.

DISCUSSION

The in vitro storage of pathogen-free plantlets at low temperature has been established in several plant species (Monette, 1986; Borkowska, 1990). In strawberries, for example, more than 50 cultivars have been maintained for up to 6 years at 2C (Mullin and Schlegel, 1976). The temperature for in vitro storage was different for each plant species. For strawberries (Mullin and Schlegel, 1976) and sour cherries (Borkowska, 1990), 4 to 5C was favourable for long-term storage,

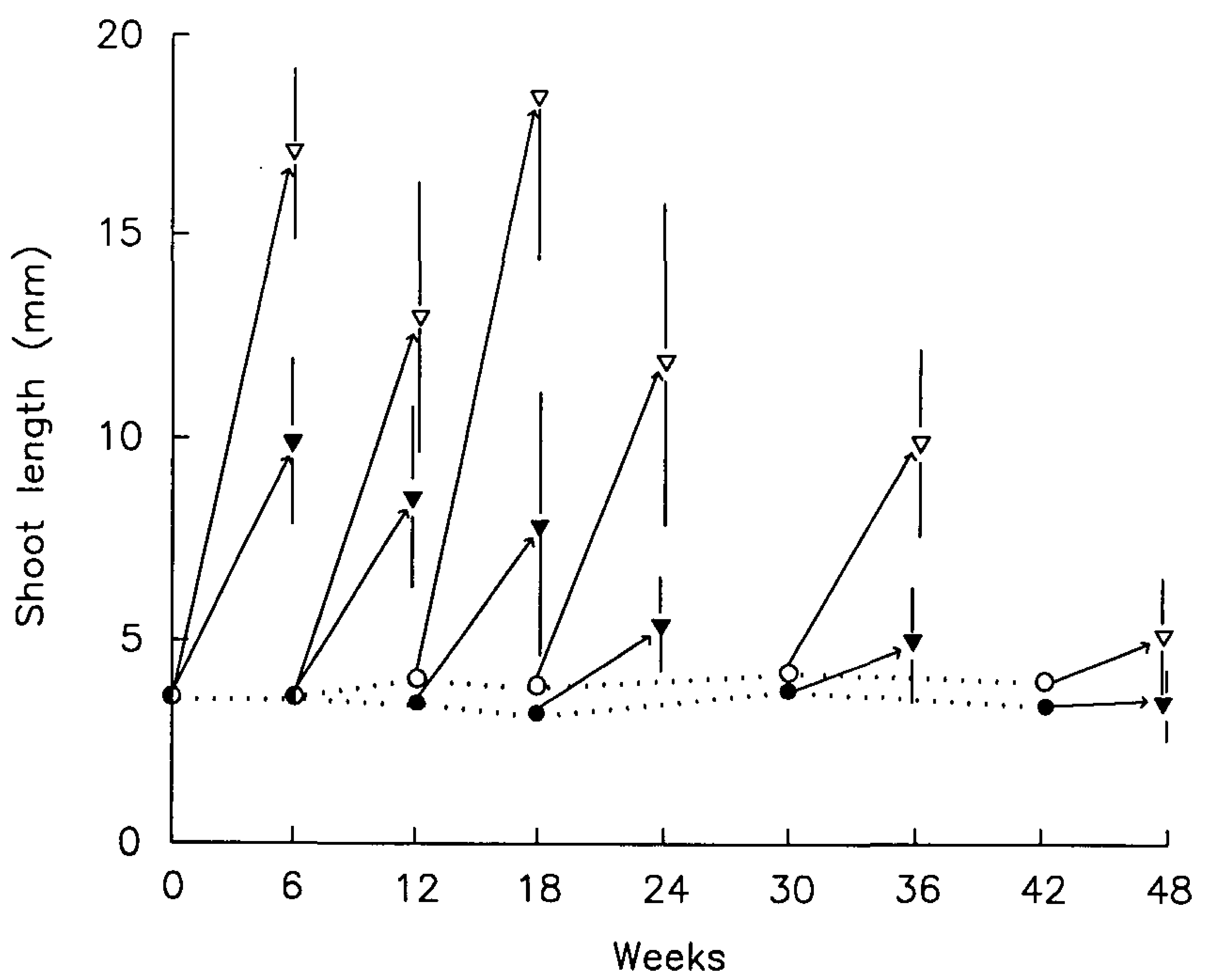

Figure 1. Shoot length of Japanese persimmon cv. Fuyu (•) and cv. Nishimurawase (○) shoot segments stored in vitro at 10C, and shoot elongation of Fuyu (▾) and Nishimurawase (▿) by culturing for 6 weeks at 25C after storage.

while 8C was best for kiwifruit. In this study, the shoot segments of Japanese persimmon survived at 10C and browned at 2C. This difference in appropriate storage temperatures might be related to the cold hardiness of each plant, and Japanese persimmon might have little cold hardiness. Bannier and Steponkus (1972) reported that the cold hardiness of in vitro plantlets was influenced by preconditioning. In the present study, the viability of Japanese persimmon after storage at 2C increased as the sucrose concentration increased during preconditioning. The preconditioning for the increase of cold hardiness, therefore, was effective in Japanese persimmon. We attempted the low temperature storage of Japanese persimmon cultivars Fuyu and Nishimurawase. The viability of 'Nishimurawase' was maintained at a high level for up to 30 weeks, but the viability of 'Fuyu' declined after 18 weeks. The bud-burst date of 'Nishimurawase' is earlier than that of 'Fuyu' and 'Nishimurawase' shows cold resistance in orchards. Therefore, we concluded that 'Nishimurawase' had a higher cold hardiness in vitro in comparison with Fuyu. A cultivar difference of viability in low-temperature storage was also observed in pears (Moriguchi et al., 1990). Monette (1986) succeeded in the long term storage of the shoot segments of kiwifruit, which grew a little during storage. In this study, the explants of Japanese persimmon exhibited no growth during storage at 2C or 10C. When a storage temperature over 10C (for example 15C) was applied, the explants grew a little and exhibited a high viability after long term storage.

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Selection and Germination of Tomato Seeds

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The effect of seed selection method on the germination percentage of a tomato cultivar (BF Okitsu 101) was studied. Seed characteristics such as weight, color, specific gravity, soluble protein content, and amylose enzyme activity influenced seed germination. Heavier seeds had a higher percentage of germination and cotyledon expansion and the young seedlings were more vigorous after germination. White seeds had a higher percentage of germination and cotyledon expansion than the darker and black seeds. Seeds which sank in a NaCl aqueous solution had a higher percentage of germination than those which floated. One hundred percent of the seeds selected from the 15% NaCl solution germinated. There was a positive correlation between the germination percentage and the soluble protein content and the amylase activity of the seeds.

MATERIALS AND METHODS

For selection by seed weight, 200 seeds were picked at random and classified into three groups: under 1.4 mg, 1.4 to 1.8 mg, and over 1.8 mg. For selection by seed colour, seeds were graded visually into white, medium, and black groups. Selected seeds were sown in a plug tray with 406 cells for the germination test in three replications. The seeds, covered with 1 cm of soil, were grown under five fluorescent lamps at 25C and 95% RH. The germination percentage was measured every 12 h after sowing. For selection by specific gravity, seeds were suspended in 0, 7.5, 10, and 15% (w/v) NaCl aqueous solutions and germination tests were carried out on the seeds which sank and those which floated. The seeds which sank in 15% (w/v) NaCl solution achieved 100% germination. Seeds which sank in 7.5% NaCl solution achieved 65% germination. Minerals, sugar, soluble protein, and amylose activity in these selected seeds were determined.

RESULTS AND DISCUSSION

Selection by Seed Weight. Seed germination started 3 days after sowing in each group (Fig. 1). Fifty percent of the seeds over 1.8 mg germinated after 3.7 days, and reached 89% and 100% germination after 5 and 7 days, respectively. The seeds over 1.4 mg started to germinate on the same day, but the final germination percentage was lower. The seeds under 1.4 mg germinated slowly and the germination percentage at 8 days was only 85%.

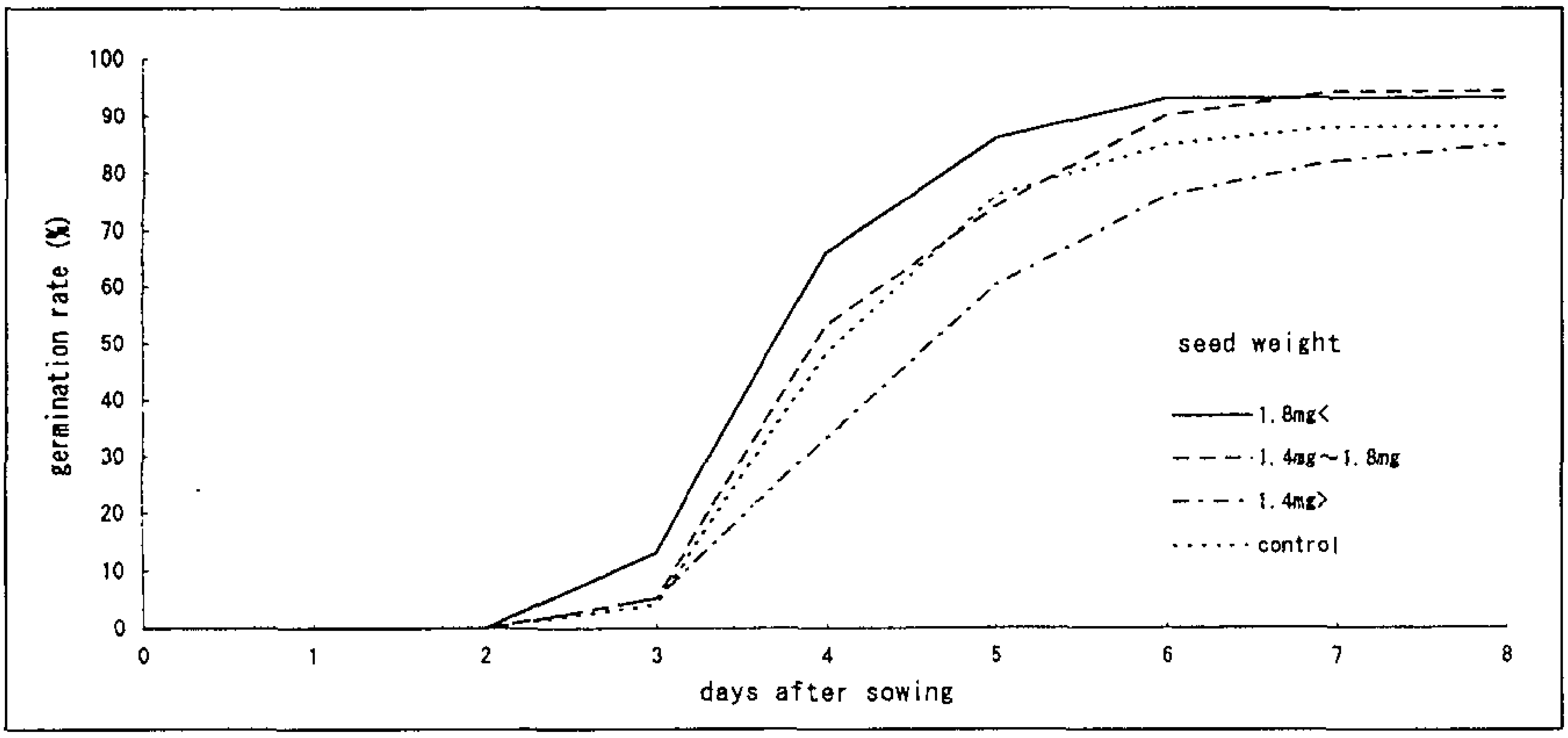

Figure 1. The correlation between germination percentage and seed weight.

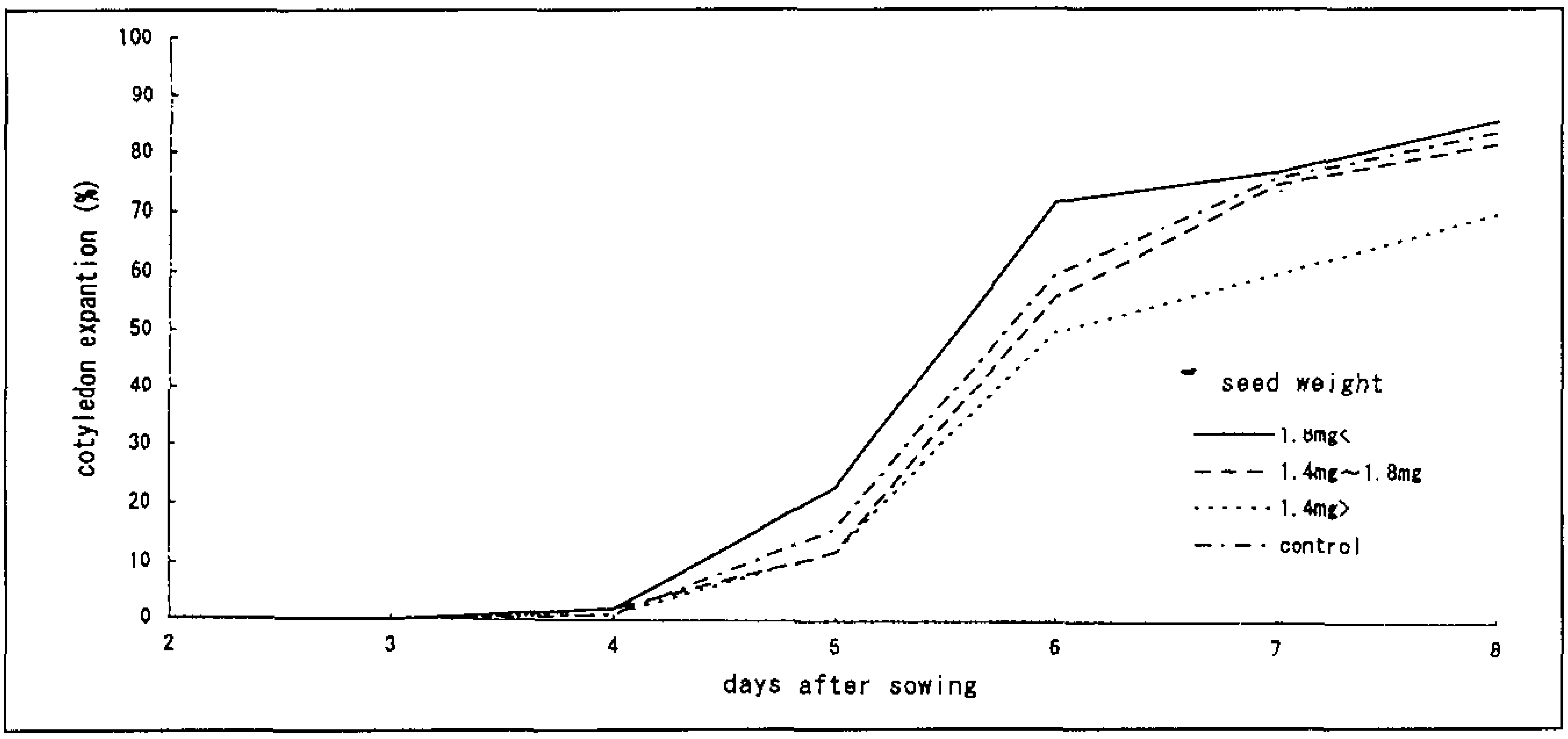

Figure 2. The correlation between cotyledon expansion and seed weight.

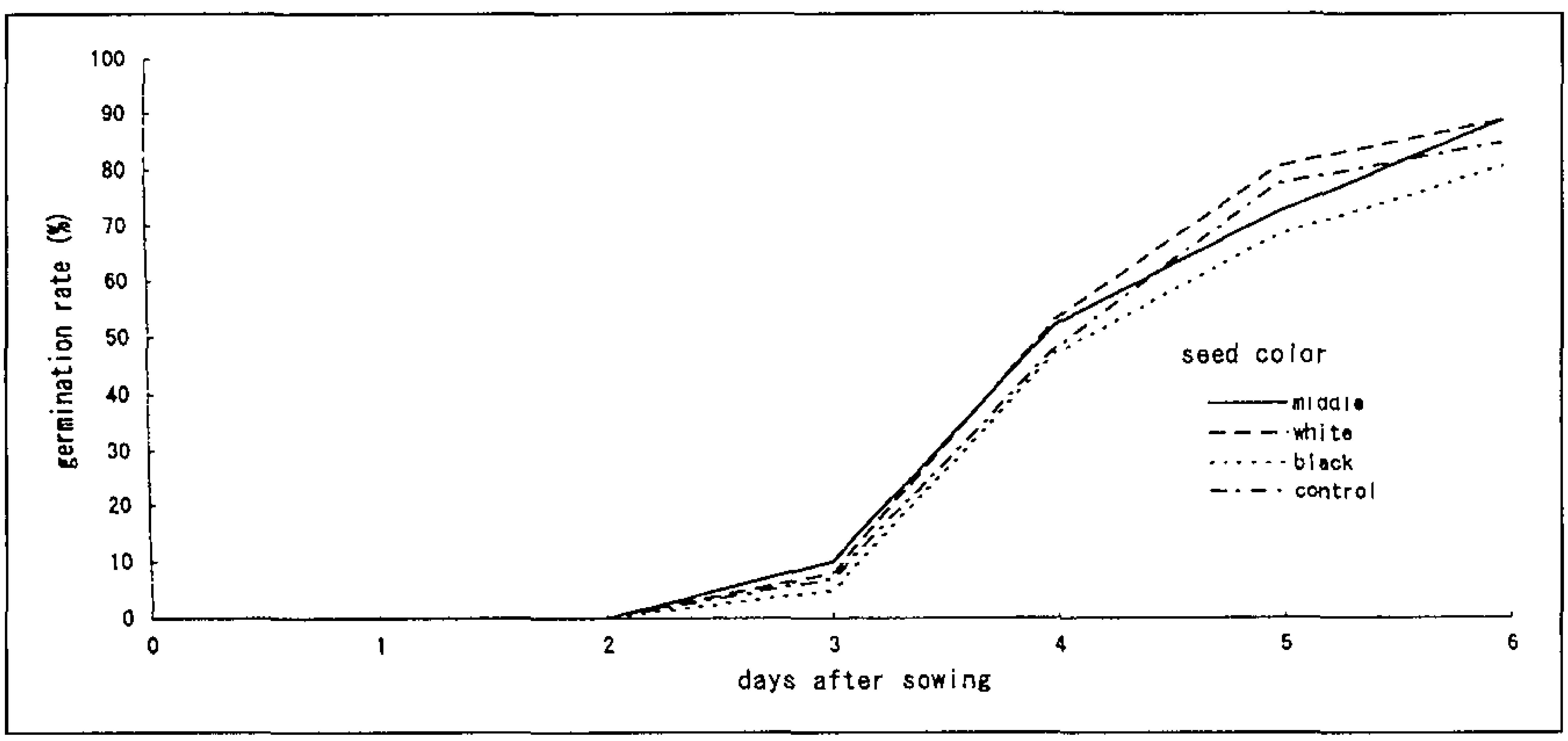

Figure 3. The correlation between germination percentage and seed color.

Cotyledon expansion started 5 days after sowing (Fig. 2). That is, the cotyledon expansion started within 2 days after germination. After 2 days of cotyledon expansion, seeds over 1.8 mg had a 15% greater cotyledon expansion than the seeds under 1.4 mg. This difference continued for 8 days after sowing.

Selection by Seed Colour. Germination started 2½ days after sowing (Fig. 3). The black seeds had a 10% lower final germination rate than the white seeds. No difference in germination was found between the medium-coloured and white seeds, and the germination rate was 50% after 4 days. The seeds started to expand their cotyledons 3½ days after sowing—that is, the leaf opened soon after germination (Fig. 4). With the progress of leaf expansion, differences in the cotyledon expansion percentage became clear and the white seeds had a higher percentage of expansion. The black seeds expanded their cotyledons slowly at 6 days, and had a lower percentage of leaf expansion. The difference in leaf expansion between the white and black seeds was about 15% at 7 to 8 days after sowing.

Selection of Seed by Specific Gravity. The germination percentage was higher in the seeds which sank in solution than those which floated, in any seed group (Table 1). The seeds selected with 15% NaCl solution especially showed complete germination (100%). The selections with 7.5% and 10% NaCl solutions seemed to eliminate the dead seeds as much as possible and germination approached 100%. This method of seed selection was considered the most effective.

Table 1. Effect of seed selection by specific gravity on germination percentage.

NaCl conc. (%)	Floated seed (%)	Germination (%) Days after seeding		
		2	3	4
15.0%	50	77	94	98
15.0%		81	100	100
10.0%	15	50	72	85
10.0%		51	93	99
7.5%	10	37	49	68
7.5%		47	93	97
0.0%	0.2	0	50	50
0.0%		29	89	98

The results of mineral and sugar contents in the 65% and 100% germinated seeds showed no big difference. The soluble protein content was relatively high at the start (Fig. 5). The soluble protein content of the 65% germinated seeds during the first 3 days was about 60% compared to that of the 100% germinated seeds. Therefore, a positive correlation was observed between the soluble protein and the germination percentage. Differences in amylase activity became greater with time and 3 days after sowing the 65% germinated seeds reached 60% activity against the 100% germinated seeds (Fig. 6). A positive correlation was recognized between the amylase activity and the germination percentage. These results suggest that

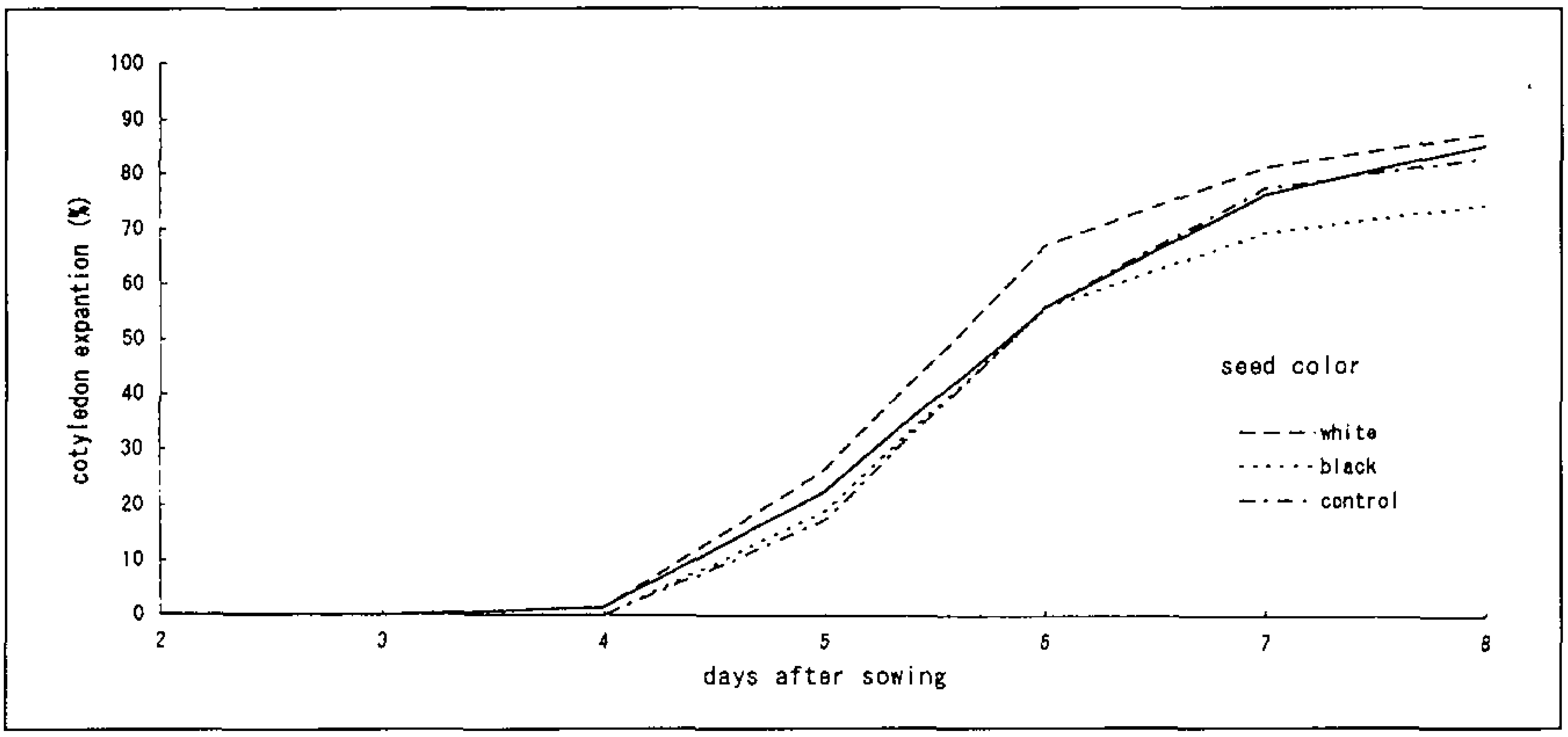

Figure 4. The correlation between cotyledon expansion and seed color.

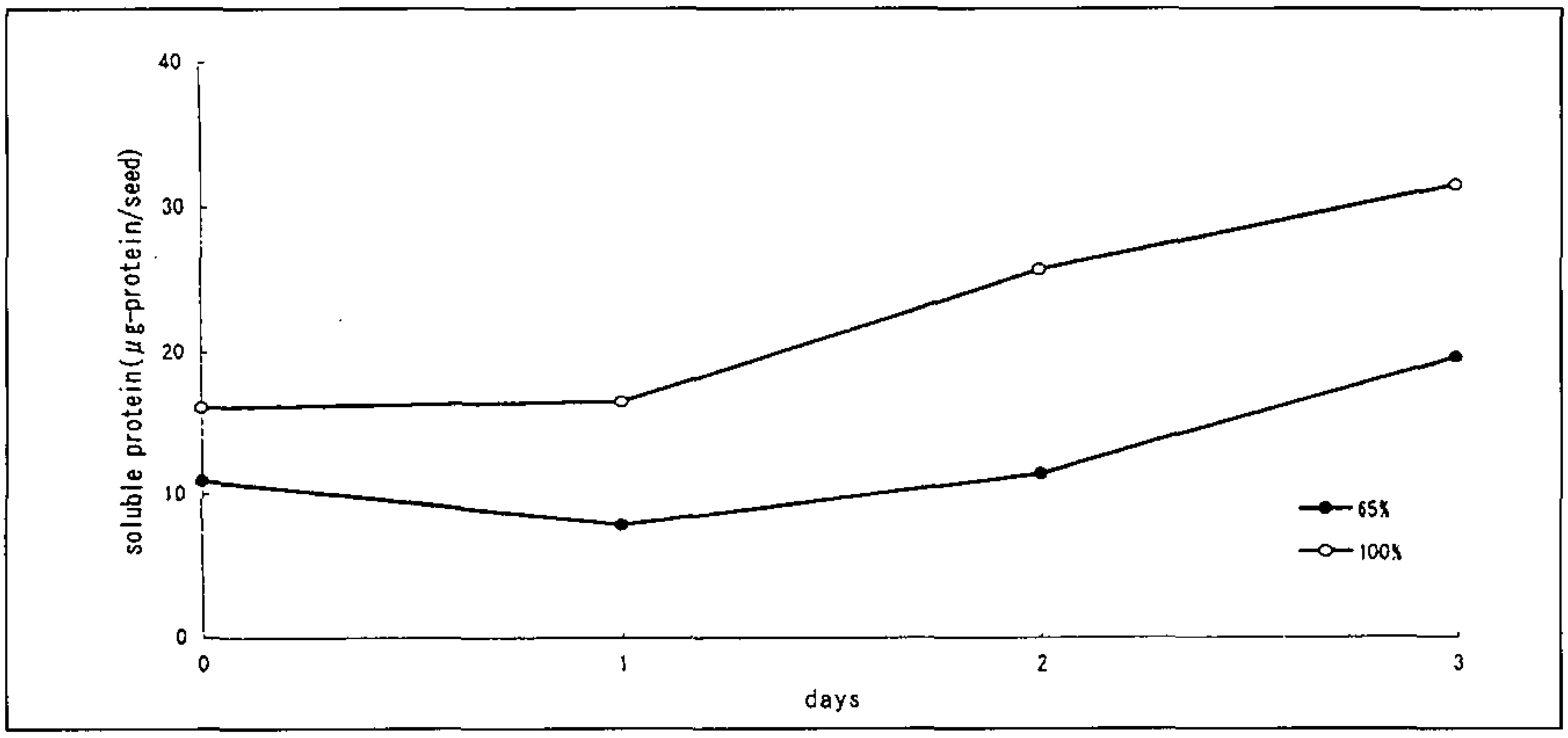

Figure 5. The correlation between soluble protein and germination percentage.

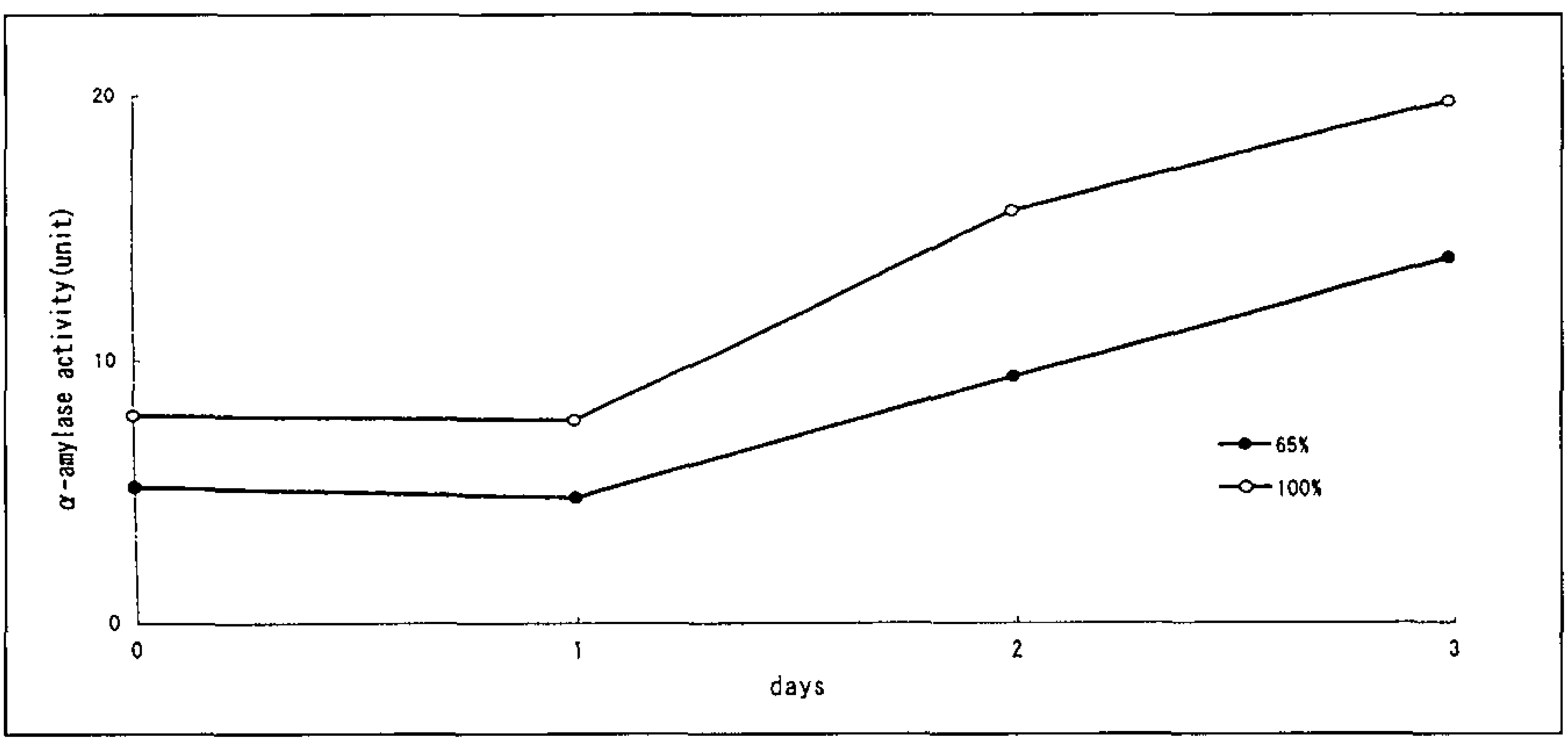

Figure 6. The correlation between α-amylase activity and germination percentage.

amylase synthesis was inhibited or the induction of amylase activity was slowed down after absorption of water by the seeds.

CONCLUSIONS

Seed characteristics such as weight, color, specific gravity, soluble protein content, and amylose enzyme activity influence seed germination. We believe that these points should be considered in selecting seeds in the future for better germination.

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Micropropagation of Crape Myrtle (*Lagerstroemia indica* L.)

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Donor plants for crape myrtle micropropagation were produced in vitro from seeds which were sown on a modified half-strength Murashige and Skoog (MS) medium. Axillary shoots were induced from the nodal segments taken from the donor plants. The shoots were transferred to the MS medium supplemented with hormones. The combination of BA (1 mg litre-1), NAA (0.02 mg litre-1), and GA_3 (0.5 mg litre-1) gave the best results for the multiplication of shoots. The multiplied shoots rooted easily in the MS medium supplemented with NAA (0.05 to 0.1 mg litre-1). By these procedures, a number of regenerated plants of crape myrtle were obtained. The potted plants were vigorous and bloomed early.

INTRODUCTION

Crape myrtle, because it blooms for a long time in summer, is a popular small tree for garden and street plantings from southern to central Japan. In addition, dwarf cultivars have been used as potted ornamental plants (Shimizu, 1992). Crape myrtle is propagated by cuttings or seed. The technique of micropropagation has been used to obtain quantities of elite clones of many plants and has the potential to be used with crape myrtle. The present paper describes the effects of hormones on the multiplication of shoots in vitro and the growth of micropropagated plants compared with those from seeds.

MATERIALS AND METHODS

The seed coats of seed from crape myrtle (*Lagerstroemia indica* L.) 'Little Chief' were peeled after soaking the seeds in water for 6 h. After sterilization with 1% sodium hypochlorite solution, the peeled seeds were sown on a half-strength Murashige and Skoog (MS) medium without hormones. Three weeks after germination, the plantlets were about 5 cm in height. Nodal segments (3 mm in length) were excised from the plantlets and placed on the same medium as that used for germination. All media were adjusted to a pH of 5.8, and solidified with 0.2% Gelrite. Each nodal explant has two axillary meristems so that leaves unfold on opposite sides of the shoot. When the shoots induced from axillary meristems of the nodal explant attained 1 to 2 cm in height, each explant was divided into two parts, so that each had one shoot. The shoots obtained by these procedures were cultured on the MS media shown in Table 1 to clarify the effect of combinations of BA (benzyladenine), NAA (naphthaleneacetic acid), and GA_3 (gibberellic acid) on the branching of shoots. The new shoots multiplied through branching were transferred to the rooting medium supplemented with NAA. Cultures were maintained at 25C with a 16-h photoperiod. For acclimatization, the regenerated plants were transferred to pots (9 cm in diameter) containing a vermiculite medium. To compare the growth between the transplants cultured in vitro and seedlings, these plants were grown under 25C, 10,000 lux, and a 16 h-photoperiod, and the shoot length, number of leaves, and fresh and dry matter weights were measured.

RESULTS AND DISCUSSION

When the nodal explants were cultured on the half-strength MS medium without hormones, the rate of induction of axillary shoots from the meristems of the explants reached about 90% within 1 week. This result was consistent with the findings for cacao (Flynn et al., 1990), *Smilax oldhami* (Yamamoto, 1992), and sweet pepper (Yamamoto, 1993), and show that axillary bud growth could be easily induced on the medium without hormones. The resulting explants with two axillary shoots were divided in two and the effect of exogenous hormones on their multiplication was examined. As shown in Table 1, the combination of BA, NAA, and GA_3 gave the best results for the multiplication of shoots. BA was effective in multiplying the shoots, while the combination of NAA and GA_3 had no effect on the multiplication of shoots without BA. Similar results had been observed with *Fuchsia* (Yamamoto, 1994).

The multiplication of shoots often consisted of a two-step process (Table 1). Within about 1 month of culture, the development of axillary shoots was observed, then axillary shoots formed from the original shoots. Figure 1 shows an example of shoot multiplication from the original shoot cultured on the MS medium supplemented with 1 mg litre^{-1} BA, 0.02 mg litre^{-1} NAA, and 0.5 mg litre^{-1} GA_3. These shoots were then subcultured on the rooting medium. The half-strength MS medium supplemented with 0.05 or 0.1 mg litre^{-1} NAA achieved good rooting results, while the rooting was poor in the medium without NAA. The period necessary for acclimatization of the regenerated plant was 1 week. After acclimatization, the growth of the plant was very rapid.

Table 1. Hormonal effects on shoot branching of *Lagerstroemia indica* in vitro.

Hormones (mg litre^{-1})			Rate of branching (%)[a]			Rate of multiplication[b]		
BA	NAA	GA_3	7	28	61(days)	7	28	61(days)
0	0	0	0	14	28	0	0.2	0.4
0	0.02	0.5	0	0	5	0	0	0.1
1	0.02	0.5	62	76	92	1.7	2.9	5.1
1	0.02	0	63	72	82	1.8	2.7	4.3
1	0	0.5	8	23	29	1.7	1.8	1.7

[a] The ratio(%) of shoots showing branching to the original shoots induced from nodal explants.
[b] Number of shoots multiplied per original shoot.

Figure 2 shows the anthesis of the regenerated crape myrtle 1 month after acclimatization. The growth of the transplants cultured in vitro by the present methods was compared with that of seedlings. When the two types of plants reached about 5 cm in height and had 10 leaves, these were transferred to the

Figure 1. Multiplication of a crape myrtle shoot. The MS medium was supplemented with 1 mg litre^{-1} BA, 0.02 mg litre^{-1} NAA, and 0.5 mg litre^{-1} GA_3.

Figure 2. Anthesis of regenerated plants of crape myrtle 1 month after acclimatization.

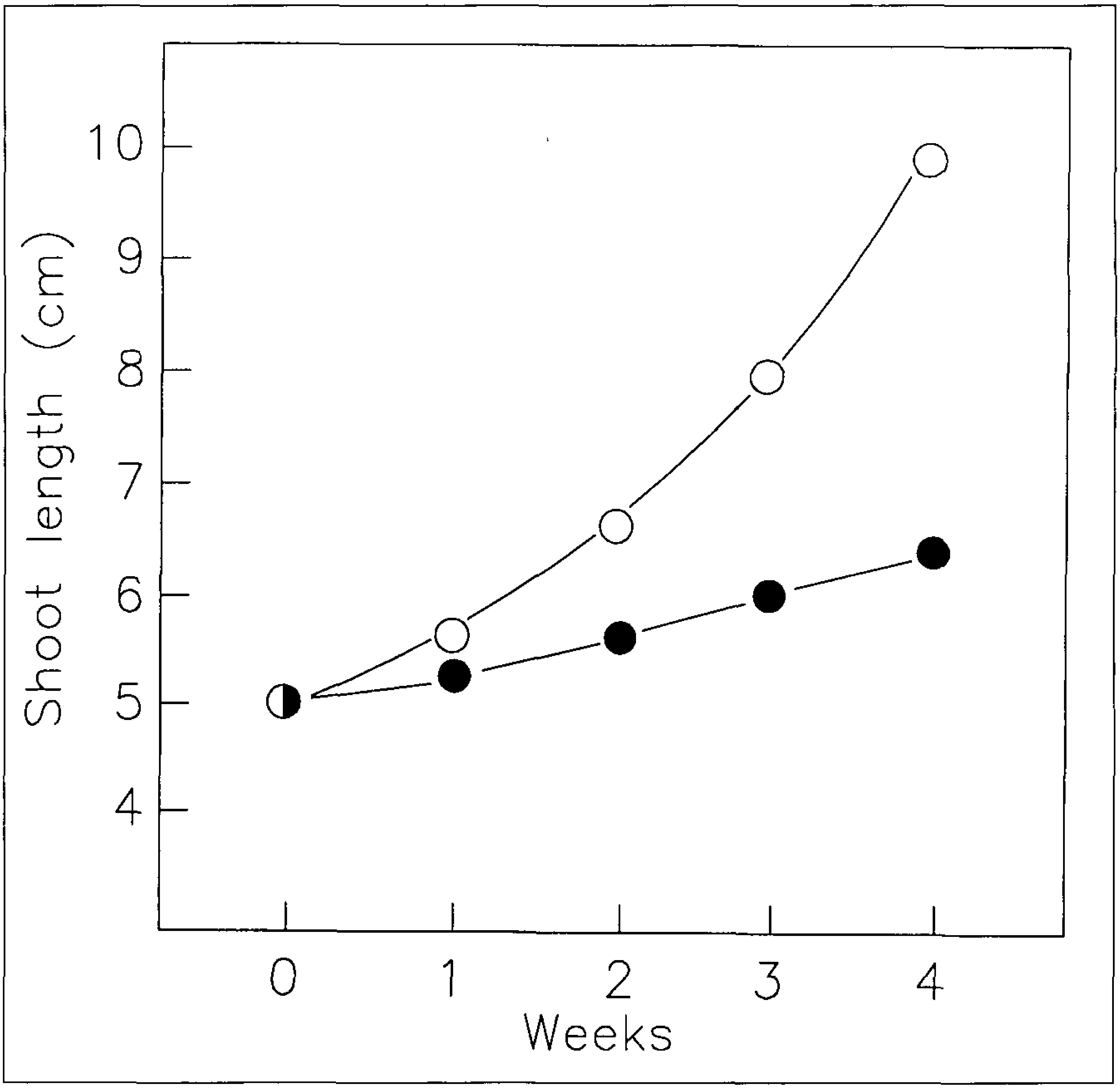

Figure 3. Comparıson of shoot length between transplants cultured in vitro and seedlings: (○) transplants cultured in vitro, (●) seedlıngs. Each value shows average of 20 samples.

growth chamber at 25C and 10,000 lux of light intensity to compare their growth. Figures 3 and 4 show the time-course changes of shoot length and number of leaves for the two types of plants, respectively. The shoot length and number of leaves of the transplants cultured in vitro increased more rapidly with time than those of the seedlings. The marked variation in the growth between the two types of plants is considered to be due to the difference in root development between them. The transplants cultured in vitro had a lot of adventitious roots formed in the medium supplemented with NAA, while the seedlings had a relatively small number of roots.

By these methods of micropropagation, we were able to obtain within several months, a number of potted plants of crape myrtle which were vigorous and flowered early.

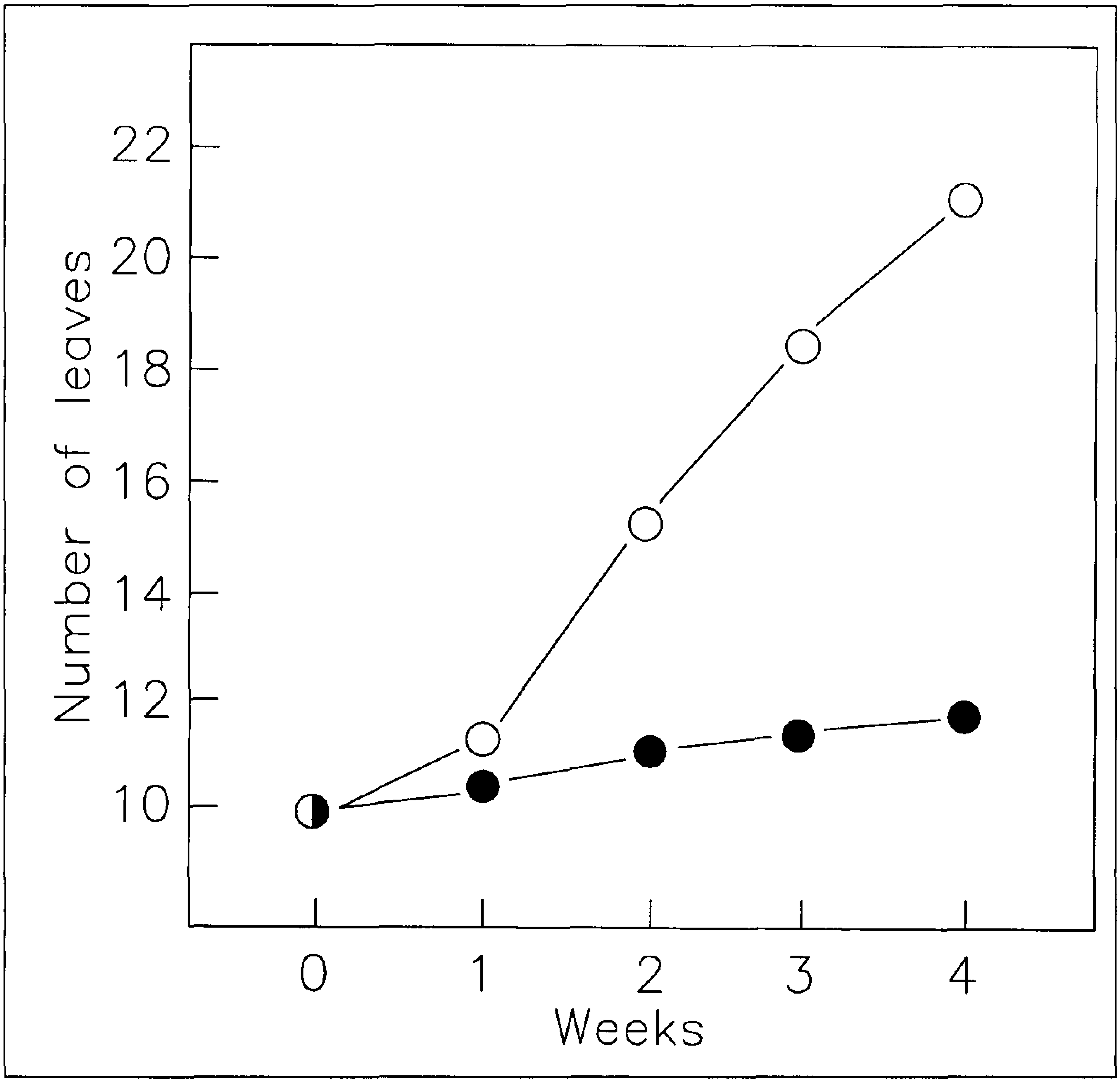

Figure 4. Comparison of number of leaves between transplants cultured in vitro and seedlings: (○) transplants cultured in vitro, (●) seedlings. Each value shows average of 20 samples.

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Water and Resource Efficient Plant Propagation

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Cooperative extension is part of the University of California's (UC) Division of Agriculture and Natural Resources (DANR). DANR is the only statewide division within the UC system. DANR was started in the late 1800s to help farmers use science-based data to improve their farming practices. As urban areas developed in the state, environmental horticulturists have joined farm advisors to work with the horticulture and landscape industry.

Cooperative Extension (CE) acts as a conduit for information from DANR to their clientele and from the clientele to the DANR. CE advisors often try to interest basic researchers in DANR to conduct research which would be applicable to the industry. CE advisors also take basic research results and try to apply that information and seek adoption of new information and techniques by industry to improve their professionalism and their productivity. An analogy would be to look at DANR as a big old tree. We have all this information stored in our roots and trunks. CE is like the fruit of that tree or the harvest of the information in that big vast knowledge base. CE then takes the seed of the fruit and plants it in growers operations to improve their growing practices.

California has been experiencing a severe drought. Because of this, several researchers have been conducting research to reduce plant water use by applying irrigation more efficiently using specialized tensiometers and computers to water the plants extremely accurately. The need for such research by scientists such as Drs. Dave Burger and Heiner Lieth at U.C. Davis was timely because many growers are still convinced that hand watering is the most efficient method of irrigation. However, it has been proven beyond a doubt that this is not only the most inefficient method of watering, but also leads to increased chances of disease. We also face regulatory problems with runoff from nurseries. Several nurseries in Orange County are under permit restrictions that limit the pounds of nitrate in runoff water per month allowed from their operations. Two of the nurseries have opted to comply by partially recapturing their runoff and using drip irrigation whenever possible. One nursery elected to comply by using computer-controlled irrigation to minimize runoff by more accurately controlling their irrigation run times and using drip, pulsed, and subirrigation. Research conducted by various advisors throughout the state to demonstrate this new technology was at the insistence of Burger and Lieth, who wanted their new technology made available to growers to help them deal with these problems.

Improperly spaced sprinklers and system design are a major problem in the nursery industry. Five CE offices (Los Angeles, Riverside, San Bernardino, Orange, and San Diego) with funding from the Metropolitan Water District developed educational materials to train irrigators to audit and schedule their irrigation more efficiently and to use crop coefficients and reference evapotranspiration to determine the actual water needs of their particular crop and then apply that water uniformly. The information to develop these training materials came from U.C. DANR basic research such as how plants use water, and ways of measuring plant water use with evaporation pans, atmometers, CIMIS (California Irrigation Management and Information System) reference evapotranspiration, and direct measurement of soil media moisture using specialized tensiometers connected to computers.

Some of the topics covered in this training include knowing the size of the soil reservoir, the precipitation rate (PR) of the irrigation system, the distribution uniformity (DU) of the system, the crop coefficient, and water-conserving methods such as drip, subirrigation, ebb and flood, and computer-controlled tensiometer irrigation.

U.C. DANR, like the industry it serves, has gone through the recession and severe budget cutbacks and has had to modify how they conduct business to make up for these cuts. The renovation of an existing old greenhouse structure into a state-of-the-art computer-controlled greenhouse is an example of how I have tried to deal with these budget cutbacks. In April of 1994, volunteers from University of California Cooperative Extension, the nursery industry, Orange Coast College, and the greenhouse manufacturing and supply industry helped remodel an existing greenhouse at the South Coast Research and Extension Center. This greenhouse is now a state-of-the-art research and demonstration greenhouse being used to conduct research on ornamental plant production and propagation, and as a permanent demonstration greenhouse featuring various technologies. Examples are: positive pressure cooling, rolling benches, Biotherm starfin heating system using a high-efficiency low-mass boiler, high-tech soil tensiometers to measure the soil moisture tension and turn irrigation on and off, state-of-the-art sensors (temperature, light, and humidity), motorized vent and curtain systems, high and low-pressure fog systems. All of this is controlled by QCOM's Gem III environmental control software and/or stand-alone zone controllers.

This has been a dynamic process with donations constantly being added and growers visiting and asking questions such as, "how long should I turn on my fog or mist system, what is the difference between a high-pressure fog system and a low-pressure compressed-air fog system", giving us ideas on what type of research is needed.

This state-of-the-art research and demonstration greenhouse was possible in spite of the recession and severe budget cutbacks because of donations from companies such as QCOM, Agratech, Biotherm, MicroCool, Spraying Systems, Cravo Inc., Bacchus Industries, Arthur Enterprises, PTI Gravel, El Modeno Gardens, and volunteers from the university, nursery industry, and Orange Coast College.

Welcoming Remarks to Latin American I.P.P.S. Members Invited to Attend the Western Region Annual Meeting

James L. Booman
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Two years ago the Western Region began to recruit membership in Latin America. We have flown some of the fresh fruit of this effort here to meet with you today.

All our guests will be giving presentations during the conference and will be meeting with the Latin America Expansion Committee to firm up plans for I.P.P.S. meetings in Costa Rica and Argentina during 1995 and 1996. Watch for details and plan to attend one of our first I.P.P.S. meetings ever held in Latin America.

Please make an effort to greet each of our guests and get to know them. Perhaps you can share an idea or two about what you have found to be valuable about I.P.P.S. membership. This may help them as they return to their own countries and try to start I.P.P.S. activities there.

It is my pleasure to introduce three I.P.P.S. members from Latin America. To help us appreciate their diverse homeland, we asked each to share a taste of music and a scene from their country. From Mexico, please welcome Daniel Zambrano; from Guatemala, please welcome Ana Bolaños; and from Argentina, please welcome Graciela Barreiro.

Production of Ornamental Trees, Shrubs, and Tropicals in Argentina—An Overview

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Argentine production of ornamental plants began in the early 20th century, when the European immigrants arrived. Most of them had been farmers in their own countries. There was a curious tendency to work on different types of plant production depending on their origin. The Italian families were dedicated to tree and shrub production for ornamental use or for fruit and forest tree production. Those coming from northern Europe (especially Germany and Holland) were dedicated to cut flower and later to foliage pot plants. The Portuguese immigrants produced cut flowers and still do; however, a large group is dedicated to growing vegetables. It was similar with the Japanese immigration; some of them still produce cut flowers, while the others began with cut flowers but now are growing flower pot plants, such as annuals or perennials like rhododendrons, cyclamen, or chrysanthemums.

Almost every nursery is still a family enterprise. Now, the 3rd or 4th generation is working at plant production. Those enterprises were managed by people with practical knowledge. Some of them used to travel to Europe, where they found novelties and could see new crop production techniques. Today, the youngest train themselves better. In many cases they have an academic degree; they're agricultural or forestry engineers or, at least, agricultural technicians, though the "field experience" is still considered more important. In fact, no university in Argentina prepares the students for an economic activity dealing with ornamentals. So, whoever wants to do it as a professional must add his own experience to the physiological principles and crop methods the university teaches.

You can see all kinds of technical methods in our nurseries. Advances have been made in greenhouse production of tropicals where the heating systems are automatic; however, in most of the cases irrigation is done manually. Some nurseries are making great efforts and new investments. Manuel Kogiso has 2000 square meters of new, plastic greenhouses with automatic shading systems for photoperiod management in *Euphorbia* production with subterranean warm water pipes for heating. Now, his owner (a new member of IPPS) is beginning with three consecutive annual cycles of *Impatiens* New Guinea hybrids, Rieger begonia (*Begonia* ×*hiemalis*), and *Euphorbia pulcherrima*. In this way, he'll grow 80,000 plants/year with earlier flowering and a sure sale.

Propagation is still conventional, though micropropagation is slowly gaining acceptance. In Argentina, laboratories that work on tissue propagation don't do it properly. Usually, they don't have enough plants at the right time. The growers don't trust the method because they have real troubles during transplantation. Despite this, some of them are introducing micropropagation by importing plants from those countries where the job is done well, such as Holland. These advanced techniques, however, are only for the best growers, those who have understood the deep changes occurring in Argentina during the last 4 or 5 years. Now, if you don't change you will not survive. Even though Argentine people are skeptical and rather pessimistic (no matter if you are a propagator or a journalist), the managers of leading enterprises have accepted the challenge of producing higher quality crops.

The estimated pot plant production during 1993 was: 30 million annuals produced, using 1000 greenhouses. That represented an annual invoicing of $6 million (US). The same number of greenhouses were dedicated to flower pot plants such as *Rhododendron*, *Cyclamen*, Rieger begonia, *Euphorbia*, growing 3.5 million units and an annual invoicing of $8 million (US). Twelve and one-half million tropicals and foliage pot plants were produced in 2500 greenhouses, with an annual invoicing of $25 million (US).

We can see some progress in shrub and tree production too. Argentine nurseries have two principal characteristics:

1) They do the entire growing process; they sow the seeds or plant the cuttings, transplant them to the field or to the containers until they reach a saleable size, and finally transplant them to the soil, package them, and sell them.

2) Every shrub and tree nursery produces an enormous number of species; the bigger ones cultivate more than 400 or 500 species. They're not specialized and, in my opinion, that's a management problem.

More than 3.5-million ornamental shrubs and trees are produced and sold in our nurseries every year. For that, 1000 ha near Buenos Aires are cultivated, with 20,000 square meters of greenhouses for cuttings, seedlings, and container crops and 70,000 square meters of shaded area. This means an annual invoicing of $25 million (US). If we add forestry and fruit trees and rose plants, the overall income comes to $60 million (US).

And what can we say about sales? Thirty years ago the retail nurseries were open to customers during fall and winter and plants were sold only during the resting stage. Then came the tropicals "boom", during the late 1970s, allowing shops to be opened year-round. Finally, the owners began to put trees and shrubs in containers and to sell them even during the summer.

At the present time, the plant shops try to offer a good service to their customers. You can buy a plant or a gardening tool or you can get a garden designer or just a gardener to maintain your garden in good condition. Customer service is not of high quality in many of our plant businesses. Some shops are well-managed, with sound business practices. In these shops, quality is considered basic. But again, in my country you'll find everything. Small shops are open every spring, waiting for the holy miracle of survival. Others keep going for several years, but people in charge do not have enough knowledge and cannot give advice to the customers. We also have street sellers and even roadside ones.

In summary, the essential troubles of plant production and business in Argentina are:

1) The low degree of investment as a result of many years of economic recession and financial speculation. This situation is reversing.

2) The seasonal sales that result in low income for cultivators and retailers.

3) An economic reality that has not stabilized enough to allow the sale of large numbers of plants, considered by most people as sumptuary objects.

Germinant Sowing in South Africa

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Germinant sowing is operational for tree nurseries in South Africa. The technique reduces seed costs for eucalypts and pines. Filled-cell percentage is usually near 98%. Seed efficiency at many North American container nurseries can be improved by adopting either germinant sowing or single sowing technology.

INTRODUCTION

Managers at most container nurseries attempt to produce one tree per container cell. This makes efficient use of containers, bench space, and potting media. Three different approaches are used to minimize the number of empty cells. A traditional approach in North America is to sow multiple seeds per cell and to thin cells that have more than one seedling (Schwartz, 1993; Wenny, 1993). A second method (developed in Sweden) involves removing dead and unfilled seeds prior to sowing (Simak, 1984; Donald, 1986). Since the germination percentage can be increased to over 93%, this practice promotes the sowing of one seed per cell. A third method involves germinating seeds prior to sowing and sowing only germinated seed. Although sowing germinants by hand is a common practice in tropical nurseries, mechanical sowing of germinants is not common in North America. However, in South Africa, mechanical sowing of germinants has been operational since 1986. This paper reviews some of the advantages of germinant sowing and suggests that managers of container nurseries in North America consider adopting this technology.

SEED EFFICIENCY

Seed efficiency is defined as the percentage of plantable seedlings produced per pure live seed (South, 1990). Achieving high seed efficiency is important when using valuable, genetically improved seed or when seed cost is high. For example, in the southern United States, seed efficiencies were often low (e.g., 33%) when nursery stock was not genetically improved. However, today, most pines are genetically improved and seed efficiencies in bareroot nurseries often exceed 80%. When seed are valued at 0.3¢ or more, there is a strong economic incentive for improving seed efficiency (South, 1990). In North America, seed efficiency in container nurseries can be low if multiple seed are sown in each cell. For example, in British Columbia, seed efficiency from container nurseries is expected to range from 28% to 40% for regular seed (Table 1). At some operational container nurseries, seed efficiency can be less than 35% (Eremko et al., 1989). In some cases, seed efficiency can be higher at bareroot nurseries (Table 2). In general, container nurseries will have high seed efficiency when single-sowing (i.e., one seed per cell) is used. Many managers will single-sow when the germination percentage is more than 90%. However, some recommend sowing two or more seeds when the germination percentage is less than 95% (Wenny, 1993). Four or more seeds are sometimes recommended if germination is less than 70%.

Table 1. Recommended seeding rates, oversowing factor (i.e., extra cells sown to ensure meeting production targets) and expected seed efficiency from container nurseries using 1994 B.C. Ministry of Forests sowing rules.

	Regular seed			Seed orchard seed		
Germination percentage	Seed/ cell	Oversow factor (%)	Seed efficiency (%)	Seed/ cell	Oversow factor (%)	Seed efficiency (%)
100	2	25	40	1	40	71
95	3	30	40	1	45	72
85	3	35	30	2	30	45
75	3	40	32	3	40	32
65	4	50	26	4	50	26
55	4	60	28	4	60	28

Table 2. Seed efficiency from container and bareroot nurseries in British Columbia during the 1980s (data from Eremko et al., 1989) and seed costs from a dealer in New York.

	No. plantable seedlings/pure live seed		Pure live seed cost
Species	Container (%)	Bareroot (%)	(¢)
Coastal Douglas-fir	23	32	0.21
Western hemlock	27	25	0.09
Western larch	28	28	0.22
Lodgepole pine	30	41	0.08
Ponderosa pine	22	38	0.80
Western white pine	53	66	0.54
Sitka spruce	35	43	0.20
Grand fir	22	24	0.42
Pacific silver fir	59	23	0.59

When seed costs and thinning costs are considered, the logic for multiple sowing is less attractive (Space and Balmer, 1977). Table 3 compares the cost of production when using seed that costs 0.3¢ per pure live seed. In this example, seeding plus thinning costs were 34% greater for double-sowing than for single-sowing. Although seed and thinning costs make single-sowing more attractive, many nurseries in North America continue to multiple-sow and thin. In North America, a typical laborer can thin about 40 trees/min.

Table 3. Estimated sowing and thinning costs associated when producing 10 million seedlings.

	Two seed/cell	One seed/cell	One germinant/cell
Cells needed	10,666,666	13,333,333	10,204,082
Germination (%)	75	75	75
Seeds required	21,333,332	13,333,333	13,333,333
Blanks expected	666,666	3,333,333	204,082
Excess trees	6,000,000	0	0
Seed cost ($)	64,000	40,000	40,000
Sowing cost ($)	5,333	6,666	5,102
Thinning cost ($)	24,000	0	0
Cost of carrying empty cells ($)	5,3332	6,666	1,633
Total costs ($)	98,666	73,332	46,735

IDS SYSTEM

In Sweden, tree seed are routinely sorted to remove dead and unfilled seeds. The Incubation-Drying-Separation (IDS) procedure is used on *Pinus sylvestris* and *Picea abies* to produce seed with a high germination rate (98%). Researchers in North America have not developed the technique to an operational level. However, this method has promise for several North American species (Donald, 1986; Edwards, 1989; Malek, 1992; McRae et al., 1994) and could eliminate the need for multiple sowing.

GERMINANT SOWING

In South Africa, filled-cell percentages of 98% to 99% are consistently achievable with the use of germinant sowing. Originally developed in the United Kingdom, the concept was refined and simplified in South Africa. Much of the initial work was conducted in Natal by Bryan's Machinery in cooperation with Sappi Forests. The equipment is now available in North America from a distributor in Ontario. With the old system, seed were germinated in a tray, "pricked out" by hand, and transplanted into containers. With this method, about 150,000 *Eucalyptus grandis* seedlings could be produced from a kg of seed. With germinant sowing, the number of seedlings increased to 600,000/kg. With a value of $2000/kg for genetically improved seed, the fluid drilling system reduced seed costs by $10/thousand seedlings.

In addition to improving seed efficiency, labor costs were reduced at the Sappi Nursery. With the old system (manual transplanting into cells), the labor for 1-million plants was 175 person-days. With fluid drilling, labor was reduced to 51 days. These are savings in the sowing operation. There are large savings in not having to thin the crop after emergence. At the Sappi Nursery, one machine can produce 10-million plants/year. An added benefit is that seedling crops are very uniform because all the seed is sown at the same stage of germination.

The key to success with fluid drilling is sorting dead from live seed. The seed sample must be clean and well-graded. This factor is imperative in order to successfully separate germinated from non-germinated seed. For pines and eucalypts, the germination fluid is water. If seeds are well-graded (of the same size and mass), germinants will imbibe water and will change in size but not mass. Therefore, germinants have a lower specific gravity than non-germinants. The imbibed (swollen) seeds are separated using a sugar solution. Seed are placed in a small amount of water and a concentrated sugar solution is slowly added until imbibed seeds float to the top. These are then removed from the solution with a tea strainer. If seeds are germinated for too long, the radicals become elongated and tangling can result in multiple sowing. Ideally, the seed coat should be broken with the radical about to emerge.

After separation, germinated seeds are placed in a fluid trough just below the vacuum head. Special needles on the vacuum head are dipped in the fluid and when removed, several germinants may adhere to each needle. A water rinse is used to remove excess germinants while one remains attached due to the vacuum. Needle size (hole size) varies from 0.1 to 0.9 mm. Correct needle selection is important (too small = misses; too large = doubles). Vacuum setting is also important (too low = misses; too high = doubles). Cycle time will vary with seed size. Large pine seeds require that the nozzles have a longer period in the fluid trough in order to become properly attached. For pine, almost no doubles occur, but with the smaller eucalypts seed, about 10% of the cavities will have doubles.

Bryans' Miniseeder will sow 60 to 225 trays/h (128 cavities/tray). The system can sow one row at a time or up to ¼ tray at a time. At the Sappi Nursery, four machines are used for sowing. Fluid drilling is used for all eucalypts and pines when germination percentage is less than 90%. Dry, single-sowing of pine is still practiced when germination is greater than 89%.

Two models of precision drilling machines are available in North America. Both are currently sold by INNO-TEC I.T.U. Inc. Thunder Bay, Ontario. The Miniseeder has a cost of $25,000 while a full size Precision Fluid Drilling System can cost about $48,000. The full-size machine can sow full trays and production is about 66% faster than the Miniseeder. Currently, two, full-size fluid drilling machines are being used in Canada and one in Mexico.

If the purchase of a germinant sowing machine (@ $48,000) would eliminate double-sowing, the potential savings in reduced seed costs and thinning costs could pay for the machine after only 10 million seedlings. For example, the estimated difference in cost between double-sowing and germinant-sowing could amount to $5100 per million seedlings (Table 3). This savings results when each pure live seed is worth 0.3¢ and thinning costs amount to $4 per thousand thinned plants. In regions where seed is provided to nurseries free of charge (e.g., Canada), savings in thinning costs could pay for the machine after sowing 20 million seedlings. However, in situations where both seed and labor are free or inexpensive, it may be difficult to justify investing in germinant sowing.

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Machine Vision Development: Its Use at a Forest Seedling Nursery

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A general overview of the current J. Herbert Stone seedling lifting and processing system is discussed followed by a discussion of the rational and processes of developing a machine vision-based system for grading seedlings.

J. HERBERT STONE NURSERY

The J. Herbert Stone nursery is located in Southwestern Oregon near the city of Medford. It is a U.S.D.A. Forest Service nursery and produces conifer seedlings and other plant materials only for publicly owned lands. The major clients of the nursery are the U.S.D.A. Forest Service and the U.S.D.I Bureau of Land Management and Bureau of Indian Affairs. The capacity of this nursery is approximately 24 million seedlings per year. Since the first shipment of seedlings in 1979, over 275 million seedlings have been shipped to planting sites throughout Oregon, Washington, northern California, northern Idaho, and western Montana.

CURRENT LIFTING AND PROCESSING

One- and two-year-old seedlings are lifted from the nursery seedbeds during the dormant season. The lifting window established for the J. Herbert Stone Nursery is between December 1st and March 1st. The lifting process begins with a machine having a blade spanning the 4-ft wide seedbed. The blade is operated at 10 to 14 inches below the soil surface. There are shaker tines attached behind the blade that shake the seedlings and soil up and down thus loosening the soil from around the seedlings.

The seedlings are then hand-lifted out of the loosened soil with any soil remaining removed from the roots by a gentle shaking motion. The bare-root seedlings are then packed into field containers. Smaller seedlings are placed into plastic tubs and covered with moistened burlap strips. Tall seedlings (over 24 in. tall including roots) are packed into bundles wrapped with burlap. Seedlings to be shipped field-run to clients are placed directly into cardboard boxes which have been lined with a paper or plastic moisture barrier.

The boxes and the plastic tubs are loaded onto pallets on specially designed field trailers. Bundled seedlings are loaded into specially designed steel bins which have been placed on the trailers.

The seedlings are then taken by trailer to the processing facilities. Field-run seedlings boxed for shipment go directly into storage. On especially sunny and/or windy days the entire trailer of tubs or bins may be run under a watering device that wets down the entire load. Eight low-pressure, high-volume nozzles deliver 300 gal of water per minute to soak down the seedlings and initiate a presorting, conditioning treatment. The pallets of tubs and the bins are then moved by forklift into a precooler that is maintained at 34 to 36F and 90% to 100% relative humidity. Additional moisture may be added through fogging devices to assure that the seedlings reach a very low moisture gradient monitored with a Plant Moisture Test device.

Seedlings are transported to the processing shed using a forklift. The plastic tubs or wrapped bundles of seedlings are placed on a moving belt that delivers them to the grading stations. Grading is accomplished by individuals taking a hand-full of seedlings and visually inspecting them by passing the seedlings from one hand to the other. Groups of 5 or 10 "shippable" seedlings are placed on the same moving belt. This belt moves the shippable seedlings to the front of the processing line where the seedlings are gathered, root pruned, and placed into their final storage and shipping containers.

The shipping containers are either 3-ply brown paper bags with a spray-on liner of plastic (for cooler storage) or cardboard boxes with a 3 mm plastic bag liner (for frozen storage). The bags are closed by either sowing, strapping, or both depending upon the request of the clients. Boxes are stapled closed.

Quality inspection is performed throughout the entire process. A minimum of 1% of all seedlings is inspected for sorting, root trimming, count, etc. Samples of culls are also inspected prior to disposal to assure that we are not destroying too many shippable seedlings.

THE CASE FOR MACHINE VISION

Unlike advances made in preparation of seed and sowing, and the culturing of the seedlings, very little has changed in the lifting and processing of tree seedlings. With the exception of forklifts and conveyers, most of the work is performed manually as it has been for decades. A visit to the J. Herbert Stone Nursery seedling processing shed, like most other nursery processing operations, reminds me of the potato and onion processing sheds in which I worked as a youth in the mid 1950s.

Within the past 10 years, the cost of seedling production has totally reversed. Ten years ago, the cost of tree production was two-thirds of the total direct cost of our program. Today, two-thirds of our direct cost is in lifting and processing. Most of this change is our lack of mechanization while facing steadily rising labor costs.

Quality monitoring also requires heavy use of labor while yielding only pass/fail information. Our personnel only take time to determine if grading, pruning, etc. is done to our standards. They do not take time to gather and record actual data such as caliper and height.

Our clients have expressed interest in having actual data on various attributes for each seedling lot they receive. They would utilize this information in making final plans for the use of the seedlings, such as, reserving the seedling lots with heavier root systems and/or larger caliper for the more harsh sites. Having nearly 100 clients and over 650 individual seeding lots each year would require some sort of Automated Data Processing system.

THE PLAN

A few years ago, Paul Morgan, Manager of the D. L. Phipps Nursery operated by the State of Oregon, called me to discuss the possibility of cooperating in the development of an automated system for sorting and handling seedlings. We had both seen attempts being made by researchers. In the mid 1980s, the State of Iowa Forest Nursery had been working with the State University at Ames, Iowa to determine root mass and other characteristics using a camera device linked to a computer. We were also aware of the growing trend towards "machine vision" in the sorting of agricultural seed such as corn and the grading of various commodities such as tomatoes, peanuts, oranges, and french fries.

We agreed to begin actively supporting an effort to develop a machine vision process for grading tree seedlings assuming that the very difficult logistics of handling them would be developed once the visual technology was available. Paul is working through his state procurement folks and I am working though the U.S.D.A. Forest Service Missoula Technology Development Center at Missoula, Montana. We are actually working individually on our own projects, but we are knowingly and willingly sharing information and are actually using a leapfrog system to progress from one stage of development to the next.

THE BEGINNINGS

The project has progressed through several stages of development beginning with lengthy discussions about grading criteria and various technologies available for sensing seedling attributes and computing data. One major choice was whether to utilize an area scan or a line scan system. The project developed along with new technologies including faster computer CPU speeds, larger memory, and more accurate camera devices. At times, the project was slowed awaiting availability of new equipment that had been developed, but had not yet been manufactured and released on the market.

In the summer of 1992, Dr. Glenn A. Kranzler and Dr. Michael P. Rigney of the Agricultural Engineering Department at Oklahoma State University successfully demonstrated a prototype machine vision unit at the D. L. Phipps nursery. That fall, the Missoula Equipment Development center issued a solicitation for technical proposals for the development of a Machine Vision Seedling Inspection Station. Oklahoma State University was successful in developing a proposal that met all requirements of the solicitation. A contract was subsequently awarded to the University for development of the Inspection Station.

THE CURRENT MACHINE

In Feb. 1994, the Machine Vision Seedling Inspection Station was delivered to the J. Herbert Stone Nursery. The unit consists of two 18-inch-wide conveyor belts mounted end-to-end to each other on a single frame. The first (upstream) belt is about 6 ft long and the second (downstream) belt is approximately 3 ft long. These belts operate at the same speed and have an electronic variable speed control that allows operating them at speeds of 1 to 3 m sec^{-1}. The distance between the first (upstream) conveyer and the second (downstream) conveyer is about 1/2 inch. This allows a space for the high-intensity fluorescent back-light mounted under the belts to shine upwards between them. A line scan camera is mounted above the conveyers and directly above the light.

This device is manually fed requiring that the seedlings be placed on the conveyer by hand. There is no supporting equipment to feed the seedlings nor to process them after going though the device (such equipment has yet to be developed). Seedlings are placed on the belt top first with their long axis running parallel with the direction of belt travel. As they cross the gap between the two belts, the camera "sees" the shadow cast by the seedling against the very bright back-light. This camera image is then digitized by a line-scan digitizer and the data is sent to a 50 MHz 486 computer.

The software runs under the OS-9000 operating system (Microware Systems Corp., Des Moines, Iowa). A combination of commercial and custom software is required to run the program. Oklahoma State University holds the copyright to the custom software. Algorithms developed for inspecting the seedlings are the intellectual property of Oklahoma State University and are considered a trade secret.

The seedling features measured include stem diameter, top height, sturdiness ratio, projected shoot area, projected root area, shoot-root ratio, root length, percentage of root area outside the root zone, percentage of fine roots, and root mass length.

Initial testing has shown that the device has some difficulty in calculating the exact location of the root collar. It also has difficulty "seeing" the terminal bud on species such as ponderosa pine where the terminal is covered by long needles. Because of these difficulties, the calculated top heights may vary from actual heights. New software upgrades have been installed, but have not been evaluated. In spite of the difficulties listed above, the stem caliper measurements are very accurate. Other measurements also appear to be accurate. Consistency of measurements has been checked against experienced quality monitors and the machine consistency is very high.

Operational speeds vary depending upon the average length of the seedlings and the distance allowed between scan lines. The machine is designed to handle seedlings with tops ranging from 7 to 91 cm tall and with roots up to 36 cm long. Operational speed will allow from 1 to 10 seedlings/sec at the 1-mm scan interval.

WHAT IS NEXT?

Paul Morgan of the State of Oregon, D. L. Phipps nursery is working with Oklahoma State University to evaluate the use of color and shades of grey in determining off-color foliage and recognizing damage such as stripped roots and other wounds. He reports that excellent progress is being made in this area.

The J. Herbert Stone Nursery will carry out more testing on the current machine. New grading criteria may be analyzed and outplanting survival checked. Current grading processes depend entirely upon human ability to judge sizes and amounts. This places a significant part of the decision as to the plant being acceptable upon the easier to visualize and describe attributes such as top height, root length, and stem diameter. The current equipment will gather more dependable information on other attributes such as shoot to root ratio, percentage of fine roots and shoot and root areas. The use of new combinations of grading rules such as stem diameter and total root mass may be much better indicators of survival and initial growth than those currently being used.

The development of a complete system is and will remain our final goal. This will include equipment that is capable of singulating and feeding seedlings to the machine, separating out two, three, or more grades of seedlings, performing root trimming and other final preparation of the seedlings, and finally packaging the seedlings. Some of these advances are difficult to even envision. Especially the singulation of the seedlings. However, need drives ingenuity. Separating the seeds and hulls from cotton was a hands-only task not all that many years ago.

Question-Answer — Monday Morning

Tom McGregor: Why did Twyford settle on Costa Rica?

Greg Lloyd: One of the things I didn't mention was that one of the weaknesses of off-shore production is that it tends to be unreliable in many cases. There are good labs and bad labs. The reason we chose Costa Rica was because it was close to Florida and we put a lab manager from the company down there. We couldn't see a lab further away (e.g., China). We could ship back and forth easily and we could get our management back and forth for training. Costa Rica has a relatively stable government and fairly decent electricity. Other places don't have these advantages.

Gary Matson: Does the change in density upon germination occur with all seeds? Does it happen suddenly at germination? Can you provide a little more detail how to take advantage of this?

David South: I can only speculate, but as seed gets bigger in size during the germination phase it gets lighter in terms of specific gravity. I don't have the data from a number of species to answer your question.

Steve Mullaney: Would you mind a couple more words on the day-night differential you mentioned, controlling it and preventing problems?

Roger Styer: So, we're talking about DIF. Going back to the concept of what DIF is, it's basically the difference between the day temperature and the night temperature, so under normal scenarios your day temperature is higher than your night temperature, you have a positive DIF. This causes stem elongation in a number of crops. If you can get it to a zero DIF where your daytime and nighttime temperatures are the same, you will slow down the stem elongation thereby slowing down stretch. If you go to a negative DIF where your nighttime temperatures are warmer than your daytime temperatures, you will slow it down even more. The difficulty is, can you do it? Do you have a greenhouse situation where you can control that? Work the Royal Heins' group has done shows that the first 2 h around sunrise is the most critical time or most influential time to do it. If you do it too much certain crops will start to yellow or develop chlorotic symptoms. *Salvia* is a good example where if you apply a -5 DIF it will turn chlorotic. If you remove it from the negative DIF and give it a positive DIF it greens back up again. So, there are also photosynthetic processes occurring here and you may also impact your root growth. Too much negative DIF you will tend to slow down growth dramatically and maybe produce undesirable results.

Kristin Yanker-Hansen: If I were doing this at home with just some seeds, about how much sugar should I put into the solution?

David South: That's a question I think you'll have to ask Chris Young. Prepare the sugar solution separate from the seed and then add this solution to the seed until they start floating. One of the things I should have mentioned is that they do have a test bag of seed and start testing 2-3 days earlier. When those seeds start to germinate then you have a good idea about the others that are about to germinate.

Kristin Yanker-Hansen: So, you don't add the sugar until you think the germination is occurring.

David South: That's right. Germination occurs in the water; the sugar is just used there for separation.

Bruce Briggs: John, on your research you were doing in containers, two questions: Did you try to raise the drainage holes in the container to hold a little volume of water in the base? Did that help in the conserving of water and the runoff? Did you try sealing off the top of the container to reduce or eliminate evaporation?

John Kabashima: The answer is no and no. With the idea of raising the drainage holes so you would have more moisture in the bottom, if you look at containers naturally, you will have most of the moisture in the bottom of the container. One of the things I have worked with quite a bit is the role *Phytophthora* and irrigations play in the production of plants. We have worked extensively in the detection of *Phytophthora* in different profiles in the pot. We find that most of it is in the bottom. I wouldn't encourage anyone to raise the drainage holes to increase the holding capacity of the soil in the bottom because then you will exacerbate the problem with *Phytophthora*. What you're trying to do is even-out the moisture within that whole profile. On the second question, the problem with putting something on the surface is that we haven't figured out how to do it economically. That would work wonderfully if the practical and economic concerns were solved. I have looked at mulches and they can have an effect. Now, with the computer and tensiometers we can really measure this. The computer logs the moisture tensions continuously over the whole period of the experiment so we have new tools to do that.

Bruce Briggs: If anyone in the room is conducting research in this area, it's one we can use because what we need is something that's easy to put on pots and something that will prevent the loss of moisture through that barrier, but will also allow something to go down into the container.

John Kabashima: We are looking at introducing some of these beneficial organisms into the pots. One of the carriers someone gave us was a clay that sealed the surface of the soil. We found we could not use it since it created an artificial layer on top that prevented water from moving into the container soil.

I.P.P.S.—Ready for the 21st Century

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It is indeed a privilege to be asked to speak to you this noon, and I assure you it is a great pleasure. There is no organization that I know of which ranks so high in my mind for the great work it does and for the ideals and motto to which it is devoted.

Mike and his Program Committee have scheduled an exciting variety of subjects and events, that will challenge all of us. I am glad to see that the committee believes in the axiom—"The mind can absorb no more than the tail can endure." I am also glad to see that they have renewed the use of the GO - Caution and Stop sign that I developed some 20 years ago.

The topic for this little talk is "I.P.P.S.—Ready for the 21st Century." I wish to announce it is not only ready but it is off and running. Membership is up and new regions are lining up to join. My recommendations are: keep doing what we are doing, only better. I will make some suggestions later.

There is only one problem on the horizon. Our international body is under investigation for living under a false motto. To seek and to share is what all members know and think. However, in our various publications, plaques and certificates, we have no less than three different spellings for the word we use for "share"—Imperture, Imperiture, and Impertire, only the last is correct.

Let us consider our organization in comparison to other trade associations. All that I can think of or name are formed for the sole purpose of control and protection of its trade. On the other hand, I.P.P.S. is a wide-open association and welcomes a wide variety of individuals engaged in the area of propagation, regardless of age, education or type of employment. We are outgoing, friendly and sharing. As a result, there is a tremendous feeling of comraderie.

This comraderie has resulted not only in greater productivity, but in better, healthier plants, and lower prices. In 1939, when I was working in sales, a 1-gal rose sold for $1.50 while the cost of labor was 35¢/h. Today a healthier rose sells for about $5.00 and labor costs are about $5.00/h.

I remember our 1960 Charter meeting so well. Jim Wells, the first president and our most enthusiastic booster, replied to a question about what we should do about a member who would not share. In his beautiful English accent, he declared emphatically, "WE BOOT HIM OUT!" Now, my field trips to nurseries were more meaningful. At I.P.P.S. member nurseries there were no locked doors or roped off areas. One outstanding nursery was the Buena Park Greenhouses run by our late President Bob Weidner and his lovely wife, Evelyn. Not only were we well-received, but Evelyn often had punch and cookies while Bob told all and answered all questions in a positive way. My students and I shall never forget the hospitality and the positive information.

What a wonderful profession to be involved in and to realize that it is the oldest to have existed. Do I see some of you in the audience shaking their heads? Shame be he who evil thinks. For those of you who doubt the above statement I refer you to the "Good Book", Genesis II, verses 8, 9, and 15. I now quote: "The Lord God planted a garden in the east in Eden and there he put man that he had just formed. And the Lord God made all kinds of trees to grow out of the ground; some were pleasing to the eye and gave food. The Lord put the man in the garden of Eden to work and take care of it." Remember, this was before the Lord God created woman and before the darned apple tree was planted.

And now a bit of the fun times we have had. Curtis Alley and I always had our crazy hats. The Liar's Forum, where members told of strange things that had happened in their propagation houses, like the 18-inch diameter pepper tree cutting that rooted at Disneyland; the timer control light, only mine had a loud bell 10 sec after the red light came on. I can remember at an Eastern Region Meeting paying the doorman $2.00 to put up under the American Flag a banner which read "W. R. I.P.P.S. is Best". It was all in good taste and the atmosphere seemed to be charged with the static electricity of good will.

I have been closely associated with the field since my graduation from Oregon State University Department of Horticulture in 1936 at the head of my class. I spent one year as assistant county horticultural agent, then three years with the California Nursery Co. of Fremont, working up from budding foreman to nursery manager. I was called to active military duty in February 1941 and served four years. The first year, before the shooting war, I was the landscape development officer for Camp Roberts near Paso Robles, California, the largest replacement Training Center in the U.S.A.

In 1946, I was called to Cal Poly San Dimas to head up the Ornamental Horticultural Department. It was a two-year school. We had 25 students, and I was the sole faculty. I built the department to 380 students with a faculty and staff of ten, a 4-year degree granting program and the second largest in the U.S.A. My first sabbatical leave was spent in Central Europe studying the institutions teaching ornamental horticulture and the horticultural firms that employed their students. In 1972, my second sabbatical leave was visiting Australia and New Zealand making a similar study. Our program became so well-known in the trade that we attracted students from Israel, France, Germany, and two from New Zealand. In 1976, I was selected as the outstanding Professor at Cal Poly Pomona from a faculty of 750. Following retirement I was the Host and leader of 17 International Horticultural tours. In 1989, my wife and I served with the Peace Corps in Western Samoa, assisting them with a botanical garden. In 1990, my wife and I served in North Yemen with VOCA (Volunteers in Overseas Cooperative Activities). My work there was to advise the nursery industry.

For my Horticultural programs I have received recognition; two International, three National, and five from the state. I do not make these statements to brag, but merely to show a background that might give credence to some of the suggestions I make.

While attending the California Association of Nurserymen's meeting on September 1st in Monterey, I became more aware of the educational program they are developing called "Growing Seeds and Growing Minds". It can be programmed for any age child from kindergarten through high school. Since I first heard of it I have made a very careful study and believe it is a very worthy project. It seems silly to try to produce a better wheel. It is more important to get behind the program and see it implemented in as many schools as possible. I believe members of the I.P.P.S. can make some valuable contributions.

At birth a child's head is larger in proportion than any other part of the body. Doctors tell us that by age two the child's brain has developed. It is a great white sheet, clean and ready to receive messages that it will call on for the rest of its life. Some computer experts say the capacity of the brain is many computer discs (with their millions of "bytes"). At two or three months the baby begins to smile and coo. This brings great joy to the parents and the child learns from this happy experiment how to get the parents' attention. Like a scientist, the baby has learned from experience what works and how to use it. "Experience is the greatest teacher, it gives you the answers and then the question." Parents go crazy when the baby first crawls. This is a pleasant feeling for the baby and so he does it again. Lo and behold it works. He can get his parents' attention this way and in his brain this is recorded. When it comes to walking, the baby will try and fall, try again, and again and again, but once walking is mastered it will last a life time.

The brain is like a super computer. It is very user friendly and does not need a "mouse" to put the information in the properly designated lobe for recording. It automatically cross references each item as to touch, smell, pain, happiness, and sound. Furthermore, the information remains in the brain and needs only the proper stimuli to bring it back. Some responses are voluntary, others are involuntary. Time does not allow us to go further into a discussion of this wonderful organ.

A scientist is one who makes a detailed study of a certain subject or material. This is done by observation, tests, measurements, and experience. This may be recorded and considered. Then true evaluations are made and, from these evaluations, conclusions can be drawn. From these conclusions predictions can be made. So, if one knows all the factors, a prediction can be made as to the outcome.

Now think for a minute. Is not a baby a true scientist? It is mostly experience that the baby uses to evaluate, but he tries and tries and tries again and again.

This "Growing Seeds, Growing Minds" program can be developed for any age group and parents are encouraged not only to know about the program but to have the students carry on some of the experiments at home. With the teachers, the students, and the parents all involved in the same exercise, it not only enhances the learning process, but gives the parents and the child an interesting and even exciting project to work on together.

Another worthwhile point to remember is that in nature the matter of the I.Q. is of no concern to the plant or animal. The plant will grow and the animal can be trained with regular proper care.

I am so excited about the potential of this program, that I have already volunteered to work with the Claremont Unified School District, to work in any capacity as teacher, program coordinator, or advisor. Remember that the basic plan is that the students will actually be involved in the planning, the recording, the evaluation of the results, the conclusions, and the predictions. For the inner city youngster this experience may be his only contact with nature and the real world. It should be exciting enough to take him away from TV and artificial and passive entertainment.

Who was it who turned you on to "horticulture"? I am sure it was not an industry or college brochure, but a dedicated and excited individual who loved what he was doing.

What I am suggesting is that you get from the California Association of Nurserymen a copy of "Growing Seeds and Growing Minds." Read it, make suggestions and volunteer with your local schools. I am sure this will bring you great recognition in your local community but also important, you are going to help many young people get a better hold on true values in life. Last, but by no means less important, you will have a deep and inner satisfaction of having done a little to help our school systems.

REMEMBER

The development of the brain occurs as challenges are presented. Learning comes as those challenges are met and conquered. The more the parents and the teachers are involved in helping the child identify the challenges and in rewarding the child for meeting these challenges, the more the child seeks recognition and praise by doing his own investigation of the challenges and solving them. The natural world of living growing things is the best possible laboratory. "For in nature there are no rewards or penalties, only consequences" (R.G. Ingersoll).

Maybe next year there can be a session where individuals who have worked in the program can give a report on what happened and what new phases should be considered.

I close this little talk by reading a statement writtenby Nobel Prize winning poet from Chile, Gabrzel Mistral:

> We are guilty of many errors and many faults. But our worst crime is abandoning the children. Many things we need can wait, the Child cannot. Right now is the time his bones are being formed his senses are being developed. To him we cannot say tomorrow His name is today.

Thank you.

Clematis for the Western States—One Approach

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Our initial involvement with clematis began about 7 years ago, when we shipped young plants from Holland and Canada to wholesale growers in California and Utah. One year of success was followed by two in which suppliers failed us miserably with poor quality, numerous shortages, and heavy substitutions. It was this repeated frustration that led us to look for a new clematis source.

In 1991, I met Raymond Evison of Great Britain, who is certainly one of the world's authorities on clematis. Soon we became a distributor of his young bareroot plants in California and other western states.

During Raymond's first visit to southern California, we toured a number of wholesale and retail nurseries to evaluate the local clematis market. We noted the presence of *Clematis armandii* in fair numbers. This native to central and southern China (Evison, 1991) is one of the few evergreen clematis and has very fragrant flowers in March and April. Its mature growth is frost-hardy to 15F, making the plant a natural for our mild southern-California climate.

We also found a few cultivars of *C. montana*, a species from the Himalayas that is hardy to about 10F. Like *C. armandii*, the *C. montana* cultivars flower in March and April in the south of our state. They are also very vigorous and are often seen covering entire fences, old barns, and other such structures.

Most abundant in our informal survey of retailers were the large-flowering hybrid *Clematis*, including old standbys ×*jackmanii*, 'Nelly Moser', and 'The President'. While in reasonable supply, mature plants were seldom seen in the landscape, likely due to our dry summers, we felt. These plants can be grown in Southern California, but require careful attention to detail in terms of planting location and watering.

We began thinking in terms of our indigenous clematis species. *Jepson's Manual of California Native Plants* (Jepson, 1993) lists three native clematis for our state: *C. lasiantha*, *C. ligusticifolia*, and *C. pauciflora*. The *C. lasiantha* and *C. pauciflora* species are found in chaparral and woodlands below 700 ft and flower from January to June. *Clematis ligusticifolia* is found at higher elevations in riparian habitats and ranges from California north to British Columbia, east to North Dakota, and south to New Mexico. Vines will grow to 40 ft in length and the plants typically are found sprawling through willows, cottonwoods, oaks, and various native trees and shrubs, flowering in June through September. All three species have lovely seedheads, inspiring the common name of "old man's beard" for *C. ligusticifolia* and, in Mexico, "barba de chivo" or "goat's beard" for *C. lasiantha* (Roberts, 1989).

While these plants have their place in nature, and are commercially produced by some native plant nurseries for revegetation purposes, they are not desirable for their ornamental effect. This is due perhaps, in part, to their relatively small flowers and their extremely vigorous growth habits.

With further awareness of our native species and their behavior in our southern California climate, we determined there was a range of Mediterranean species and cultivars that were worthy of trialing.

Clematis cirrhosa is an evergreen species native to Southern Europe and North Africa. The cultivar *C. cirrhosa* var. *balearica* 'Freckles', introduced in 1989 by Evison (1991) has very dense foliage and 2-inch, creamy-pink flowers with red spots. The plants flower here in both winter and summer, and, like our native *Clematis*, will sometimes lose their leaves in late summer. In my garden, with summer irrigation, the plant has been nearly too vigorous and the nodding flowers not quite so visible, but grown properly the plant can make a very nice specimen.

The species, *C. viticella,* is from Italy and perhaps Spain, and seemed like a natural for our very dry and harsh Southern California summers. The species and its forms are fully hardy to -13F. While having smaller (2 to 3 inch) blooms than the early, large-flowering hybrids, the *C. viticella* cultivars are quite showy and are well-suited for growing over other plants or for climbing upright through trees and shrubs, much as our native clematis behave. These plants typically begin flowering in May and June here and then flower off and on all through the summer and early fall.

Our customers have had very good success with cultivars like: 'Madame Julia Correvon', a plant reaching about 11 ft with wine-red flowers; 'Little Nell', with many whitish-blue flowers; and 'Polish Spirit', a relatively new deep purple-blue introduction from Poland. At present, we are looking at others for our market, including 'Alba Luxurians', a white with reflexed, green-tipped tepals; 'Blue Belle', recently introduced to the U.S.A., is a vigorous blue-violet with yellow anthers; 'Minuet', a white with mauve veins; and 'Venosa Violacea', a larger flowering white with purple veins.

Still another Mediterranean species that may do well in our California climate is *C. campaniflora*. This native of Portugal has very pretty white to pale-blue, bell-shaped flowers that appear in July and August. The plant is rather vigorous and will reach a height of 10 ft.

Based upon these observations in southern California, one could look at the native clematis species of the other western states as a means of determining what other species and cultivars might perform well in these areas.

Moving to the east is our neighbor, Arizona. *Clematis ligusticifola* also exists in the wild here, again in riparian environments. A second species, *C. drummondii*, a native of Baja California, is cultivated by some specialty nurseries for landscape purposes.

The extreme summer temperatures and very low humidity of the lower Arizona deserts are not well-suited to any of the large-flowered hybrid *Clematis*, although with extreme diligence and careful attention to shade and watering one might have some success with the smaller flowered hybrids. At the higher elevations of the Prescott Valley and Flagstaff, the *C. montana*, *C. vitacella*, and large flower hybrids should perform fairly well, but are rarely seen.

New Mexico and Colorado can claim *C. ligusticifolia* as a native plant as well; it is found in these states from 3000 to 8000 ft along roads and in moist canyons (Carter, 1988). There are at least four other native or naturalized *Clematis* known to these parts of the rockies: *C. columbiana*, *C. hirsutissima*, *C. orientalis*, and *C. pseudoalpina*.

The native *C. columbiana* is found in a large area of the west, ranging from Chihuahua, Mexico to British Columbia. The species grows from 2000 to 10,000 ft. among sagebrush and pines and its blue to purple flowers are found spring through summer.

Clematis hirsutissima, or sugar bowls, is another common native that is found from New Mexico to Montana and west to Washington and Nevada. This species has pale-blue to purple campanulate flowers and is found in canyons and on hillsides from 5000 to 9000 ft.

Clematis orientalis is a native of Turkey that has naturalized over a great part of the western U.S. There remain arguments about the correct identification of this species here; ours is probably a hybrid between *C. tangutica* and *C. orientalis*. This plant is found from 6000 to 8000 ft., often in dense tangles along streams (Kelly, 1970). Beautiful nodding yellow flowers appear in late summer, followed by attractive seedheads that remain all winter.

The fourth species is *C. pseudoalpina*, which may also be known as *C. alpina* var. *occidentalis* in the literature (Means, 1993). This plant is found in shady places and is small, with scrambling vines up to 5 ft in length, flowering May through July. It is this species that is most like *Clematis alpina*, the native species of the European Alps.

This close relationship suggests that many of the cultivars of *C. alpina* would be worthy of greater garden use in these states. They are some of the earliest flowering clematis, beginning in April, are fully hardy; the species *C. alpina* ssp. *siberica* has even been reported flowering in the north of Norway, within the Arctic Circle (Fisk, 1994). Unlike many other *Clematis*, the *C. alpina* forms tolerate open and exposed conditions (Brickell et al., 1989). Some of the cultivars to look out for include 'Columbine White'; 'Willy', a pink with some summer flowers; and 'Helsingborg', a deep purple.

The Chinese compliment of the *C. alpina* species is *C. macropetala*. Also from the high mountain regions, the species and its cultivars are well-adapted to extreme cold and low humidity and do very well in our Rocky Mountain states. The macropetalas all flower in early April and have slightly open, semi-double flowers. There are at least eight cultivars that are commercially available, including 'Markham's Pink', 'White Swan', and 'Jan Lindmark'.

The native *Clematis* of Utah, Idaho, Wyoming, and Montana are almost the same as those of Colorado (Welsh, 1987). Given the climates of all of these mountain states, the hardy *C. alpina* and *C. macropetala* species and cultivars are very good choices for early flowering. They may be complemented with selections of the montanas and viticellas and large-flowered hybrids for later flowering in the season, although the latter group would require some cold protection.

The native clematis of Washington, Oregon, Northern California, and British Columbia have already been discussed and include: *C. columbiana*, *C. ligusticifolia*, and *C. pseudoalpina*. Other species in evidence, depending upon reference sources, include *C. douglasii* and *C. occidentalis ssp. grosserrata* (Huxley et al., 1992).

The climate in many parts of this region is much like southern England, normally with ample rainfall and relatively mild winters. Those of us who are not from the Pacific Northwest can be quite envious, for all of the groups of clematis can be grown here. This area is particularly known for the early, large-flowering hybrids, including 'Asao', 'Fireworks, 'Haku-oôkan', 'Niobe', and 'Snow Queen', as well as many later flowering hybrids like 'Ernest Markham', and 'Madame Edouard André'.

A few more recent introductions of the large-flowered hybrids would include 'Arctic Queen', a superb and very free-flowering new double white; 'Blue Ravine' a UBC introduction with 8-inch, blue-mauve flowers with red anthers; 'Guernsey Cream', perfect for a shady position with 5-inch, creamy-yellow flowers; 'Masarad' (syn. 'Masquerade'), with mauve-blue flowers 6 inches across with light-brown centers; and 'Multi Blue', a deep blue with double-centered tepals tipped with white.

This has been a very brief look at *Clematis* for production in a very large geographic area. There are a number of other species from Europe, the Mediterranean, and New Zealand that would also be worthy of trials or more frequent use in this region, including the shrub forms of the herbaceous *C. heracleifolia*.

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Jewels of the Plains: Selection and Propagation of Native Perennials

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INTRODUCTION

Paulino's is a retail nursery and produces over 1300 types of perennials grown from seed, cuttings, and bareroot divisions.

The growing area for perennials covers 5 acres where over 300,000 1-gal-size and 500,000 4-inch-size perennials are grown. Soft cuttings are rooted under shade in humidity tents using one layer of 4-mil clear poly and another layer of 50% shade cloth.

Display gardens at the nursery help maximize sales and serve as trial grounds for new varieties. Paulino Gardens builds feature gardens and educational displays for organizations such as the American Rock Garden Society.

USE OF NATIVE PLANTS IN THE DENVER AREA

The Denver Botanic Gardens Plains Garden inspires many gardeners in the use of native plains plants. The Denver Zoo utilizes native plants (*Sorghastrum nutans*, *Chrysothamnus nauseosus*,*Schizachyrium scoparium* (syn. *Andropogon scoparius*), *Yucca glauca*, etc.) in displays near the native animals.

WILD PLANT SELECTIONS

Most of my plant selections are made in Colorado, Wyoming, Montana, and South Dakota. *Iris missouriensis* is a favorite wildflower that when grown from seed is typically pale blue. I'm working on selections of pure white and deep purples. Propagation of the selections must be by division. Hopefully, we will soon be able to propagate them by tissue culture. The best selections have come from Wyoming.

In western and central Colorado, I find a lot of drought-tolerant plants such as *Echinocereus reichenbachii* (syn. *E. caespitosus*) (a crested form) which is multiplied by grafting pieces of the crest onto *Opuntia phaeacantha* yearlings that are still in a cylindrical, juvenile form.

I am particularly interested in larger flowered forms of *Zinnia grandiflora*. This is one of the few perennials that blooms all summer. Seed will usually germinate after a cold stratification of 2 weeks at 38 to 45F.

Claude Barr (1983), a famous Great Plains plantsman who wrote *Jewels of the Plains*, was passionate about roses such as a lovely, near-red form of *Rosa arkansana* selected near Sheridan, Wyoming. The plant is growing in loose shale and is nearly 200 ft across. It is propagated by root or stolon-root cuttings at any time of year. Hardwood cuttings are relatively successful.

Other native plants such as *Dodecatheon pulchellum* are selected for white and crimson color forms that are best propagated by division. *Lewisia rediviva* has been selected for white flowers and is a choice plant among rock gardeners. It is generally grown from seed because it is too slow by division (cold stratify for 6 weeks). *Lilium philadelphicum* var. *andinum* is a favorite in the Black Hills of

South Dakota where I am hopeful to find a true red or other variant. This lily can be propagated from bulbils or bulb scales. On the high prairie of Wyoming I find deeply colored forms of *Oxytropis lambertii*, a beautiful, silver-leafed pea. I stratify the seeds for 6 to 12 weeks at 38 to 45F.

Penstemon species are often considered among the choicest perennials on the Great Plains. Breeding and selection are performed at the North Platte Experiment Station in Nebraska.

On Mount Evans in Colorado, we find both deep purple and white forms of *Penstemon whippleanus*, with no color variation in between. Fresh seed sown in August or September germinate readily.

Penstemon grandiflorus is one of my personal favorites. It is a very showy, large-flowered species. Mary Ann Heacock of Denver selected these many color forms from her early crosses with other species. Six weeks of cold stratification is beneficial.

Undoubtedly, one of the showiest penstemons is from Wyoming. *Penstemon glaber* is generally royal blue and occasionally a natural hybrid is found such as the one I call 'Purple Banner'. *Penstemon glaber* may be useful in *Penstemon* breeding because of its longevity. Many penstemons are short-lived.

CONCLUSION

I'm just beginning my work on native perennial plant selections and I'm looking forward to many years of further exploration. I suspect that Colorado's water availability may decrease in the next few years with the influx of people into the state and I want to be prepared with a whole palette of colorful native plants to offer water-restricted gardeners.

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Plugs and Automation—"The Future is Here!"

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HISTORY OF BEDDING PLANT PRACTICES WITH REFERENCE TO SEEDING AND TRANSPLANTING

The old practice of seeding was to seed into flats using 1000-1500 seed per flat. After germination, transplant 64 seedlings to the same size flat. After 3 to 5 weeks, transplant those to the various finished product sizes. The only automated process of this practice was the flat filling and dibbling (dibble board).

CURRENT PRACTICES—COLORAMA

Assumption: Decision made to use plugs after going over the pros and cons. Our nursery grows its own plugs. Now that we have a viable plug, we decided, based upon the volume of plugs we need (approx. 750 thousand per week), that we still needed our original Blackmore seeder for certain varieties. However, we also needed to go faster with the same or better accuracy. We chose a Williams Drum Seeder (product of Australia). We currently have two of these machines, one being used for our 406 cavity plug tray and the other on our 162 cavity plug tray. The speed on the Williams Drum Seeder can go as high as 1.7 million seeds per h. We do not run this fast, since we're making small runs of many varieties. Plus, there is no way one human being can remove that many trays at that speed.

Now that we have the seeder, we went to a larger capacity tray filler, on which we can set compaction percentages, speeds, and soil depths. We also added an automatic plug tray dispenser. With all of the machines set to seed, we decided to put this all in a climate-controlled warehouse setting. We added "dutch trays" (containers) to take care of the handling problems we had prior to automating the seeding line.

From this point, we built a computerized, state-of-the-art greenhouse, solely for plug production equipped with automatic watering booms, grow lights, auto shading curtains, and a Mee Fog System.

Carrying this process further, what we have now is a viable, living plug to transplant to a finished product. We now go through our potting area where we've been using a Timmer robotic transplanter for the past 5 years. This particular model is a double trolley, utilizing 2 rows of plug trays, one on each side of the machine. There are two sets of fingers, one for each plug tray run. When one side of plugs is being picked up, the other is being planted in the finished product coming through the middle of the machine; the process then reverses. This machine does not electrically scan each plug cell, consequently, it will plant a blank. We still need repairers after planting to catch those "blanks"; obviously, it is not completely foolproof. The capacity of this machine is 20,000 plugs/h.

Our 4-inch pots are planted on a super Javo, 6400 pots/h. Two people are needed with plug trays. Those plug trays are dislodged prior to planting.

CONCLUSION

Growing plugs can save time and enhance profits. If you choose to automate, it can be done at the very beginning of seeding, in the germination area or during the transplanting process. My personal feelings are that automation keeps us cost effective and on top of technology. I've always been a believer in putting capital back into the business. We have to stay competitive and one way is to use automation. Consider a few of the following factors prior to automating: What do you want to accomplish, what support equipment will be needed, what is the cost, and what is the payback period?

New Varieties For Today's Market

Jamie Kitz
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With bedding plants being the fastest growing sector of floriculture in the United States, new varieties are needed to meet the changing requirements of the commercial grower, as well as the bedding plant consumer. There have been increases in the number of F1 hybrid varieties available that offer new crops, colors, and performance improvements, thus improving upon existing bedding plant species.

The methods of bedding plant production as well as the distribution of bedding plants have necessitated changes in our industry. All the changes have provided Goldsmith Seeds with an opportunity to produce varieties that exceed the requirements of our customers.

Goldsmith Seeds' chain of distribution for F1 hybrid seed renders many tiers of customers, each with their own distinct requirements for a variety. Seed is sold directly to seed brokers, who in turn sell the seed directly to growers. Seeds are then grown out and sold to garden centers and other plant merchants in packs and other containers. The flowering plants are then purchased and used by landscapers and consumers.

To ensure that we exceed the requirements of all customers in the chain of distribution, several criteria are assessed before introducing a variety: a wide adaptability to climates and day length for both greenhouse and garden performance, seed production requirements, and seed quality .

THE ADVENT OF THE PLUG

With the advent of plug production, the chain of distribution has changed, as well as magnifying the germination requirements for a variety. Many growers purchase plugs rather than buying their own seed. This has resulted in more seed being purchased by fewer growers. With this revised structure, the plug producer greatly influences those varieties that are available in the market. Regardless of the performance of a variety, if it is not producible in a plug, the chances of survival in the market are reduced.

INDUSTRY INFLUENCES

The key to success is introducing new varieties that reflect the changing requirements of the bedding plant industry. Some of these industry influences are crop time, diversity, performance, and customer preference.

Crop Time. Crop time directly affects the cost of production. With a shorter crop time, quicker crop rotations can be accomplished. This is an important factor in a highly competitive market. The challenge from a breeding perspective is to develop a hybrid that is earlier to bloom without sacrificing garden performance. The recently introduced 'Antigua' dwarf African marigold, *Tagetes erecta,* met this objective. 'Antigua' is earlier than other dwarf African marigolds, while still exhibiting strong garden performance. The variety maintains a 10-12 inch height in the garden, with good basal branching habit, and proportional flower size.

An additional feature of the 'Antigua' marigold is day length neutrality. Marigolds typically are produced in early spring, requiring short days to initiate flowering. Production of African marigolds has extended into both summer and fall markets. 'Antigua' marigolds enable growers to supply African marigolds without the added expense of black clothing to ensure bud set and proper crop time under long-day conditions.

Diversity. Diversity is a very strong influence on new variety selection, both with traditional bedding crops as well as developing new classes. With growers expanding their shipping areas, their customer base has become more diverse. A broader product line is essential for their distinct clientele.

Multibloom geraniums, *Pelargonium ×hortorum*, introduced a diverse class of geranium with a shorter crop time. Producing twice the flowers as an ordinary F1 seed geranium, it brought a new appearance to seed geraniums. Compared to the original F1 hybrid geranium, Sprinter hybrids introduced 20 years ago, Multibloom hybrids decreased crop time to 10 weeks from 16 to 18 weeks, compacted plant size, and added unique colors. Growers can produce quicker crop rotations with a more adaptable variety, resulting in a more profitable crop.

With a need for diversity in petunia, Goldsmith Seeds will be introducing a new class of petunia, the milliflora. The milliflora petunia is unique; it is a true miniature petunia, with the plant being proportional in size with the flower. The advantages to the producer are, that the compact habit decreases the need for growth regulators, which in turn reduces cost. Earlier crop time and excellent pack performance compared to other F1 hybrid petunias gives quicker turns and a high-quality product. For the consumer, mini petunias bring diversity as well as a plant with very good garden performance. Mini petunias continue to produce multiple blooms throughout the season, while maintaining an attractive plant habit.

Primula obconica also has potential for diversity and has been available for years as an F1 hybrid for bedding plant and florist crop producers. Production has been decreasing in recent years though, due to the skin irritation caused by the chemical, primen, that is carried in the leaves. In response, Goldsmith Seeds will be introducing, a primen-free F1, *Primula obconica.* Without the risk of primen irritation, this new variety will help revive a declining, but much desired crop.

Performance. Garden performance as well as greenhouse performance are important factors for continued customer satisfaction. Bells dwarf snapdragons, *Antirrhinum majus*, took a class of bedding plant and enhanced it with a drastically improved garden performance. Equipped with a peloric flower form rather than a standard snapdragon form, Bells snapdragons bloom longer into the season, giving the consumer a more desirable plant. The peloric flower form allows the plant to avoid seed set, thus giving more flower production. Brighter colors give an added appeal to the consumer, as well as a compact, well-branched variety for the grower.

Cyclamen is an expanding crop with developments on diversity. The majority of cyclamen are now produced as an F1 crop rather than an open-pollinated crop. The improvements of the F1 hybrid of decreased crop times and increased uniformity and flower quality have popularized the F1 cyclamen. With the advent of F1 cyclamen, three types emerged: Sierra hybrids for 6-inch container production, Laser hybrids intermediate for 4- to 5-inch production, and Miracle hybrids mini for 3- to 4-inch production. By developing three classes of cyclamen hybrids, growers have the opportunity to choose types that complement their production techniques and clientele.

Customer Preference. *Impatiens wallerana* continue to be the leading bedding crop, with consumer preference continuing to increase. They are relatively trouble-free, perform in a wide variety of conditions, and provide a magnificent show of color. Presently, Accent impatiens series is offered in 20 distinct colors. Consumer color preferences can change rapidly. With 3 to 5 years needed to develop a new variety, it is important to have a wide color range available so the product is available to respond to fluctuating color preferences. The influence of the consumer requires the continued development of new colors in this series.

Mechanization. As the number of plugs produced increases, so does the technology used for production of bedding plants. To facilitate the mechanization used in production, seed is now sold in many product forms such as coated, primed, and pelleted. The challenge to seed producers is to offer enhanced seed that maintains the necessary germination standards.

New varieties meet the opportunities our industry provides. Goldsmith Seed continues to breed new varieties to stay abreast of our dynamic industry. Through extensive trials for germination quality and greenhouse or garden performance, varieties are introduced that exceed the requirements of all levels in the chain of distribution. The end result is a company in the industry offering the best varieties for the producer for the maximum enjoyment of the consumer.

Unusual Perennials

Ed Wood
Owner, Bonsai Village, P.O. Box 327, Wilsonville, Oregon 97070

Here's a list of interesting perennials from the Pacific Northwest:

Aquilegia flabellata var. *pumila* (syn. *A. akitensis*), *A. vulgaris* 'Nora Barlow', *Anemone blanda, Anemone pulsatilla, Arenaria balearica, Aster novi-belgii* dwarf, *Astilbe chinensis, Aubrietia gracilis, Bolax gummifera* (syn. *B. glebaria nana*), *Claytonia parvifolia* (syn. *Montia parvifolia*), *Cyclamen hederifolium, Dianthus chinensis* (syn. *D. laciniatus*), *Erysimum* dwarf, *Euphorbia polychroma, Genista tinctoria* 'Humifusa', *Globularia repens* (syn. *G. nana*), *Gypsophila aretioides, G. aretioides* 'Caucasica', *Helleborus orientalis, Herniaria glabra, Iberis sempervirens* 'Pygmea', *Iris* dwarf bearded, *I. innominata, I.* Pacific coast hybrids, Leucanthemum ×*superbum* (syn. *Chrysanthemiun maximum*), Lewisia cotyledon, *Phlox* 'Santa Fe', *Pimelia prostrata, Potentilla crantzii, P. eriocarpa, Primula* Gold Lace Group, *P.* Jack in the Green Group, *P. prolifera, P. pulverulenta, P. seiboldii* 'Snowflake', P. *vialii, Raoulia subsericea, Saponaria* ×*olivana, Saxifraga umbrosa* var. *primuloides, Scleranthus uniflorus, Solenopsis fluviatilis* (syn. *Laurentia fluviatilis*), Thalictrum rochebrunianum, and *Tanacetum densum ssp. amani*).

QUESTION-ANSWER PERIOD

Kristin Yanker-Hansen: When you talk about new crops, are you at all interested in growing something other than what is already grown in the trade? Do you ever deal with annuals that you have never heard of?

Jamie Kitz: Yes. It has to be an excellent F1 hybrid because that is the only type of bedding plants we work with. The breeders are constantly looking for new crops to bring to the market.

Steve Mullaney: Are the plants actually free of the hairs or are the hairs free of the primen?

Jamie Kitz: I believe the chemical is in the tissue and not in the hairs.

Bruce Briggs: How do you measure public demand?

Cynthia Chandless: Usually the hobbyist and gardening magazines are generating or responding to those demands.

Bob Hugart: Do you see the trend in perennials going more toward smaller containers or more toward larger 1's, 2's, and 5's?

Cynthia Chandless: I don't think there is just one answer here. It does depend on the person or business itself and what market shares you are serving. On the one hand, I've got one client telling me that they are putting all their energy into 4 in. because their return was greater than when they sold gallons. In colder climates it makes sense to plant bigger plants.

Kristin Yanker-Hansen: Where can we get these perennials?

Ed Wood: Contact me and I will be happy to make plants available.

Unusual Perennials

Ed Wood
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Aquilegia flabellata var. *pumila* (syn. *A. akitensis*), *A. vulgaris* 'Nora Barlow', *Anemone blanda, Anemone pulsatilla, Arenaria balearica, Aster novi-belgii* dwarf, *Astilbe chinensis, Aubrietia gracilis, Bolax gummifera* (syn. *B. glebaria nana*), *Claytonia parvifolia* (syn. *Montia parvifolia*), *Cyclamen hederifolium, Dianthus chinensis* (syn. *D. laciniatus*), *Erysimum* dwarf, *Euphorbia polychroma, Genista tinctoria* 'Humifusa', *Globularia repens* (syn. *G. nana*), *Gypsophila aretioides, G. aretioides* 'Caucasica', *Helleborus orientalis, Herniaria glabra, Iberis sempervirens* 'Pygmea', *Iris* dwarf bearded, *I. innominata, I.* Pacific coast hybrids, Leucanthemum ×*superbum* (syn. *Chrysanthemiun maximum*), Lewisia cotyledon, *Phlox* 'Santa Fe', *Pimelia prostrata, Potentilla crantzii, P. eriocarpa, Primula* Gold Lace Group, *P.* Jack in the Green Group, *P. prolifera, P. pulverulenta, P. seiboldii* 'Snowflake', P. *vialii, Raoulia subsericea, Saponaria* ×*olivana, Saxifraga umbrosa* var. *primuloides, Scleranthus uniflorus, Solenopsis fluviatilis* (syn. *Laurentia fluviatilis*), Thalictrum rochebrunianum, and *Tanacetum densum ssp. amani*).

QUESTION-ANSWER PERIOD

Kristin Yanker-Hansen: When you talk about new crops, are you at all interested in growing something other than what is already grown in the trade? Do you ever deal with annuals that you have never heard of?

Jamie Kitz: Yes. It has to be an excellent F1 hybrid because that is the only type of bedding plants we work with. The breeders are constantly looking for new crops to bring to the market.

Steve Mullaney: Are the plants actually free of the hairs or are the hairs free of the primen?

Jamie Kitz: I believe the chemical is in the tissue and not in the hairs.

Bruce Briggs: How do you measure public demand?

Cynthia Chandless: Usually the hobbyist and gardening magazines are generating or responding to those demands.

Bob Hugart: Do you see the trend in perennials going more toward smaller containers or more toward larger 1's, 2's, and 5's?

Cynthia Chandless: I don't think there is just one answer here. It does depend on the person or business itself and what market shares you are serving. On the one hand, I've got one client telling me that they are putting all their energy into 4 in. because their return was greater than when they sold gallons. In colder climates it makes sense to plant bigger plants.

Kristin Yanker-Hansen: Where can we get these perennials?

Ed Wood: Contact me and I will be happy to make plants available.

Tissue Culture of Roses: Past, Present, and Future

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Roses have been the subject of myriad tissue culture studies for the last fifty years. The justification for most of the studies has been based on either crop improvement (breeding) or propagation. Early work focused on seed germination and embryo culture; artificial culturing (*in vitro*) of embryos followed. Micropropagation, *in vitro* morphogenesis, and genetic engineering have been the most popular areas of study in the last twenty years.

THE PAST

In the 1940s, Lammerts (1942) developed a technique for the culture of rose embryos. This was not done *in vitro*, but the work did show that rose embryos could be excised from seeds and germinated. A decade later Asen and Larson (1951) developed a technique for the artificial culturing of rose embryos. Their major contribution was in the use of a seed coat softening solution known as Cross and Bevan's Reagent. This reagent was made by dissolving 30 g of $ZnCl_2$ in 50 ml concentrated hydrochloric acid. After varying times (2-16 hr) in this reagent the seed coats of various rose species were softened to the point where they could be cut away and the embryos removed. They also found that immature embryos could be removed from hips and cultured immediately using this seed coat softening technique.

Hill (1967) successfully developed a system for the regeneration of shoot primordia from stem tissue. This was important work since it showed that roses had the capability to form adventitious organs *in vitro*. Hill's most successful culture medium included (in mg/liter) 0.5 α-naphthaleneacetic acid, 0.2 kinetin (6-furfurylaminopurine) and 20 gibberellic acid. Other work also in the 1960s, 1970s and 1980s focused on the use of apical and axillary meristems as primary explants to establish *in vitro* cultures for rapid micropropagation (Bressan et al., 1982; Davies, 1980; Elliot, 1970; Hasegawa, 1979; 1980; Hyndman et al., 1982a,b; Jacobs et al., 1969; 1970a,b; Jacobs et al., 1968; Khosh-Khui and Sink, 1982a,b,c; Skirvin and Chu, 1979a;b).

THE PRESENT

Our work has focused on embryo rescue. In cooperation with Bear Creek Gardens, Inc. (Somis, CA), we cultured immature embryos resulting from crosses between *Rosa* Bridal Pink® and six separate pollen parents. It had been observed that these crosses resulted in no or few progeny probably due to abortion sometime during embryo development. Questions requiring an answer included: How would the various crosses (genotypes) respond to tissue culture?, What was the optimum time of removal of the immature embryo?, What was the optimum tissue culture medium?, and What was the optimum culture environment? The original goal was to simply learn how to germinate excised immature embryos in vitro. This goal was not realized since germination was never observed. The response of the excised embryos was to develop an organogenic callus that, after 6-9 months, was capable of forming adventitious shoots that could be excised and rooted on a different culture medium (Burger et al., 1990). In short, we found that:

There were significant differences in how the six genotypes responded to tissue culture. One genotype (code #174) responded well by forming adventitious shoots that rooted well and were easily transplanted to greenhouse conditions. Three genotypes regenerated plantlets, but to a much lesser degree than #174, and two genotypes were not capable of regeneration under our experimental conditions. Since all six genotypes had the same maternal parent ('Bridal Pink'), it's remarkable that there was such wide variation in their capability for regeneration and points to an important genetic component when selecting plant materials for tissue culture studies.

Table 1. Summary table of in vitro responses from various rose cultivars.

Author(s)	Explant	Response
Hill	stem pith	callus, *shoot primordia
Jacobs et al.	stem pith	callus, *buds
Mollard et al.	stem pith	callus
Nesius et al.	stem pith	callus
Weinstein et al.	stem pith	callus
Amorim et al.	stem pith	callus
Burger et al.	peduncle, callus	roots
Tabaeezadeh and Khosh-Khui	anther	callus
Davies	axillary buds	callus, shoot elongation, roots
Elliot	shoot apex	callus, shoot elongation, roots
Hasegawa	shoot apex	shoot development, roots
Hyndman et al.	shoot apex	roots
Jacobs et al.	shoot apex	callus, leaf development, roots
Khosh-khui and Sink	shoot apex	shoot elongation, roots
Skirvin and Chu	shoot apex	shoot elongation, roots

* no further development observed.

Embryos had to be at least 25 days post-pollination for them to develop an organogenic callus capable of regeneration. The seed coat of rose become very hard after about 40 days post-pollination. After this time embryos are quite difficult to remove from the seed.

The culture medium had to include a cytokinin and an auxin for regeneration. Our choices for a cytokinin and auxin were 1 μM 6-benzyladenine (BA) and 0.05 μM α-naphthaleneacetic acid (NAA), respectively, in a half-strength Murashige and Skoog Medium (1962).

Embryos formed the organogenic callus and regenerated shoots only on a semi-solid medium (0.6% agar) in the light (50 $\mu moles \cdot m^{-2} \cdot sec^{-1}$ or about 150 fc).

The regeneration system has been exploited for mutation breeding purposes.

Calli were exposed to Cobalt 60 for varying lengths of time to give varying doses of irradiation. Doses above 4 kRad killed the callus tissues. Irradiated calli were then placed in tissue culture conditions stated earlier to undergo regeneration. Mutant plants obtained from callus that had been irradiated formed flowers that had fewer petals and the petals had lower levels of red pigmentation. The benefit of irradiating organogenic callus can be appreciated when the mutants maintained their unique characteristics for more than three years, showing a stability that had not been possible when axillary buds had been irradiated (Wang and He, 1990).

THE FUTURE

The capability for regeneration of whole plants is necessary for modern genetic engineering techniques to be useful in rose improvement. We are working on two new regeneration systems: leaf disc method and fragmented shoot tip culture. The leaf disc method has been used successfully with many other species. It utilizes leaf discs as the primary explant and depends on the formation of adventitious organs from the wounded margin of the disc. Fragmented shoot tip culture was developed by Barlass working with grape (Barlass and Skene, 1978). In this technique, shoot tips, 1 mm long, are excised from the plant, macerated with a scalpel, and plated onto tissue culture media. The meristematic cells of the shoot tip provide excellent explants for regeneration.

Several laboratories around the world are working on using *Agrobacterium tumefaciens* as a means of incorporating new genetic information into roses. This bacterium is a causal agent for crown gall in roses. It has the capability of inserting part of its DNA into wounded plant cells once it becomes associated with the cell, thus transforming it. Techniques have been developed whereby genes of interest (e.g. RoundUp resistance) can be engineered into that portion of the DNA that *Agrobacterium* inserts into the plant's DNA. Ultimately, the usefulness of *Agrobacterium*-mediated transformation depends on the ability to regenerate whole plants from transformed cells.

In summary, the interest in using *in vitro* techniques for rose improvement continues today. Several rose cultivars have been successfully regenerated using tissue culture techniques and the list will surely grow. There is great variation in the ability of various cultivars to undergo organogenesis or embryogenesis, even those that are very closely related. Regeneration is a necessary process to make use of the genetic improvement techniques such as *Agrobacterium*-mediate transformation.

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Tissue Culture Propagation of *Zantedeschia* (Calla Lily)

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INTRODUCTION

The *Zantedeschia* or calla lily belongs to the aroid family (Araceae) and is commonly known as arum lily, pig lily, or yellow and pink arums. It belongs to the same genera as *Anthurium*, *Caladium*, *Dieffenbachia*, *Monstera*, *Philodendron*, *Scindapsus*, *Spathiphyllum*, and *Syngonium*. The genus was named by Sprengel in 1826, in honor of Professor Zantedeschi. There are numerous species: *Z. aethiopica*—the common white calla lily or arum, *Z. rehmannii*—narrow lanceolate leaves with flowers varying in color from ivory-white to deep-pink, *Z. jucunda*—yellow flowers in the summer, *Z. elliottiana*—yellow flowers with spotted leaves, *Z. pentlandii*—varying colors from white to yellow, and *Z. albomaculata*—strong growing with pale cream-lemon flowers.

The hybrids we are working with at the lab were developed in New Zealand from these species.

The calla lily comes from the summer rainfall areas of South Africa, growing and flowering in the early summer and dying back in late autumn to a fleshy tuber that remains dormant until spring. It was back in 1930 that hybridizing work started with these plants. The commercial objective of the breeding work is productivity, longer and stiffer flower stems, uniformity, and larger spathes.

For many years seed production has been carried out and it is well-known that this will provide a varying color range, many of which are unacceptable for the cut flower industry. With markets wanting quality, the use of tissue culture is imperative to ensure that this crop will, first, produce the flower with the necessary characteristics to satisfy the client and, consequently, demand the highest return.

The technique for propagating Zantedeschias was developed at the DSIR, Palmerston North, New Zealand by Cohen (1983). It is now the commonly accepted means of bulking up new cultivars. The initiation in culture is simple and multiplication rates are high. Dasheen mosaic virus (DMV) and *Erwinia* are the main concerns with zantedeschias and, therefore, the importance of tissue culture. Tissue culture is the only means of insuring clean propagules for planting (Zettler, 1988).

MICROPROPAGATION

Stock Solution and Media Preparation. We prepare all stock solutions and media in the preparation room. The Murashige and Skoog mineral medium is supplemented with vitamins, cytokinin, carbohydrates, and agar to promote shoot formation and root initiation. The mixture is brought to proper pH (5.8) with sodium hydroxide and/or hydrochloric acid and then heated and stirred until the agar is melted. The mixture is dispensed into culture vessels. All vessels are carefully labelled and autoclaved at 121C for 15 min.

Initiating Cultures. Zantedeschias need to undergo a dormancy period before they can be replanted. Buds can be dissected either during the dormant phase or as the buds begin to swell. The rhizome is first washed to remove surface dirt and a section of the rhizome with a bud is removed with a sharp knife. These sections are dipped in 95% ethanol and flamed twice. A small piece of tissue (2 to 4 mm long) containing the apical bud is cut out. The vessels are taken to the incubation room where they receive continuous light for 16 h and the temperature is 70 to 75F.

Shoot Multiplication and Elongation. Before opening any vessel, we check for contamination that might appear either in the media or directly on the explants and begin to subculture. Buds that are initiated expand rapidly and are split to enhance the development of a proliferating bud mass consisting of small buds. This mass can be cut into sections and replanted onto the same medium indefinitely.

Root Formation. The cultures are placed on a rooting medium with 0.1 mg/liter BA where rooting usually occurs within 2 weeks. After another 2 weeks, the leaf sheath grows to about 30 to 50 mm. The plantlets are easily handled at this stage and can be transferred directly to a potting mix.

Transfer to Potting Mixes. The rooted shoots are rinsed to remove agar and are planted in freely draining soilless mixes and placed directly into a shaded greenhouse under a fertilization program. The leaves start to unroll and new leaves develop. After approximately 6 months, the plantlets form a small rhizome that is harvested and cured. These rhizomes need to undergo a 6- to 8-week dormancy period before they can be planted. They can be planted into 2-, 4-, or 6-inch pots and will develop well as pot plants or they can be planted out in the fields to grow them on to larger flowering sizes.

TRANSFER TO THE FIELD

In the field, the ground beds are prepared to provide the best soil drainage possible for the rhizome. Pumice, organic matter, complete fertilizers, and soil disinfectants are applied to the beds before planting. During planting, the rhizomes are handled with the greatest care to avoid bruising them. The worst enemy of zantedeschias is *Erwinia* and this can be controlled by careful, hygienic handling of the bulbs and by providing excellent soil drainage. The rhizomes are covered with 2 to 3 cm of light soil, pumice, sawdust, or rice hulls; the amount varies according to the size of the rhizome.

The rhizomes will begin to flower 8 to 12 weeks after planting. The flower is a transformed leaf bract and is composed of a central spadix bearing true male and female flowers, a colored spathe, and a flower stem. The top of the flower spathe is round or pointed in shape and the front can be open or semi-open. Flower quantity depends on cultivar, rhizome size, storage treatments, and growth regulator applications.

ADVANTAGES AND DISADVANTAGES OF MICROPROPAGATION

The technique for micropropagation developed in New Zealand has been a great accomplishment for the commercial development of callas.

Advantages of Micropropagation.

1) Only a small amount of source plant material is required. Once clean material is initiated *in vitro*, it can be rapidly bulked up and maintained over a long period of time in very little space.

2) Micropropagation is a much more rapid mass production method due to the high *in vitro* multiplication rate of the plant material.

3) The plant material obtained through micropropagation will be of the highest quality, free of any pathogen, and producing a crop identical to the parent plant. Tissue culture is the only means of ensuring clean propagules free of DMV and *Erwinia*.

4) The rooting percentage *in vitro* is high and the plantlets can be transferred easily to the greenhouse.

Disadvantages of Micropropagation.

1) It is still, today, a more laborious method requiring a controlled environment.

2) It takes approximately 9 months to produce a 1 to 2 cm rhizome (0.50 to 0.75 in.) and this size rhizome cannot produce a long-stemmed cut flower for the cut flower industry. Therefore, due to the work involved in propagating *Zantedeschia* and the time required to obtain a good quality rhizome, the cost of initial stock rhizomes is somewhat high.

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Propagation of Ornamental Varieties of Spruce (*Picea* spp.) through Somatic Embryogenesis

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Somatic embryogenesis (SE) is a potent tool for rapid vegetative propagation and can produce high volumes of cloned embryos from a single seed. The impact of this new propagation technology on the ornamental conifer landscape industry may be substantial. Grafting of named cultivars is expensive and results in poor form requiring years of pruning and shaping. Somatic seedlings have the trueness-to-type of grafts, but also demonstrate the growth and form of true seedlings. We describe applications of SE for the commercial development of ornamental varieties of Colorado blue spruce (*Picea pungens*) and white spruce (*P. glauca*). At least 150 clonal lines of somatic seedlings have been established in nursery trials and cryopreservation. Trials will be assessed for landscape characteristics over the next several years prior to volume production of selected clones.

INTRODUCTION

Somatic embryogenesis (SE) is a relatively new technique for vegetative propagation of conifers and can produce high volumes of cloned embryos from a single seed. SE of conifers was first reported in 1986 (Hakman and vonArnold, 1985) and this tissue culture propagation technique has developed rapidly since then to the first pilot-scale forestry applications in recent years (Cervelli et al., 1994; Roberts et al., 1994). SE potentially offers a cost-effective replacement for other forms of vegetative propagation (Cervelli and Senaratna, 1994). At present, the technique is limited to the use of seed embryos or young seedlings as a source of tissue for induction of embryogenic culture lines. We describe applications of SE for the commercial development of ornamental cultivars of Colorado blue spruce (*Picea pungens*) and white spruce (*P. glauca*).

The impact of this new propagation technology on the ornamental conifer landscape industry may be substantial. Grafting of named cultivars is expensive and results in poor form requiring years of pruning and shaping. Somatic seedlings have the trueness-to-type of grafts, but also demonstrate the growth and form of true seedlings. In addition, clonal SE lines can be preserved indefinitely by storage in liquid nitrogen and bulked up for production at any time (Cyr et al., 1994). This unique ability to store clonal lines in this manner is significant because germplasm banks of superior material can be established and maintained at low cost while field trials are being performed. Production and delivery of somatic seedlings from the germplasm bank to the nursery can be accomplished within 6 to 8 months.

SE has been evaluated throughout the tissue culture, nursery production, and field establishment phases. Studies of the biochemistry and patterns of gene expression during development of somatic and zygotic embryos (Flinn et al., 1993) and during germination (Cyr et al., 1991) revealed that they are similar with respect to the accumulation and utilization of storage proteins and lipids. Assessment of genetic stability during SE using isozyme analysis (Eastman et al., 1991) and before and after cryopreservation using RFLP analysis (Cyr et al., 1994), indicate that somaclonal variation is very infrequent compared to other micropropagation methods (Scowcroft, 1984). Finally, intensive morphological and physiological assessments during nursery and field growth show that somatic seedlings are normal with respect to their performance and phenological patterns (Grossnickle et al., 1992; Grossnickle et al., 1994; Grossnickle and Major, 1994a and 1994b). At present we have established approximately 80,000 spruce somatic seedlings in nursery and field trials in at least six separate locations throughout North America, the oldest of which were field planted in 1990.

METHODS

Seed from the Kaibab and Piedra River provenances of Colorado blue spruce was obtained from Dean Swift Seed Co., Jaroso, CO. In addition, half-sib seed was obtained from the top four families ranked for color at the Michigan State University orchards established by the late Dr. Hanover. Full-sib white spruce seed of the variety Sunburst™ was obtained from the National Forestry Institute, Petawawa, Ontario. Sunburst™ spruce is characterized by a brilliant yellow spring foliage due to delayed chlorophyll development.

Seed were dissected and SE calli induced from seed embryos following the protocol described in Webb et al. (1989). These callus lines have been cryopreserved according to the protocol described in Cyr et al. (1994). Embryo maturation, desiccation, and germination were performed according to protocols described in Webster et al. (1990), with significant modifications (unpublished). Somatic seedlings were hand-potted to ray-leach tubes or by machine to 415B styroblocks containing a standard peat and perlite mix and grown in a controlled-environment room or greenhouse before transfer to the field. Styroblocks were planted by the Fast-Plant™ semi-automated planting technology developed for this purpose (Edmonds and Cervelli, 1993). The Fast-Plant™ machine utilizes a series of "open-books" of pre-moistened potting mix for the accurate and damage-free planting of 4- to 6-week-old somatic seedling germinants.

CURRENT STATUS AND DISCUSSION

SE is being applied to the establishment of germplasm banks of potentially valuable clones and nursery trials are being conducted to identify those clones with desirable landscape traits. Trials are currently being established as somatic seedlings are delivered from the laboratory. These seedlings are derived from clonal SE culture lines obtained from seed of both Colorado blue spruce and white spruce (Table 1). The induction frequencies of SE calli from dissected seed embryos ranged from 6% to 47%, depending on seed source and induction protocol (unpublished data). Cryopreservation of these lines have been achieved with greater than 80% success rate (unpublished data). In pilot production techniques, somatic seedlings are handled in a similar manner to true seedlings in the greenhouse and nursery.

Table 1. Current status (September 1994) of somatic embryogenesis (SE) culture and nursery trials of ornamental conifers.

	Colorado blue spruce			White spruce	
	Piedra River	Kiabob	Michigan State Univ.	Sunburst™	Total
# Seed dissected	1314	1601	932	1270	5117
# SE clonal lines in culture	116	57	57	87	317
# SE clonal lines in nursery trials	70	33	35	12	150

Both field and greenhouse trials of this material have been established in at least four separate locations representing different climates, soils, and cultural conditions. These locations include Nova Scotia, coastal British Columbia, western Maine, and western Michigan. These trials will be assessed for landscape characteristics, such as color and form, and winter hardiness over the next several years. Clones will be selected over this time for volume production.

Somatic embryogenesis offers a new potential for high-volume propagation of ornamental conifers. The technology provides genetic uniformity as with other forms of vegetative propagation, such as grafting or rooted cuttings, but the resulting propagule is identical in form and growth habit to a true seedling.

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QUESTION-ANSWER

Anonymous: What's the best way to do the irrigation?

Fred Rauch: In that particular case he waters them in very well and with the use of the plastic covering he's able to keep enough moisture in there especially for seeds that germinate quickly. If you had something extremely slow (several months) then this probably wouldn't be useful.

Anonymous: Do you have any strains from western Samoa?

Chuck Ades: No.

Anonymous: They have plants with leaves that are 15 to 18 in. long with beautiful variegations?

Chuck Ades: Do these characteristics hold in the United States?

Anonymous: They seem to.

Anonymous: What kind of insect problems to you have on your plants?

Chuck Ades: The main problem with pothos (*Epipremnum aureum*)is spider mites. Syringing the undersides of leaves gets rid of the mites.

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Palm Seed Germination

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INTRODUCTION

The production of indoor tropical foliage plants in Hawaii has increased significantly over the past 20 years. This growth peaked in 1990 at a wholesale value of $14.6 million with about 30% of this production in palms.

Palms are generally slow-growing, but the growing conditions found in Hawaii give our growers an advantage. Palms are generally propagated from seeds, but growers have reported that many palm species are slow to germinate or are irregular in their germination pattern. I would like to summarize some of our observations and research findings relative to palm seed germination.

PROPAGATION

Seed Collection. It is generally recommended to collect mature seeds from the tree, as those from the ground are often infested with seed weevils. Maturity is indicated by a color change, usually from green to that appropriate for the species (red, yellow, black, etc.). Most tropical seeds have a short storage life, so they should be planted when fresh.

We also recommend removal of the fleshy seed coat, as it often contains a germination inhibitor, unless you have had experience with the species. This is illustrated in Table 1 which shows a difference between two species of *Pritchardia* (Yoshii and Rauch, 1989a). T50 is a measure of how long it takes 50% of the seeds to germinate (Orchard, 1977).

Table 1. The effect of seed coat removal on germination of palm seeds.

Treatment	T50[1] (weeks)	Final germination (%)
Pritchardia hillebrandi		
With	7.6	90
Without	1.9	76
Pritchardia thurstonii		
With	2.9	96
Without	2.1	96

[1] $T50 = D = \Sigma fx / \Sigma f$.

We tried a simple bioassay of the seed coat of areca palm (*Chrysalidocarpus lutescens*) by removing the fleshy pericarp, macerating the pulp in a blender, and filtering through cheesecloth and then filter paper (Rauch and Crivellone, 1989).

This solution was used to germinate lettuce seeds compared to seeds watered with deionized water (Table 2).

Table 2. Bioassay test of areca palm seed pericarp solution.

	Lettuce seed germination (%)	
Days	Water control	Pericarp solution
1	86 7	0
2	89.3	0
7	91.3	0

Preplant Treatments. There have been a number of other preplant seed treatments proposed to improve the germination of palm seeds, such as soaking in water with or without chemicals. In earlier trials we found that presoaking the seeds in water or gibberellic acid GA_3 solutions increased the germination percent of areca palms (Rauch et al., 1982). However, with bamboo palm (*Chamaedorea seifrizii*), the water soak proved beneficial, but there was no response to the GA_3 treatment (Yoshii et al., 1989). Our current recommendation is to soak cleaned palm seeds in water for 3 days prior to planting, changing the water each day.

Postplant Treatments. There is very little information on the best medium for germinating palm seeds. To date, the results are somewhat mixed with well-drained cinder or perlite resulting in better germination percentages than peat moss as shown in Table 3 for the germination of *Ptychosperma macarthurii* seeds. However, there was no difference due to the medium in the germination percent of *Pritchardia thurstonii* seeds (Table 4) (Yoshii and Rauch, 1989a).

Table 3. The effect of media on germination of *Ptychosperma macarthurii* seeds, after 14 weeks.

Treatment	T50[1] (wks)	Final germination (%)
Cinder	8.5 a[2]	60 ab
Peat : cinder	8.2 ab	35 c
Peat	7 3 bc	46 bc
Peat : perlite	7 1 c	32 c
Vermiculite	7.0 c	56 ab
Perlite	6.7 c	63 a
Perlite : vermiculite	6 5 c	60 ab

[1] $T50 = D = \Sigma fx / \Sigma f$.

[2] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 4. The effect of media on germination of *Pritchardia thurstonii* seeds, after 12 weeks.

Treatment	T50[1] (wks)	Final germination (%)
Perlite	3.1 a[2]	97 ab
Cinder	2.5 b	93 c
Vermiculite	2.4 bc	97 abc
Perlite : vermiculite	2.4 bc	94 bc
Peat	2.3 bcd	98 a
Peat : perlite	2.1 cd	98 a
Peat : cinder	2.1 cd	96 abc

[1] T50 = D = $\Sigma fx / \Sigma f$.

[2] Mean separation within columns for each treatment group by Duncan's multiple range test, 5% level.

One of the more beneficial treatments for enhancing the germination of palm seeds is bottom heat. The suggested medium temperature is 95 to 105F. This is especially beneficial for slow-to-germinate seeds such as bamboo palm (Table 5). Germination time can be reduced from 8 months to 8 weeks (Yoshii et al., 1989).

We were interested in the effect of combinations of some of these treatments, so we set up a trial using areca palm. While most of the treatments proved beneficial in improving the germination rate, the best was a combination of water presoak and bottom heat (Yoshii and Rauch, 1989b) (Table 6). It should be pointed out that for the most part we have only been able to improve the rate of germination and not the germination percentage.

Table 5. Effect of medium temperature on germination of *Chamaedorea seifrizii* seeds after 20 weeks.

Temperature (±1C)	T50[1] (wks)	Final germination (%)
Unheated control	0.0 a[2]	0 b
25	0.0 a	0 b
30	10.8 b	60 a
35	9.0 c	62 a

[1] T50 = D = $\Sigma fx / \Sigma f$.

[2] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 6. The effect of temperature, water, and GA_3 combinations on germination of areca palm seeds, *Chrysalidocarpus lutescens* Wendl., after 20 weeks.

Treatment	T50[1] (wks)	Final germination (%)
Control—no treatment	6.4 a[2]	94 ab
100 ppm GA_3 pre-soak	6.2 ab	89 b
Water pre-soak	6.1 bc	95 ab
Bottom heat	5.8 c	93 ab
100 ppm GA_3 pre-soak + bottom heat	5.4 d	95 ab
Water pre-soak + bottom heat	5.1 e	97 a

[1] $T50 = D = \Sigma fx/\Sigma f$.
[2] Mean separation in columns by Duncan's multiple range test, 5% level.

TRANSPLANTING

In trials to determine the best time to transplant palm seedlings, we found that the spike or 1st leaf stage was best (Murakami and Rauch, 1984). This resulted in less transplant shock and plant loss.

SUMMARY

- Use fresh seeds harvested from the tree.
- Remove fleshy seed coats.
- Use a preplant water soak treatment.
- Plant shallow in a well-drained mix.
- Use 95F bottom heat.
- Transplant at spike or 1st leaf stage.

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Pothos: Identification, Selection, and Propagation

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CULTIVARS AND USES

Pothos or more correctly, *Epipremnum aureus* 'Gold' (syn. *Scindapsus aureus* 'Gold Pothos'), a native to the Solomon Islands, is one of the staple plants in the United States indoor houseplant trade. This is due primarily to its colorful variegated leaves, durability, and versatility. Additional cultivars include: 'Marble Queen', 'Green Queen' (a sport of 'Marble Queen'), and 'Leilani' (a sport that I developed from 'Gold' Hawaiian strain) and *Scindapsus pictus* 'Argyraeus' (syn. 'Satin Pothos') from Indonesia and the Philippines.

Epipremnum aureus can be used as a cascading or hanging plant, a groundcover, or climbing plant. The leaf form most commonly seen is actually the juvenile form of *E. aureus*. The adult or mature form of the leaf is quite large, often more than 2 ft long and split similarly to the leaves of *Monstera deliciosa*, split-leaf philodendron.

SELECTION

Variation in leaf coloration and form can result not only from selection, but also in response to light intensity, temperature, and possibly daylength. I have worked the last several years to select and develop what I consider to be a superior strain of the Hawaiian strain of golden pothos. First, I had to define what I considered to be desirable leaf characteristics. I decided to select for medium-sized more rounded and thicker leaves. After I had a sizeable inventory of the desired leaf type, I began to select for leaves showing outstanding yellow or gold markings. However, as I built up my inventory of high-color stock, I noted most of the color disappeared during the shortest days of the winter months—December and January. I then started selecting for plants that kept their high-color look during the winter. This is a slower process since I can only do it once a year. I am presently building my stock of those plants and will probably not be releasing any until 1996.

Further selecting, that could and should be done, is for:

- Internode length—I prefer the short internode.
- Rapid growth of the plants.
- Leaf orientation on the stem.

The development of the 'Leilani' strain of the Hawaiian gold pothos has been a simpler process since they all were developed from a single stem and have a shorter history of development. I haven't observed the variability I observed in the Hawaiian strain. One characteristic that I think is interesting is that it occasionally produces a single small dot or eye of yellow on the leaves.

In general, my experience has been that the Hawaiian Leilani strain has superior vigor to the extreme of occasionally pushing itself out of a 6-inch pot due to a vigorous root system.

PROPAGATION

The normal cutting used in propagation is a "leaf-eye" cutting, discarding the tips. Pothos can be easily propagated without disease problems if the following rules are followed:

- Plant only clean stock, free of leaf and vascular diseases.
- Do not break the leaves when moving plants from one location to another. We use boxes as opposed to plastic bags.
- Never let the leaves dry out; this, at the very least, delays rooting.
- Plant in a light, airy mix that drains well.
- Provide a soil temperature of between 65 to 75F.
- Prevent desiccation of the leaves by: 1) providing a high humidity environment, 2) covering the cuttings with a light cover such as wetted newspaper or 3) providing a light mist of water.
- Groom the propagation material periodically and remove any infected cuttings and soil.
- Start with disease-free media.

General observations on propagating pothos.

- Leave enough of the vine stem above the leaf to act as a means of holding the cutting when planting.
- The new stem from a leaf eye cutting generally grows away from the leaf at a slight angle to the right or left.
- There is variation in rooting and growing time related to the position of the leaf on the vine.

GROWING-ON

The important considerations in growing-on pothos are temperature, light, and disease control.

Temperature. Pothos loves it hot, 85 to 90F day temperatures and 65 to 70F at night are ideal for pothos as long as there is adequate humidity. Lower temperatures slow the growth rate (increase production time) and decrease the color. At temperatures below 60F, small off-color leaves are produced.

Light. Foot candles between 3500 and 4500 produce the best color on the leaves. High light intensities will burn or bleach the leaves. Lower intensities will decrease the leaf color.

Disease. The most common diseases of pothos are root rots. These are caused by infested soil through poor soil handling, poor watering methods, and contamination from other plants or benches.

The principle pathogens affecting pothos are *Rhizoctonia*, *Pythium*, *Phytophthora*, and *Erwinia*. Smog can cause stippling and yellowing of the older leaves. The Hawaiian strain of pothos, in particular, tends to produce small leaves after being repeatedly cut back. This can be corrected by transplanting to a larger pot or top dressing with dolomite lime and single superphosphate.

Fertilizer. Pothos seems quite tolerant of a wide range of pH, salts, and fertilizer levels. However, it seems to do best at moderate to high levels of fertilizer.

Technical Assistance. Soil and Plant Lab, Santa Ana, California; Dutch Growers, San Marcos, California; Mountain View Nursery, San Marcos, California

REFERENCE

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Variation in Water Use of Container-Grown Plants

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INTRODUCTION

The nursery industry is taking steps to reduce its use of irrigation water. Public concerns about water use and pollution prevention and increasing irrigation costs are motivating this change. Kabashima (1993) believes nurseries will reduce water use by recycling water, increasing the water application uniformity, and by improving irrigation scheduling. Water is conserved when irrigation is scheduled to apply only the amount of water used by the plant. Growers have found that certain plants need more water than others, while other plants are easily overwatered. Burger et al. (1987) showed that water use varied greatly between different plant varieties when they reached market size.

The amount of water used by container-grown plants is influenced by the climate, production practices, and crop characteristics (Regan, 1991). Plants use the most water on sunny days that are hot, dry, and windy. Growers can use local daily meteorological data or reports to schedule irrigation. When container-grown plants are moved to a more open spacing their water use increases. Pruning a crop usually results in less water being used until shoot growth begins. Crop coefficients are used to adjust irrigation to specific production practices and crop characteristics (Doorenbos and Pruitt, 1977). Comparison of crop coefficients shows the relative difference in water use between plants or crops.

In 1989, a 5-year project at Oregon State University began to estimate water use of #1-size, container-grown, woody landscape plants. This report of a 1992-1993 study will discuss some of the variation in water use.

MATERIALS AND METHODS

Rooted liners or seedlings of 23 different woody landscape plants were potted on 5 May 1992, in #1 (3.0 liter) plastic nursery containers. The medium consisted of 0.5 inch minus Douglas fir bark (90%) plus sphagnum peat moss (10%) amended with 20 lb per yd^3 North Willamette Container Mix (25% Nitroform, 12.5% gypsum, 12.5% dolomite #10, 5% ammonium nitrate, 5% potassium sulfate, 5% ferrous sulfate, 0.5% F.T.E. 503). Plant containers were placed on gravel and overhead irrigated at the North Willamette Research and Extension Center, Aurora, Oregon. Containers were arranged by variety in plots, seven containers wide by eight containers long. The plants were over-wintered in a polyhouse covered with 4 mm white copoly. The following spring, the plants were fertilized, pruned, and spaced as needed to reach marketable quality.

Crop coefficients (k_c) were calculated as described by Burger, et al. (1987) every 2 to 4 weeks during the irrigation season (May-October 1992, March-June 1993). Ten plants were randomly selected from each plot and weighed 2 h after irrigation (8:00 A.M.) and again in 24 h. The reference crop evapotranspiration was determined using the FAO Blaney-Criddle method (Doorenbos and Pruitt, 1977) on a daily basis (Allen and Brockway, 1983).

RESULTS AND DISCUSSION

This study found that k_c values vary greatly. The range of k_c values was from less than 1.0 to greater than 5.0. The range is greater than other agricultural crops. Doorenbos and Pruitt (1977) reported a range of k_c values for field-grown citrus between 0.45 and 1.0. The high k_c values are artifacts of the calculation method. If the calculation were based on the surface area of the plant spacing (as with field-grown plants), instead of only the container top surface area, container-grown nursery crops would have k_c values similar to other crops. Actual water consumption during the production of dry matter (grams transpired per gram of dry matter produced) is less for trees than field crops (Table 28, Larcher, 1975). Variation in water use existed within the major plant groups (conifer, deciduous, broadleaf evergreen) as well as between the groups. For example, *Hydrangea macrophylla* 'Nikko Blue' used over twice the amount of water compared to *Acer palmatum* f. *atropurpureum*.

The k_c is different for each growth and development stage of a given crop. For this discussion, three crop stages will be used to describe the production of container-grown plants. The first stage begins when the liners are potted until the plants become established. Generally, spring plantings take 6 to 10 weeks under favorable conditions to become established. The second stage is characterized by active shoot growth and development until the onset of dormancy. The third stage begins in spring when the crop resumes active growth and matures to marketable size and quality.

The lowest K_c values occurred during crop establishment, the first stage. The plants were small and shoot growth slowed down or stopped while the roots explored the medium. Containers were arranged can-tight during this stage which contributes to lower k_c values. In addition, k_c values did not change very much during this crop stage. An exception to this was *Cotoneaster apiculatus* that established itself quickly and resumed shoot growth soon after potting.

Water use during crop development, the second stage, was influenced by the type of shoot growth and dormancy. *Chamaecyparis pisifera* 'Boulevard' (syn. *Cupressus pisifera* 'Boulevard') grew continuously (free-growth) and reached a k_c value of 4.0, compared to *Pinus nigra* ($k_c = 2.9$) which had only one growth flush (fixed-growth). Another growth factor that appears to affect water use is growth rate. Slow-growing *Juniperus squamata* 'Blue Star' consistently had low k_c values, even though it grew continuously. Slow-growing plants remained at can-tight spacing longer during this stage than did plants with rapid growth. Water use declined rapidly during October for all plant varieties with the onset of dormancy and winter acclimation.

The highest level of plant water use was observed during crop maturity, the third stage. A sharp increase in k_c occurred during shoot growth following spring bud break. *Hydrangea macrophylla* 'Nikko Blue' showed the greatest increase in k_c. Water use of certain plant varieties, including *Arctostaphylos uva-ursi* 'Massachusetts' and *Viburnum tinus* 'Spring Bouquet', remained relatively low ($k_c < 2.8$). Plants were not pruned during this stage and were grown at an open spacing (16 in. o.c.).

This experiment demonstrates that crop water requirements of container-grown plants can be estimated to help nursery managers improve irrigation practices. To conserve water, plants with similar k_c values should be grouped under the same irrigation zone. This allows irrigation water to be scheduled for both daily evapotranspiration and crop stage.

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Using Computer Technology to Improve Irrigation Uniformity

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INTRODUCTION

The application of computer technology as an aid in the process of selection and design of irrigation systems has been growing rapidly in recent years. Previously, sprinkler spacings were based on "rule of thumb" guidelines established by the sprinkler manufacturers themselves. With overlapping sprinklers, phrases such as "head-to-head spacing" or "50% of diameter" were often used by manufacturers to assist customers in making the right decisions. These recommendations were based on previous experience and did not assure that uniformity of water applied would be acceptable. And to compound the problem, different crops had different requirements for acceptable uniformity. A pecan orchard in Willcox, Arizona, for example, required far less sprinkler uniformity than container-grown plants in Southern California because of the extensive and deep-rooted nature of the crop. Many resulting installations have applied extra water in order to adequately irrigate the driest areas. With today's increasing water shortages and increasing emphasis on applying fertilizers and chemicals through irrigation systems, there is a need for making decisions based on science rather than art, especially for new installations.

To this day, almost all sprinkler manufacturers still publish information on each sprinkler device in terms of flow rate and the distance of throw at a given pressure. Most customers still use this information as the only factors in making their decisions on how to space the sprinklers in order to achieve a desired precipitation rate and uniformity. Many other customers contact the manufacturer for recommendations. As the Technical Services Manager at the Agricultural Division of Rain Bird, I have been asked this question for a variety of applications including field crops, vegetables, trees and vines, wastewater, and nursery irrigation using a variety of irrigation products. All of these applications have a similar design goal of achieving acceptable uniformity and precipitation rate using the appropriate device for the application.

The appropriate device for an irrigation application includes many factors which must be considered by the customer before a final decision is made. Some of these factors include:

- Ease of maintenance
- Trajectory height
- Susceptibility to clogging
- Pressure requirements
- Effects of wind (for outdoor use)
- Durability and reliability
- Cold weather operation
- Cost

Many devices have been tried and failed because of one of the above factors in addition to poor uniformity. Poor uniformity may not be the fault of the sprinkler, but rather inappropriate spacing. This is where the computer can help us make more informed decisions. However, in order for the computer to simulate the real world, its results must be based on real world information.

PROCESS

In addition to flow and distance of throw, many manufacturers also test their sprinkler devices in a zero-wind environment for either single-leg catch can distribution or grid catch can pattern. In the case of rotating sprinklers, a single-leg distribution catch can test is normally sufficient to establish a "signature curve" detailing the sprinkler's precipitation rate radially from the sprinkler. For fixed spray devices and small micro sprinklers a grid pattern of catch cans are placed around a device to establish the signature pattern in two dimensions. This is necessary because most of these devices will not have a similar radial precipitation rate at different angles. Each of these tests are performed at a given pressure, riser height above the catch cans, and nozzle size. Many of these tests are performed at the Center for Irrigation Technology, an independent testing facility in Fresno, California. Rain Bird also has a similar test facility in Glendora, California and many hundreds of tests have been performed on a wide variety of sprinkler products, from large-volume guns flowing over 1000 gpm to small spray devices at less than 1 gpm.

First, lets look at rotary sprinkler distribution testing. Each sprinkler to be tested must be representative of production so that tests results will be valid for field installed units. Then a matrix of common values for pressure, riser height, and nozzle size are established to determine the number of tests required. As is always the case, there are many applications outside of this matrix, but many will be relatively close to these setup parameters. Catch cans are then evenly spaced (usually 1 or 2 ft apart) in a radial fashion away from the test sprinkler device. All parameters are setup in accordance with American Society of Agricultural Engineers (ASAE) Standards for sprinkler testing. After operating the sprinkler for a period of time, each can volume is recorded and entered into the computer as raw data for that particular combination. After all tests have been completed, analysis can begin for a wide variety of applications.

Although this type of testing has been performed for many years, it wasn't until recently with the advent of personal computers, that we could put this information to widespread use in irrigation design. A software program called SPACE (Sprinkler Profile And Coverage Evaluation) is now commercially available from the Center for Irrigation Technology (CIT), which is capable of overlapping this sprinkler in virtually any spacing desired. Most exciting of all is the ability to graphically present the resulting distribution in a "densogram", a dot density shading technique illustrating relative distribution within the given spacing.

Briefly, the program calculates the contribution from all nearby sprinklers in every square foot of the spacing area and then performs various uniformity calculations before presenting the densogram. Along with the densogram are presented three yardstick uniformity parameters CU, DU, and SC:

- **CU is** (Christiansen's) **Coefficient of Uniformity (%) defined as:**
  CU = 100(1 - average of all deviations from average value/average value)
- **DU is Distribution Uniformity (%) defined as:**

DU = 100 (average low-quarter depth/average depth)

- **SC is Scheduling Coefficient defined as:**
  SC = average depth / average depth of a window 1, 5, or 10% of total sprinkler spacing area

CU is still widely used because of its familiarity since its establishment in 1942. Unfortunately, it does not put a heavy weighting on inadequately watered areas allowing dry spots with relatively high numerical values. Because of this, both DU and SC are important, especially for container-grown plants where dry spots have a direct effect on plant growth, since there is no chance for soil moisture movement to even out poor distribution. It is the densogram though that tells the story most clearly regarding the expected uniformity of water placement.

Before an actual analysis is run some final questions must be answered. Some bed widths are narrow and a single row of sprinklers or microsprinklers may be all that is required whereas larger bed widths may require overlap from opposing lateral sprinklers in a rectangular or triangular placement. Finally, the desired precipitation rate must be approached by adjusting the flow rate of the sprinkler in question at the spacing desired. In many cases, not all this information is known and several combinations must be tried before a final decision is made. The decision will be an informed one though.

EXAMPLES

To best illustrate this process lets look at some real world examples. In a recent case, a large wood products company planned to setup a fully automated tree seedling establishment block which required frequent, short-cycle irrigations. Bed widths were 36 ft. A small droplet size was desired for a gentle application so higher pressures were analyzed. A low trajectory was also desired to reduce wind effects. A SideWinder™ sprinkler model (SW200-HF) recently introduced and tested at CIT was chosen as a candidate for its adjustable trajectory, (9° setting) and faster rotation speed. Figure 1 illustrates the single leg profile curve of that particular sprinkler operating at 40 psi and 1.38 gpm with catch cans 1 ft below the sprinkler. Looking at the curve does not tell us how well this sprinkler will do when spaced

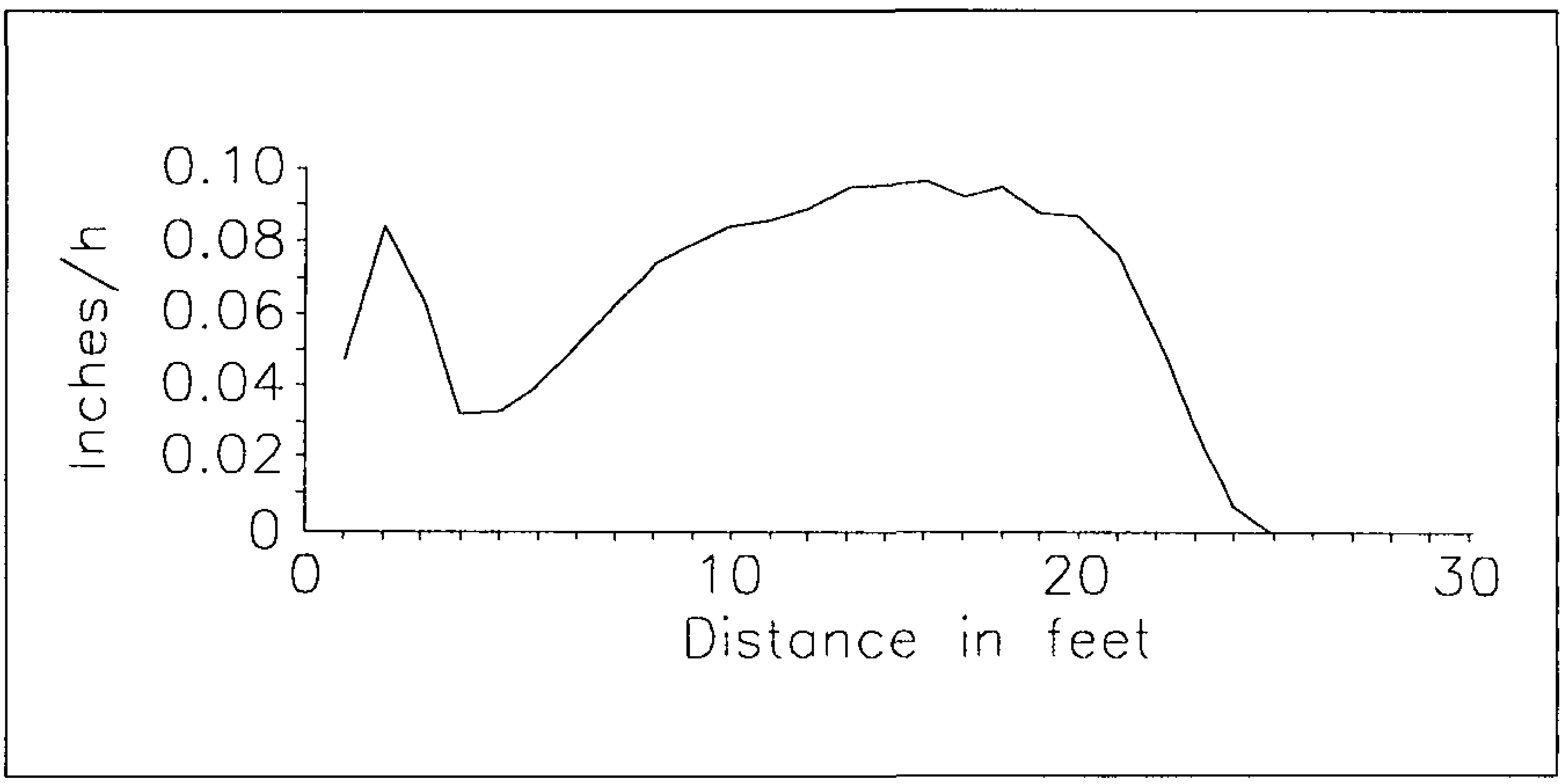

Figure 1. Example 1: Single leg distribution curve.

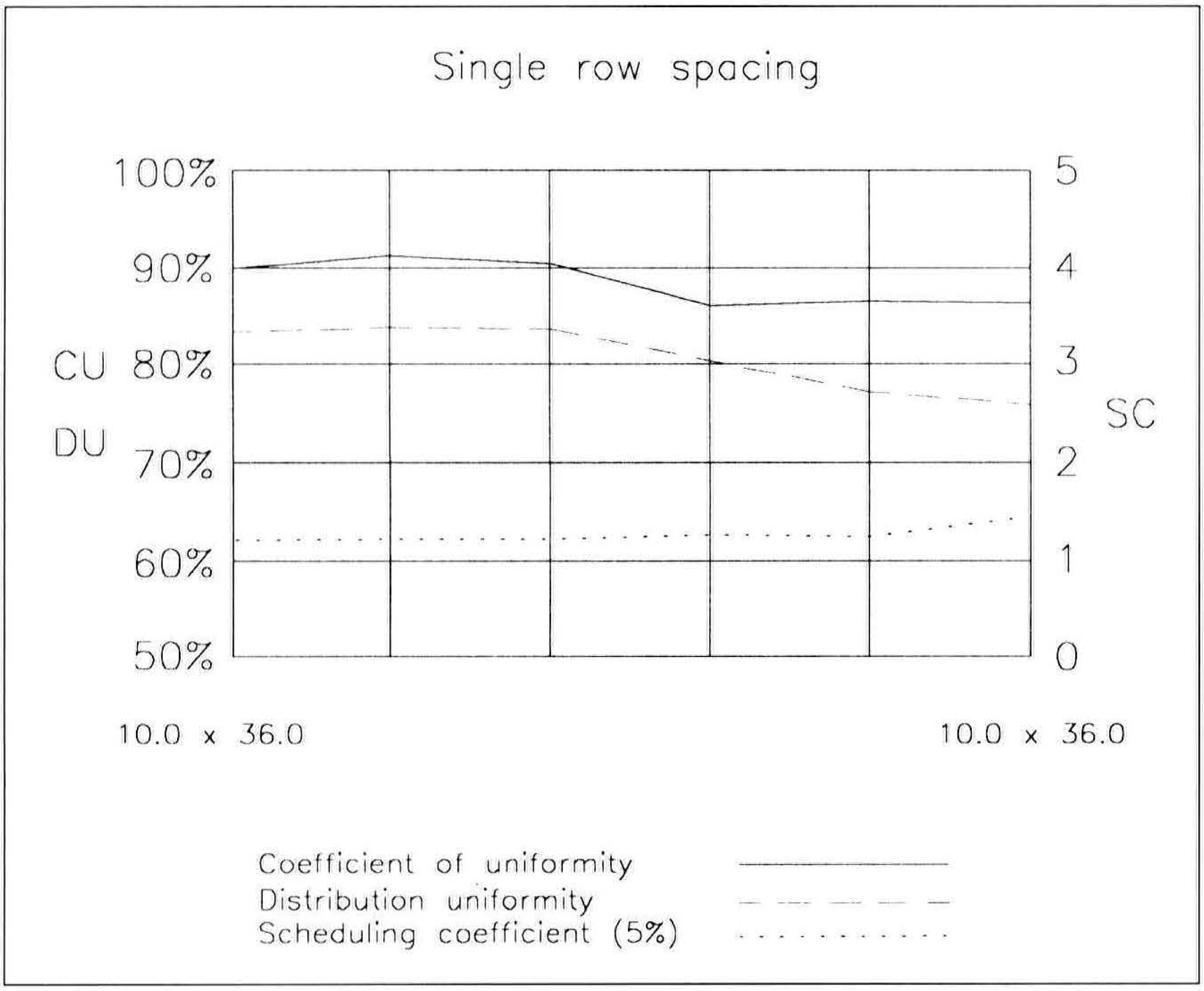

Figure 2. Example 1: Multiple spacing uniformity graph.

in a single row down the middle of the bed. First, a multiple spacing of sprinklers down the single row is run and uniformities are plotted (Fig. 2) for sprinkler spacings from 10 to 20 ft apart. It is noticed from this plot that uniformity begins to worsen beyond 14-ft spacing. A densogram is then run at the 14-ft spacing (Fig. 3). The densogram illustrates where relatively more water is applied in the darker

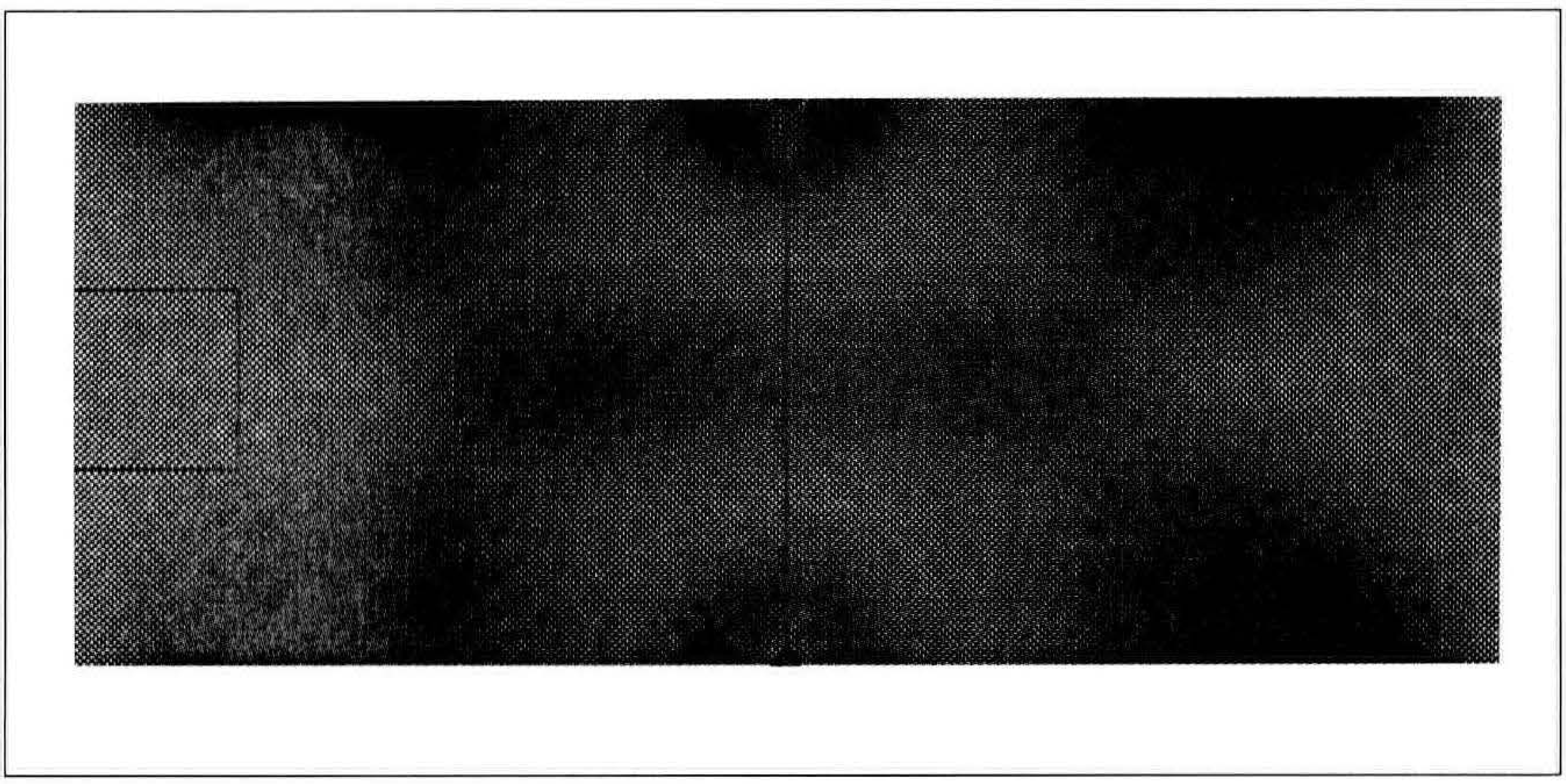

Figure 3. Example 1: Densogram for single row spacing.

areas. The window highlighted by a black box in Fig. 3 pinpoints the lightest application area (5% of the total area shown). It is decided that not only is the uniformity acceptable (CU of 90% or greater) but precipitation rate is near the desired .25 inches/h. The whole process usually takes less than an hour even after several nozzle and pressure combinations are reviewed.

It should be noted that this procedure may not prove adequate for some applications. Outdoor locations with mild to high winds will have sprinkler distributions which vary significantly from the assumed zero wind environment. Conversely, special installations with sprinklers mounted upside down indoors may need to be tested in their actual settings with grid catch can tests verifying uniformity. One such example is at La Verne Nursery in San Dimas, California where Sidewinder sprinklers were tested indoors in an inverted position. A special nozzle orientation was also adjusted to improve distribution. Catch cans were placed in a grid at one-ft spacing 6 ft below the heads. Catch values were recorded and uniformity calculated according to Christiansen's formula. Results verified that uniformity was over 85% and plant growth has been exceptionally uniform according to the grower since the installation was completed.

FUTURE

The SPACE program is not the only program that allows an irrigation designer to perform this type of "what if" analysis. More manufacturers are developing technical software of their own to provide this type of graphical analysis illustrating field uniformity. PCTAPE™ is a software tool provided by our company to irrigation designers of drip tape systems. It provides graphical presentation of field

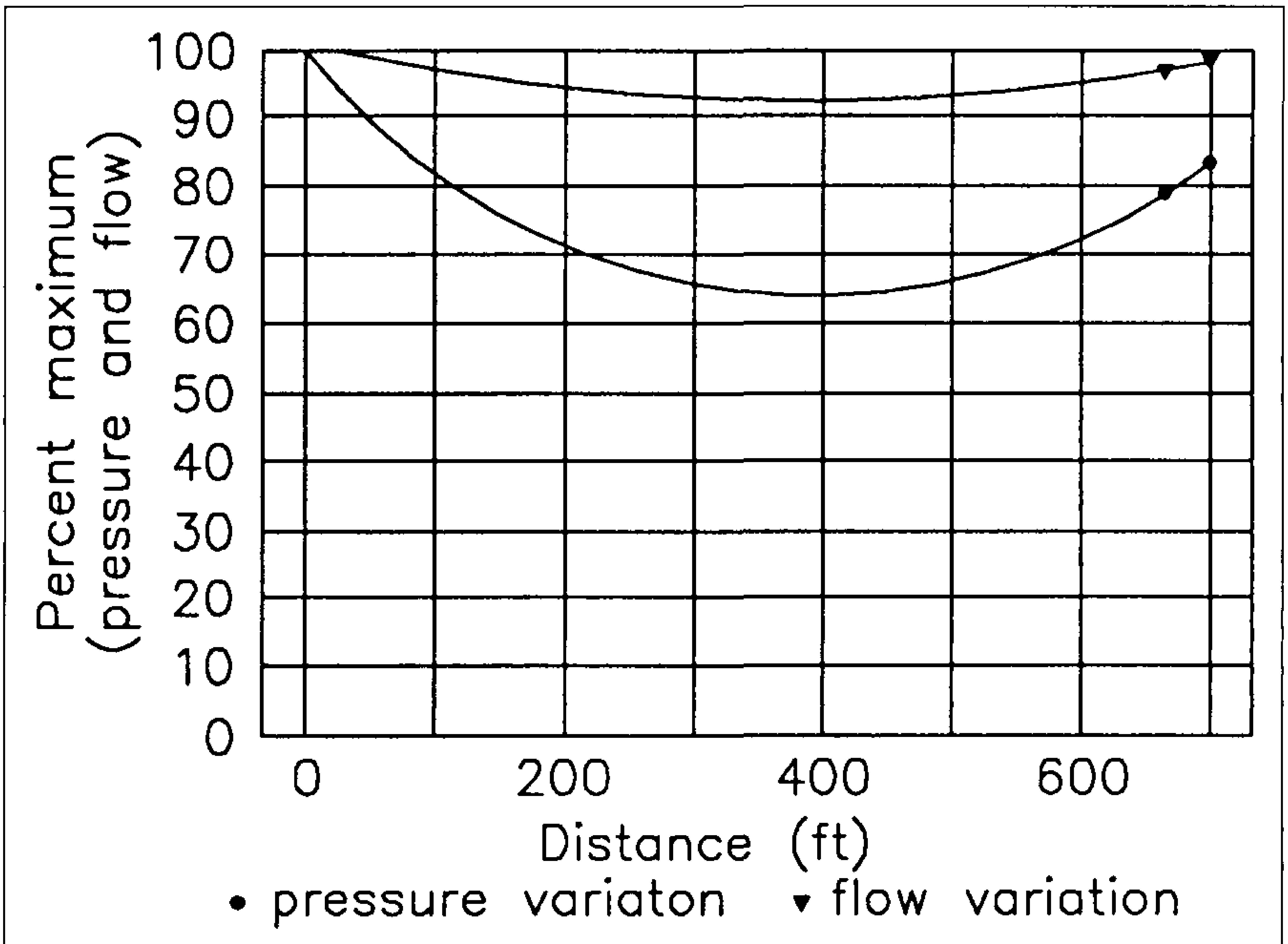

Figure 4. Sample PCTAPE analysis of drip tape uniformity.

pressures and relative distribution of water (Fig.4) even for undulating terrain. As drip tapes become more commonly used in nursery applications this will help verify performance.

Another software tool recently introduced is a program called TREE-GRAM. This program has the capability of overlaying a tree canopy with a micro-spray pattern. The user is able to change tree and row spacing as well as the placement of the Micro-Quick™ pattern as illustrated in Fig. 5. Although this program was primarily developed for tree crops, future releases of the program will allow overlapping the micro-spray patterns, a common practice in the nursery industry.

As you can see, the gap between making more informed decisions versus decisions based only on past rules of thumb is narrowing. As manufacturers provide product performance testing for use in the above software tools we will be able to further reduce water consumption while encouraging more uniform plant growth. This is truly a win-win proposal.

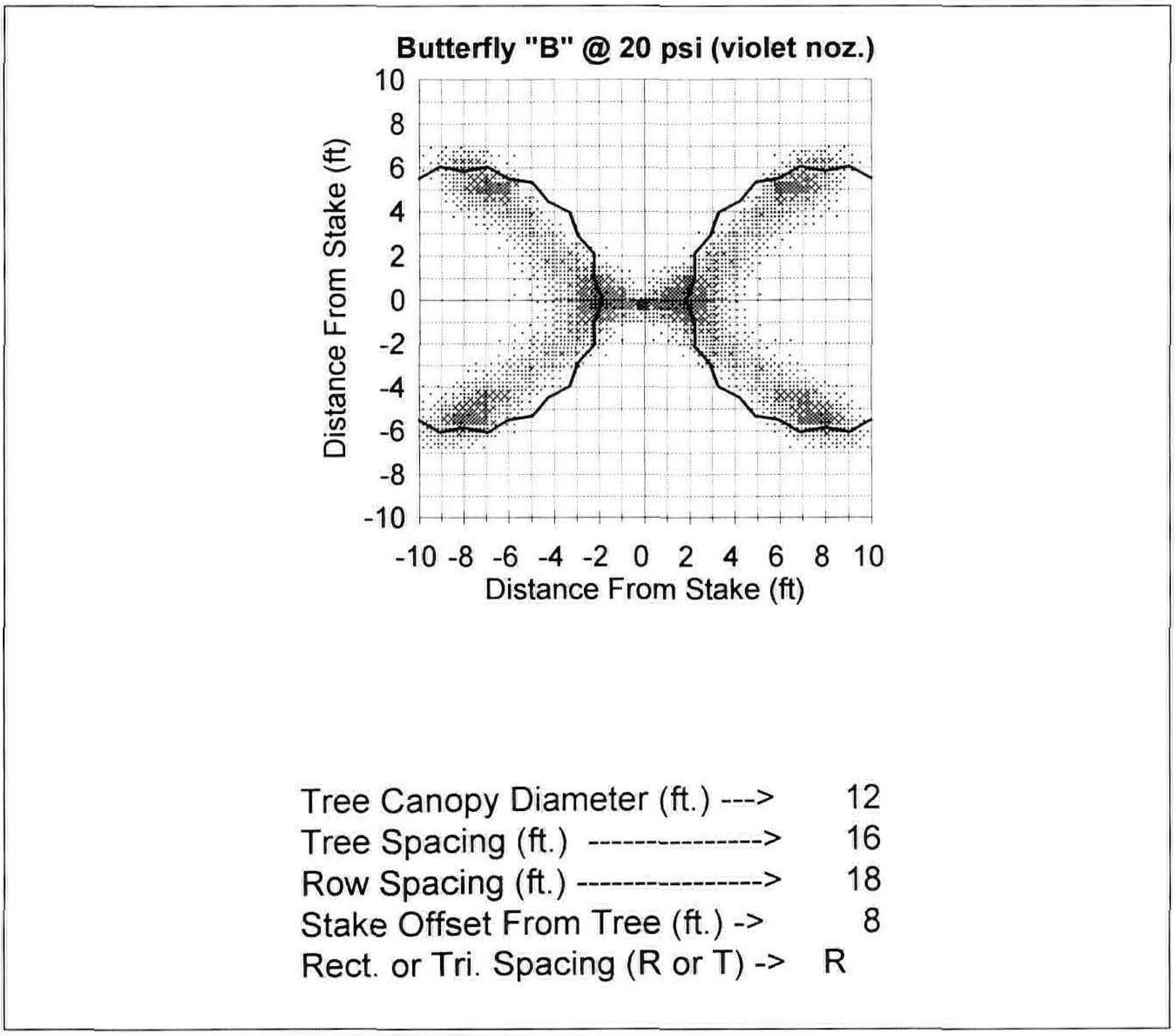

Figure 5. Sample TREE-GRAM analysis of micro-spray pattern.

Water Filtration for Propagation Systems

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In standard irrigation practice, filtration is regrettably often one of the last components of the irrigation system considered. In propagation irrigation, it is vital that it be considered first. Filtration protects any system against pitting, corrosion, and plugging of irrigation emission devices, and, in so doing, leads to greater uniformity and more even distribution patterns of water and nutrients for any crop. The most sophisticated irrigation system cannot perform adequately if the drippers, sprayers, misters, or sprinklers are clogged. In standard, crop irrigation applications, clogging can result in lower yields for the grower. The grower will realize something less than 100% of the potential crop and suffer a concomitant loss of income. In propagation applications, where the crop value is inordinately high, if the distribution patterns and uniformity are compromised by emitter clogging the cost is potentially much greater. The propagator may realize a total loss of an extremely valuable crop and the investment that went into developing the crop. The intensive, propagation "season" requires an irrigation system operating at peak performance at all times. Short periods of inadequate or uneven watering and applying of nutrients are unacceptable.

In irrigation practices today there are three major types of filtration elements: screens, disks, and media. All three types serve as traps for debris or "filter cake". During the filtration process, filter cake builds up on the filter element, a pressure differential is created, and then, the element requires cleaning which can be done manually or automatically.

Criteria for acceptable filtration are: 1) that the filter element be reliable (i.e., that it does indeed trap the filter cake and prevent it from going downstream), 2) that the element not require abundant maintenance, and 3) that the filter be durable and, therefore, economical. All three above-mentioned filtration elements are reliable means of trapping filter cake. They are all relatively durable as well. Where the three different methods of filtration differ significantly is in their performance in various applications. When a filter is improperly applied the level of maintenance and, conversely, the level of inefficiency rises.

When is it best to recommend either a screen, disk, or media filter? First of all, a short description of the process of media filtration is in order. Media filtration is generally constructed of large (24 to 48 in.) carbon steel, stainless steel, or fiberglass tanks in which finer and coarser grains of sand are layered to various depths. The individual sand particles are faceted and three dimensional. When organic contaminants (algae or bacteria) pass through this medium they adhere to the facets of the grains of sand. When enough algae have attached themselves to the sand the water's path becomes obstructed and a pressure differential is created. Then, either automatically or manually, a backflush command is given that reverses the flow of water expunging the algae to the atmosphere.

Media filtration is an excellent means of trapping organic matter. However, in order to insure that the facets of the sand are always sharp and capable of providing the surface area necessary for trapping the algae, it becomes necessary to replace the media (the edges of which have become rounded due to the continual flow of water at a high velocity) periodically, as frequently as once a year. It is also very important to maintain the solenoids, valves, and electronic controllers of the automatic backflush system as well. If the automatic system fails or if the backflush system is not initiated manually at proper intervals a high pressure differential is created across the media. At high pressure differentials the water has a more difficult time passing through and "tunneling" or "channeling" results. When such tunneling occurs, the media becomes impacted, the backflush system becomes ineffective, and it becomes necessary to extricate the cement-like media and replace it. It is not uncommon, in these circumstances, to be left no choice but to cut off the top of the tank, remove and replace the sand, and then weld on a new lid.

Media filtration is not an efficient means of trapping inorganic matter. It is not advisable to filter sand with sand. Inorganic particles do not have the sinewy, adhesive nature of algae. Inorganic matter will not penetrate the middle or lower layers of the media tank and will instead coat the uppermost layer of the media bed. As a result, a pressure differential is quickly created and frequent flushing becomes necessary.

Disk filtration was designed to imitate sand-media tanks. Disk elements are cartridges of polypropylene grooved rings that resemble poker chips. They are compressed together during service and the flow of water is directed from the outside of the disk toward the center. The grooves of the disk element serve to trap the algae in much the same way as the facets of the sand trap organic matter in media tanks. When substantial levels of organic matter have been trapped by the disk, a pressure differential is created. The disks must then be loosened and separated. High pressure water is then applied from the outside of the disk cartridge toward the middle, spinning the disks, in order to fully clean the element. Periodic bathing of the disks in an acidic solution is recommended. Just as the sand media tank is limited in its applicability, so are disk filters. Inorganic matter does not penetrate through the grooved disk and only coats the outer surface. A pressure differential is quickly created and frequent flushing becomes necessary.

Screen filtration serves to trap both organic and inorganic matter. Screen elements have much larger "effective filtration areas" than do disk filters. Here it is necessary to define two terms: 1) "filtration area" and 2) "effective filtration area". Imagine a screen element. Take a knife and slice one side of the element so that it could now be spread flat onto a table. Solve for the area of that surface and that represents the "filtration area". Now, take that same element and eliminate the plastic or steel construction, the mesh itself, seals, etc., so that all that remains is the space or holes. Measure those holes and that represents the "effective filtration area". When you hold up a disk or screen filter of the same size and mesh you can see through the screen filter and cannot see through the disk element. That is simply because the screen element has a much greater effective filtration area. If the particles are inorganic and cannot penetrate the disk element or the sand media, i.e., the matter cannot avail itself of the third dimension that sand media and disk elements provide, then an element with a greater effective filtration area will hold that many more inorganic particles. The result is that a much greater interval will be created between occasions when a pressure differential is created. Generally speaking, given two identically sized elements, a screen element will require cleaning one-third as often as a disk element when the filter cake consists of inorganic matter. The converse is also true. A disk filter will have to be cleaned one-third as often as will a screen when the contaminant consists of organic matter.

Since the potential loss of a propagation crop is so high, it may not be economical or wise to depend on manual labor to clean the filter elements. That is to say, while it is recommended to clean a filter when the pressure differential reaches 7 psi, if one relies on manual cleaning of the element on any regularly scheduled basis then the chances are great that the filter will either not be cleaned frequently enough leading to potential problems downstream or the filter will be cleaned too frequently leading to unnecessary expenditure.

If the water source is domestic and the filter's prime purpose is really for "insurance" purposes, then cleaning the element on a scheduled basis may be sufficient. However, if the water source is less than tertiary-treated and if the level of debris in the water changes over time as a result of weather conditions, demand on the line, or seasonal variations, then the filter will require cleaning on an irregular basis to insure that a dangerously high pressure differential is not created.

The rapidly growing dependence on effluent or reclaimed water for irrigation purposes has resulted in more frequent filter flushing in general and has demanded of the filtration industry products that are reliable in heavily contaminated conditions and that require minimal amounts of flush water per flushing cycle.

Media filtration is maintenance-laden and requires as much as 5% of the total capacity of the irrigation system's delivery system for flush water. One of the most successful alternatives to media filtration is the self-cleaning screen filter. Compact in size, automatic self-cleaning screen filters consist of a durable, multi-layered screen element with a "suction scanner" within the element itself. When a pressure differential is created the scanner rotates inside the screen and, because it is hollow and connected to the exhaust valve, acts like a vacuum and sucks the debris off the filter element. One self-cleaning filter can replace a bank of seven or eight media tanks. The total flush water is less than 1% of the irrigation system's delivery capacity. For example, a battery of eight media tanks will flush for a period of 10 to 15 min where an automatic self-cleaning filter will flush for 40 to 50 sec. The bank of media tanks will flush approximately 2500 gal water and the self-cleaning screen filter will flush approximately 140 gal.

Sizing the filter for any irrigation system requires answering a regimen of questions. The most important question that needs answered, and which will go the furthest in determining the estimated cost of the filter, is that of "flow rate". Once maximum flow rate is determined, then it is necessary to gauge the quality of water, its chemical and biological makeup and source(s). Finally, it is imperative to consider the orifice size of the irrigation emitter. Filter manufacturers measure their filter elements by "micron" and "mesh" and may also have tables in millimeters and inches. A general rule of thumb that can be used to determine the degree of filtration necessary for any irrigation system is as follows: sprinkler type emitters should have filtration elements equivalent to one-third of their orifice and drip emitters should have filtration elements equivalent to roughly one-fifth to one-sixth the size of their orifice. Propagation mister and fogger emitters generally require 100 to 130 μm screens.

In summary, improper maintenance of irrigation filters for propagation applications can be devastating for the grower. It is important to identify the nature of the filter cake that is to be trapped and to install the proper element. Manually cleaned disk filters and media filters are reliable methods of trapping organic matter. They are not efficient methods of filtering inorganic matter, and media tanks, in particular, are maintenance intensive.

Screen filters are efficient means of trapping inorganic matter and self-cleaning screen filters are reliable alternatives to media tanks and capable of effectively filtering both organic and inorganic matter. Although a self-cleaning screen filter will flush more frequently than a bank of media tanks, the reduction in exhaust water and the negligible pressure loss during flush make it energy efficient and environmentally friendly.

Treasures of The Sierra Madre Oriental

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My home is Monterrey, México, a city of three million inhabitants right at the footsteps of the Sierra Madre Oriental, (Eastern Sierra Madre), on the frontier between the desert and the mountain forests. My first experiments in propagation of native plants began 2 years ago on a very small scale.

Everything started on weekend trips to the sierra. On these trips I was not only surprised by its beauty and majesty, but also with the great diversity of conifers, oaks, and other plants that grow on its slopes, rivers, and cliffs. There were trees and plants I had never seen before in the city and yet of unique beauty. Then the idea of learning more about the native species as well the techniques to propagate them, came to me.

In November, 1992, I had the opportunity of visiting South Africa. What surprised me on this trip was to see that in a country where there are no native pines, they have planted them on thousands of acres. According to Department of Forestry, Republic of South Africa, in the year 1990, they planted an average of 300,000 trees per day. These trees were to supply not only their domestic needs for pulp and lumber, but also to export some of their surplus to neighboring countries. It is very meaningful that a great percentage of those trees come from seeds imported from the Sierra Madre Oriental.

The range called Sierra Madre Oriental, backbone of the Mexican northeast, has been for millennia the nest that has protected the proliferation of plant and animal species. It runs from northwest to southeast, 300 miles long and 70 miles wide. It crosses the states of Coahuila, Nuevo León, and Tamaulipas, only 150 miles south of the Texas border.

Up to 60 million years ago, at the end of the Cretaceous period, this region was covered by waters from the Atlantic Ocean. Then, thanks to plate tectonics, the pressure of the Pacific Plate against the continental North American Plate, caused the big folding of the earth's crust that gave birth to the Sierra Madre Oriental.

Later on during the Tertiary Period, the continental uplift made this range rise even higher. Some of its peaks like Cerro de la Viga, Cerro del Potosí, and Peña Nevada rise up to 12,500 ft above sea level. Very intense rains washed its basins of the marine salts, in such a way, that the sierra as we know it today, can embrace one of the most precious treasures of the earth´s flora.

The abrupt climatic changes that occur every year have produced a great variety of ecosystems, rich in the number of plant species. Here you can find climates from dry summers to freezing winters, to hurricanes that now and then blow from the Gulf of Mexico bringing heavy rain to places generally dry.

According to prestigious researches like N. Mirov and J. Perry, in this small extension of land smaller than the state of Vermont, almost 20% of the pine species of the world grow as natives. Some of them like *Pinus catarinae* and *P. johannis* are of recent discovery. Others like *P. pinceana, P. nelsonii,* and *P. culminicola* are considered very rare, in danger of extinction.

Other conifers like firs, douglas firs, yews, cypresses, spruces, and junipers are abundant in this region. Last December, on a botanical excursion with Dr. Miguel

A. Capo, Director of the Forestry School of Universidad Antonio Narro of Saltillo, to Puerto el Conejo in the limits of the states of Coahuila and Nuevo León, we counted up to 12 different native conifers, growing on just a few acres of land.

Mingled with the conifers we found oak forests. In this region grow more than 40 species. Among the most distinguished are *Quercus fusiformis, Q. polymorpha, Q. canbyi,* and *Q. rysophylla,* which are very much sought after by foreign nurseryman for their beauty and adaptability to the urban environment.

In the valleys, canyons, and river banks one can find a great range of trees and shrubs like ebonies, bald cypresses, madrones (*Arbutus*), aspen trees, sycamores, bumelias (*Bumelia*), anacuas (*Ehretia anacua*), red buds, dogwoods, buckeyes, Mexican plums, palms, magnolias, maples, native pecans (*Carya*), elms, and many others, very beautiful and apt to be grown in nurseries.

Many botanists have spent many years exploring, collecting, and classifying the Sierra's species. Nevertheless, the treasure chest has been only partly open. How many more conifers, oaks, trees and plants wait to be discovered?

In spite of the unique beauty of the flora hidden in the Sierra, one visit to the city is enough to realize the abandonment and desolation of our parks and gardens. There is a dramatic contrast between the natural diversity of regional trees and plants and the poverty of vegetation in the urban landscape.

When the conquerors first arrived, they found a fertile valley covered by a forest of oaks, ebonies, anacuas, hackberries, bald cypresses, sycamores, mesquites, huizaches, and other species. Throughout the years, this natural garden was cut down to open up new land for agriculture, for construction lumber, and railroad ties and coal for cooking. Four hundred years after the foundation of the city, I tried to find some relics of the original forest. It is a shame to say, but the only oak I could find was the one that appears in its coat of arms. Of the rest, there were not even samples for tourists to admire.

What has happened with the attempts towards urban reforestation?

In the belief that all the exotic plants are better than native ones, nurseryman have cultivated only imported species for more than 50 years, often from the other side of the world. We can find that almost 95% of the trees that beautify the city are exotics. The other 5% grow, thanks to the fact that the original woodcutters forgot to cut them down.

Among the species we can find in the gardens, we can mention the following: ashes from Arizona, aleppo pines (*Pinus halepensis*) from Syria, eldarica pines (*P. brutia* ssp. *eldarica*) from the transcaucasus, deodar cedars from the himalayas, tallows from China, jacarandas (*Jacaranda*) from Brazil, *Eucalyptus* from Australia, and magnolias from the southwest.

Some of them have adapted well to the regional climate. Others grow sickly or show the scars of past frosts or droughts. This was nonsense having so many botanical riches on hand. Time has come to rediscover ourselves and bring back the trees that the aborigines and first conquerors enjoyed. Of course, not all the species that grow in the mountains are suited to the climate and soil of the city. Therefore we must select and experiment with the most desirable ones in order to propagate them on a larger scale.

My first step was experimenting with a selection of trees. The criteria I used was to begin with those that, due to their geographical location, had the greatest probability of surviving in the city. Some disperse samples gave me some clues as to which ones were good candidates. Second, criteria were established to select those that were personally attractive to me.

When the fall came, I devoted myself to the collection of acorns from the nearest mountains as well as seeds of ebonies, anacuas, red buds, comitas, and buckeyes. In March, after soaking the seeds in water for 24 h, I placed them in humid folded newspapers in a germinating box at 72F. To my surprise, a good percentage of them germinated after a week. As soon as the roots broke, I planted them in small plastic containers, using a mixture of peat moss and perlite supplemented with Osmocote 18N-6P-12K and Micromax as fertilizer. I used the same method for ebonies, anacuas, bumelias, red buds, and mountain laurels, which did very well.

As for the pines, their seeds being very small, we set them in a tray with peat moss in a germinating chamber at 72F and have had very good results. For those trees whose seeds were over 1 inch in diameter, such as the native pecans and the buckeyes, I planted them directly into 1-gal containers. The seedlings stayed in the greenhouse for 2 months.

My first big surprise was when I put the first set of mountain laurels out in the sun, they were burned in a single day. Fortunately, it was only a small percentage of the crop. In Monterrey in 1993, we had an extremely hot summer, with temperatures over 100F for 3 months.

To solve this problem, I built a tunnel covered by a plastic net of 60% shade. All the seedlings that were placed in this tunnel withstood the summer heat satisfactorily.

After 4 months, the seedlings were transplanted to 1-gal containers, using a pot mix of pine bark, sand, peat moss, soil, and Osmocote 17N-7P-12K and Micromax as fertilizer. All the seedlings were placed in the shade tunnel over a wire net to allow root pruning by dehydration.

The mix used in the 1-gal containers worked fairly well for all, except for the pines. Their needles grew yellowish and very weak. When they were planted in the field, many were lost.

Ten months after their germination, trees were transplanted in the field in fabric containers. After one year, they have had to face many problems such as fire ants, weeds, root fungi, nematodes, worms, grasshoppers, pruning bees, and intense summer heat. Those that were strong and well-developed continued their growth without many problems; the weaker ones died on the way.

It is now too soon to evaluate the results. We have to wait 3 to 4 years for the trees to mature before their final transplanting into the gardens. Meanwhile the test continues, trying new native species like yellow chapotes and other pine species. It is very important to mend the errors and improve the methods of cultivation in order to avoid the problems that can be controlled. Time will tell which species will adapt to the urban landscape and which will remain only as jewels amid the mountain forest.

To conclude this presentation, I wish to say that the Sierra Madre Oriental, due to its geographical location and its diverse microclimates, has become a gigantic biological laboratory for the planet earth. Here, the evolutionary and creative process of new species development has not ended yet. And as Mirov has said "*in the tropical highlands of Mexico, there has developed a secondary center of evolution and speciation of the genus Pinus*" (Mirov, 1967). And as Perry states "it seems then, that a number of writers are in general agreement that among the Mexican and

Central American pines there are indeed many very variable species and that there is widespread interspecific hybridization. This is an ancient process and at the same time a very real and current one. Evolution is not something that only happened a million years ago, it happens every year" (Perry, 1991).

Therefore, there is a great opportunity for me to learn in my own backyard, living in this gigantic natural laboratory. These are only the very first steps of a life-long, and maybe, multi-generational project towards restoring and putting back 60-million years of splendor into our urban landscape.

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Forest Nursery Production in the United States and Mexico

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INTRODUCTION

Timber harvests in the United States have increased 57% over the last 40 years without a loss in timber growth. In fact, timber growth has increased 45% in the same period. In contrast, timber harvests in Mexico have declined 29% in the last 5 years because of deforestation, resulting in the closure of mills and the loss of jobs (Anon., 1994). Both countries have a large forested land base covering 30% to 40% of the country. Mexico has 0.58 ha forest land/person, while the United States has 0.75 ha forest land/person. The United States has reforested at least 200,000 ha every year since 1950 (Fig. 1). Mexico reforested 100,000 ha for the first time in 1991 (Fig. 1). Consequently, deforestation is claiming over 400,000 ha/year. Before the forest industry of Mexico can recover, deforested lands must be replanted and reforestation must become part of the land use plan. The objective of this paper is to compare the forest nursery production systems in the United States and Mexico.

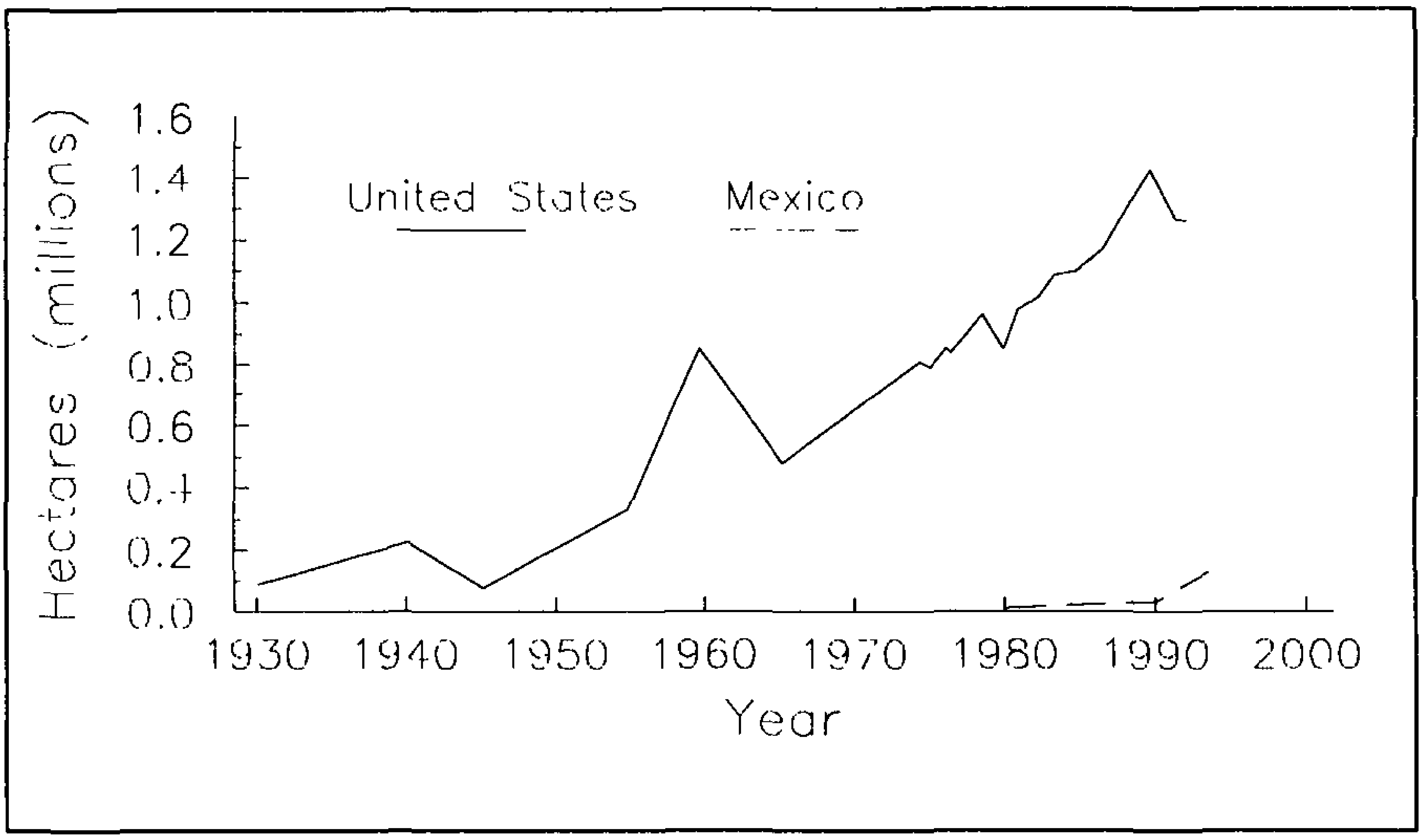

Figure 1. Reforestation in Mexico and the United States (Mangold et al., 1991; R. Sanchez, pers. comm.).

BACKGROUND

The United States has two major forest production regions: the southeast and the northwest. These two regions account for 87% of the nearly 2 billion seedlings planted annually (Mangold et al., 1991). Reforestation occurs primarily during the rainy season of winter to early spring. The primary species in the southeast are *Pinus taeda, P. elliottii,* and *P. palustris.* The major species in the northwest are *Pseudotsuga menziesii* and *Tsuga heterophylla.* Most of these seedlings are hand-planted on forest lands that have been clearcut and site-prepared. The rotation age varies from 20 to 60 years depending upon site quality, desired end product, and ownership.

Mexico has three regions of forest production: the tropical rainforest, coniferous forests, and oak/conifer woodlands. However, the coniferous forests account for 85% of the wood product production. Reforestation occurs during the summer monsoon season (July-October). The major species include: *P. montezumae, P. pseudostrobus, P. ayacahuite, P. oocarpa, P. michoacana,* and *P. durangensis.* However, Mexico has over 50 species of pine, many of which have economic importance (Perry, Jr., 1991). Seedlings are planted following fires, on abandoned farmland, and in forested areas that have been selectively thinned. Mexican forest laws require 10 seedlings be replanted for each m^3 harvested. The rotation age will vary with the shortest rotations in the tropical and central regions.

NURSERY PRACTICES

The United States relies on the forest industry to produce most of the forest tree seedlings. Forest industries operate 22% of the nurseries, but produce 53% of the seedlings (Mangold et al., 1991). State nurseries produce 29% of the seedlings and the federal nurseries produce only 7%.

The dominant production system is the bareroot nursery. Over 99% of the seedlings in the southeast and 82% in the northwest are produced as bareroot seedlings (Anon., 1987). The remaining percentage is seedlings produced in fixed geometry containers. Bareroot nurseries are highly mechanized and, as a consequence, tend to be large. The average industry nursery produces 16 million seedlings/year, and nurseries with capacities of 40 million are common. More efficient operations produce about 4 million seedlings per permanent employee. Temporary or contract laborers are used during the lifting and packing season. The increase in reforestation and concomitant increase in nursery production has been, in part, due to supportive research. There has been a tremendous effort in improving nursery productivity and seedling performance (Duryea and Daugherty, 1991; Duryea and Landis, 1984). One result of this research has been a better understanding of the parameters governing seedling survival and growth. It is likely that future developments from research will continue to improve nursery productivity and seedling performance.

Mexico relies on state and federal nurseries to produce most of the forest tree seedlings. State and federal governments operate 87% of the nurseries in Mexico. There are over 450 government nurseries with a capacity of about 500 million seedlings. This compares to about 110 nurseries in the United States with a capacity of over 700 million seedlings. Industry, usually pulp mills, operate only 13% of the nurseries in Mexico.

The dominant production system in Mexico is the polybag-container nursery. However, there are small bareroot nurseries and a few fixed-geometry-container nurseries. Mexico's nurseries are labor intensive. The average nursery produces about one million seedlings/year, with an average productivity of about 300,000 seedlings per permanent employee. This is less than one-tenth the productivity of the United States.

Forest soil is used as the medium for the polybag system. Typically, this medium is heavy, tends to compact and drains poorly. Nevertheless, one large nursery uses 35,000 m^3 forest soil/year at a cost of $13/$m^3$. The bags are filled by hand and either direct seeded or transplanted with germinants. Seedling age at time of transplanting may range from 4 to 14 months. depending on availability of labor and seed. Weeding and fertilization are manual. One of the inherent problems with the polybag system is the lack of pruning of the root system. The seedlings with the best quality shoots have roots growing out of the bag and into the nursery bed. At lifting, most of the root system is left in the nursery; resulting in poor root : shoot ratios. This can be a major deterrent to high survival. Once lifted, the polybag trees are usually transported in open trucks to the planting site or holding area. The polybags offer no structural support and the heavy medium and harsh handling contribute to further root damage. There is little interaction between the nursery production scheme and the needs at the reforestation sites.

OPPORTUNITIES IN MEXICO

Opportunities for improving reforestation activities will require additional research to define target seedling characteristics and site specific requirements (Mexal and Landis, 1990). This will require cooperation among nursery managers, reforestation foresters, and forestry researchers. Specific nursery practices that could contribute to improved seedling quality would include modification of current practices in seed handling, media formulation, fertilization, irrigation, root pruning, and seedling handling.

Currently, seed is collected from natural stands for immediate use in the nursery. They lack the facilities and equipment to test and store seed. Seed germination testing should be initiated as a routine component of the crop growing process. Testing would help identify seed quality problems, conserve scarce seed, and define sowing requirements.

Opportunities exist to improve growing media with locally available material such as bark, compost, and scoria. This would preserve not only irreplaceable forest soil, but also conserve a usually sparse nursery budget. Current practices contribute to problems of drainage, weed populations, disease, and handling during transport. Alternative media could be developed that provide good drainage, high CEC and moisture-holding capacity, and low weight.

Fertilization and irrigation practices are inadequate. Many nurseries use high-priced special formulations of fertilizer. Agricultural fertilizer could be used at 1% of the cost of current materials. Irrigation uniformity is often poor. Training and testing of current equipment could improve the current system. Capital investments in new equipment should be made only after current systems have reached maximum efficiency. Virtually all training manuals in polybag nurseries stress the need to root prune the seedlings regularly. However, this is not a standard practice in Mexico's nurseries. Pruning at time of harvest creates a serious imbalance in the root : shoot ratio and may help explain the high mortality in plantations. The nurseries also need innovations in the shipping and handling of seedlings from the nursery to the plantation. The current system causes extensive root damage and contributes to planting failures.

Nurseries, particularly federal and state nurseries, are viewed often as employment centers. Thus, the introduction of new technology may be met with resistance if it results in a net loss of jobs. However, technologies exist that improve productivity without a loss of jobs. For example, most nurseries lack the labor resources to hand weed in a timely fashion. Thus, weeding is often late, resulting in decreased growth from competition and damage and even mortality from weeding. Herbicides would reduce weed populations and the damage to seedlings caused by late or no weeding. At the very least, these types of technologies could double productivity with no increase in cost and no change in labor or capital investment (Fig. 2).

Future quality and production gains can be made by implementing a second level of technology that would include converting from polybag systems to fixed geometry (containerized) or expanding the bareroot nursery system. These systems provide increased opportunities to mechanize operations and increase productivity. However, the technology must be appropriate for the region or nursery and nursery managers must have the opportunity to become familiar with these systems prior to converting their nurseries.

Mexican nursery managers do not have easy access to a supportive research program. Certainly, there is nothing similar to the forest nursery cooperatives at Auburn University and Oregon State University. Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) has good researchers, but

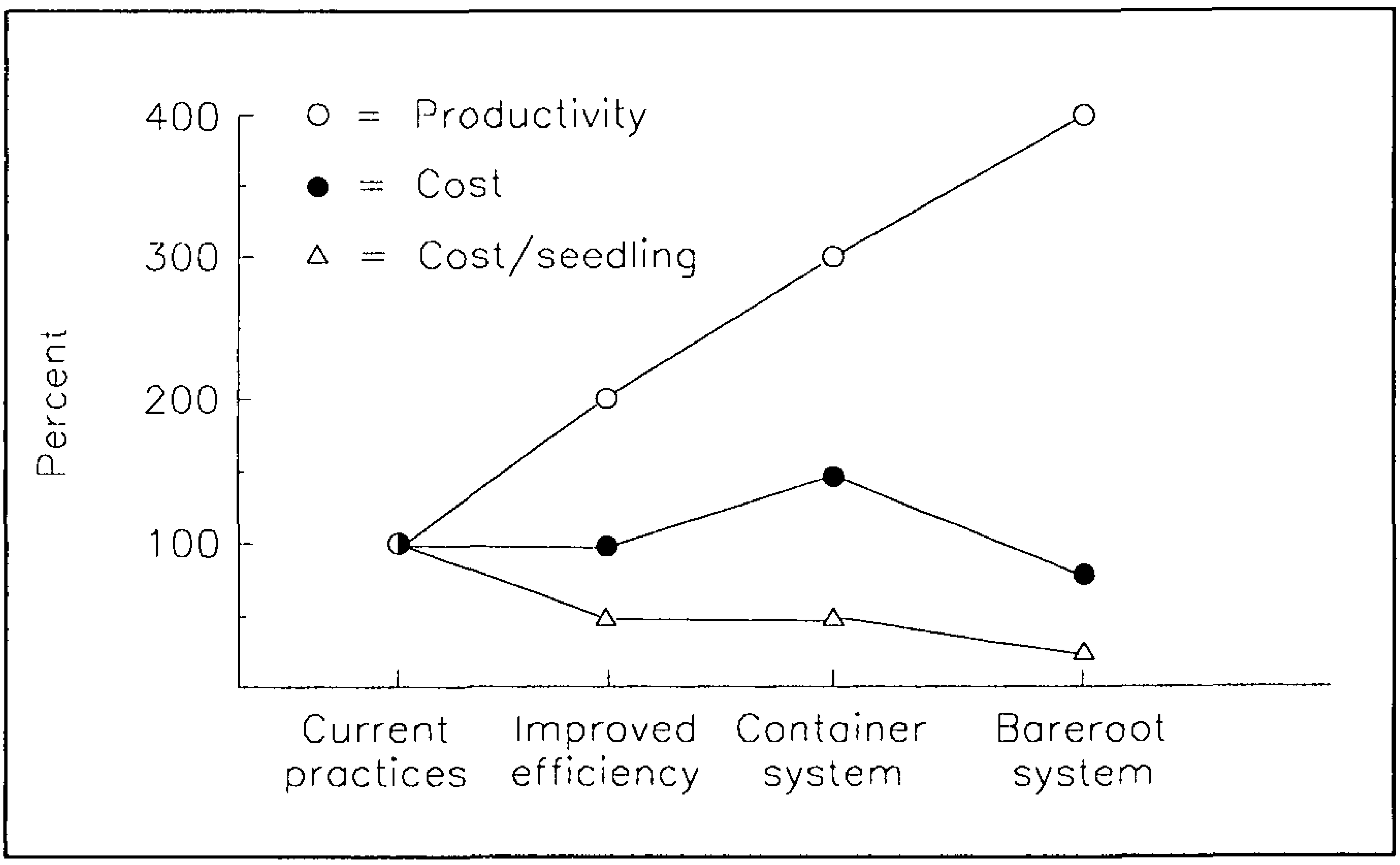

Figure 2. The hypothetical effect of changes in technology on the productivity, costs, and capital investments in nursery systems (opportunities for improving nursery production in Latin America).

little funding to develop technology. Industrial research programs are almost non-existent. Since 1991, New Mexico State University's Forestation Center for the Americas (CEFORA) has worked with over 80 Mexican nursery and reforestation foresters to improve forest nursery production. In 1994, CEFORA in conjunction with Programa Nacional Reforestacion (PRONARE), INIFAP, and the U.S. Forest Service conducted a 3-week training course in central Mexico. This training opportunity along with limited in-country short-term programs are the only programs available to Mexican forest nursery managers. Future improvements in Mexico's forest nurseries will, in part, depend upon developing a strong forest nursery research program and developing a communication network between nursery research and nursery management.

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Hawaiian Native Plants in the Landscape

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The Hawaiian flora developed on islands that range in elevation from sea level to 14,000 ft and rainfall varying from only a few inches per year to the world's wettest place, Waialeale on Kaua'i averaging over 500 inches of rainfall per year. Temperatures vary from hot/wet to hot/dry tropical with every gradation in between. Areas above 4,000 ft elevation may experience light frosts. Two mountains, Mauna Kea and Mauna Loa, are snow-capped each year while Mauna Kea has a permanently frozen lake at its summit. Soils are equally variable, ranging from sand and cinder (a'a and pahoehoe) to heavy latosols and rich alluviums.

The flora that evolved under these circumstances is unique. Approximately 1,000 species of flowering plants are native to the Islands. Of these, 89% are endemic, the highest of any floristic area of the world. Unfortunately, 38% of these species are considered threatened or endangered while 10% of previously recorded species are considered extinct. Only the State of California exceeds Hawai'i in the total number of endangered species. Their relative land masses, however, are not comparable.

Within the native Hawaiian flora are a number of species of great value for the landscape. It must be noted that interest in growing native plants in Hawai'i's gardens is a fairly recent phenomenon. Two decades ago few gardens in Hawai'i could be found with more than one or two native species. There are now native plant societies and programs dealing with the horticulture of native species are well-attended.

In my view, the most useful and colorful of the native species is 'ohi'a lehua (*Metrosideros polymorphus*), an endemic first cousin to the New Zealand pohutukawa (*M. excelsus*) seen as a street tree along coastal California.

'Ohi'a lehua is found in the wild from sea level to 9,000 ft, primarily in mesic to wet forests. It is highly variable, growing as a stunted shrub in new lava or as a small to medium tree of 30-40 ft, but attains its full stature in high rainfall areas of good soils where it attains almost 100 ft in height. Its growth habit is broadly columnar. Most bear masses of bright red flowers while yellow, orange, and coral-colored flowers are less common. Its normally slow growth is greatly enhanced with regular fertilizing and watering. Three flushes of flowers can be realized each year. It is extremely wind-tolerant and makes an excellent windbreak or tall screening hedge. It is a beautiful color accent in the overall garden design and, due to its relatively open crown, can be used as a specimen in a lawn area. It also makes a fine tubbed or potted specimen and has been successfully used as a bonsai subject. 'Ohi'a lehua fares best in open, well-drained soils. It should do well in sheltered coastal areas of California.

'Ohi'a lehua may be grown readily from seed, but to assure desired flower color, both rooting by cuttings, using a rooting hormone under intermittent mist, and air layering are commonly employed. It is highly variable in its ease of rooting.

Koa (*Acacia koa*) is endemic, one of about 1200 species in the genus. A large tree up to 100 ft in height, koa is frequently a dominant element of the vegetation in dry to wet areas from nearly sea level to over 6000 ft in elevation. It is a nitrogen fixer and may be among the first to revegetate eroded or other stressed areas. Koa is wind-tolerant, partially drought-tolerant, and rapid growing. Koa is used for quick garden effects where an open broad canopied tree is needed to furnish light shade for tropical understory plants. Its light canopy also makes it useful for shading lawn areas. Koa grows easily and quickly from seed. A healthy koa tree grew well in the hills above the Berkeley Campus of the University of California during the 1940s.

Wiliwili (*Erythrina sandwicensis*) is an endemic tree to 30 ft in height with a wide canopy. It is found on dry, leeward coastal areas on all the main islands and is very drought-tolerant. The unique feature of wiliwili is the remarkable color variation found in the flower where color ranges from red, orange, burnt orange, yellow, chartreuse and combinations of two colors such as chartreuse with burnt orange petal edges. Flowering time is variable, some trees flower during the hot summer months while others flower in October and November. Variability characterizes wiliwili.

As with other native species, wiliwili is only now beginning to be used in the landscape where it functions as the perfect tree in the xeriscape garden. It grows readily in any well-drained soil and, with a modicum of water, may grow rapidly. Like many other members of the bean family, wiliwili is a nitrogen fixer. It does not like overly wet soils and should, therefore, be used as a color accent among other dry-loving natives.

Wiliwili is easily grown from seed using scarification or hot water treatment to hasten germination. Cuttings must be used to guarantee flower color. Wiliwili does not always form roots easily. A strong rooting hormone and intermittent mist produce more certain results.

Koki'o ke'oke'o (*Hibiscus arnottianus* var. *punaluuensis*), is one of several white-flowered, fragrant, endemic hibiscus which develop blossoms up to 6 in. across. For landscape purposes this is the finest. Found only in a small section of the middle part of the Ko'olau mountains behind Honolulu, this small tree, to 30 ft in height, makes an excellent hedge or tall screen, specimen tree for a courtyard or entry, or as a tubbed specimen in full sun. It flowers all year as long as water and fertilizer are applied, grows rapidly, and takes pruning very well. It is moderately wind-tolerant and thrives from sea level to elevations of about 2500 ft. It grows well along the coast, even in sandy loams, if protected against the worst of the on-shore salt winds. All native hibiscus grow readily from seed or cuttings.

Hapu'u (*Cibotium spp.*), the endemic Hawaiian tree fern, is found on most of the main islands where rainfall is plentiful. There are several species still under study by taxonomists. Suffice it to say that hapu'u, widely grown the world over for its large fronds, is an important element in the Hawaiian garden and has been for many years. It is unparalleled as overstory for shade and moisture-loving ornamentals. Hawaiian tree ferns tolerate some shade, but prefer strong light and will tolerate a light frost.

Propagation by spores can be readily achieved given the appropriate conditions, but keikis or side shoots are easily rooted. Most Hawaiian tree ferns are harvested from the forest, a practice which should soon be curtailed to assure their conservation. Trunks, which may attain 16 ft in height, may be cut off at any height and planted directly in the ground, well- guyed and watered. The cut top soon roots and resumes growth.

A'e (*Sapindus saponaria*), the indigenous soapberry tree, is a useful landscape subject. In Hawai'i, found only in mesic forests on the Island of Hawai'i between 3000 and 4000 ft elevation, its use in the landscape extends to low coastal areas where it tolerates poor soils, wind, and irregular watering and fertilizing. A'e produces a rounded, dense crown with large, pinnately compound, attractive dark-green leaves. The fruit is translucent brown, attractive and contains a black seed that germinates readily. Although rarely seen in cultivation, a'e makes a useful shade tree and is becoming more available to the landscaper.

Two endemic members of the Aralia Family, 'ohe makai (*Reynoldsia sandwicensis*) and 'ohe (*Tetraplasandra hawaiensis*) are excellent landscape subjects where their large leaves form a useful accent in the garden design. Both are rare in cultivation and almost never found in general nurseries. 'Ohe was offered during the 1950s by a rare plant nursery in West Los Angeles, while it was unknown to local Hawaiian gardeners.

'Ohe makai, as the name implies, grows at lower elevations than its cousin and tolerates considerable heat and drought. It is a wide-crowned tree to 60 to 70 ft in height with purple fruits borne in attractive clusters. It grows readily from seed, less readily from cuttings.

'Ohe, from cooler, moister areas, is of comparable size. The foliage is dense, its large leaves lightly brushed with white on the underside. It makes a striking foliage accent in the landscape where it is seen in a few local botanical gardens. It is easily propagated by seed; cuttings are difficult to root. Little is known of propagation techniques for both 'ohe and 'ohe makai.

Ho'awa (*Pittosporum confertiflorum*), an endemic species, is one of about 150 species worldwide, 10 of which are endemic to the Hawaiian Islands. *Pittosporum confertiflorum* is a shrub or small, densely canopied, 20-ft tree found on many of the main islands, but never encountered in local nurseries. It has solid, dark-green, rough foliage with a golden underleaf color. It will withstand considerable drought and heat and can be used as a small tree, hedge, screen, or windbreak.

Another endemic species, *P. hosmeri*, is occasionally found in specialty nurseries. It has similar properties but has a more open canopy and reaches 30 ft in height. Flowers of both species are wonderfully fragrant at night. The pittosporums may be grown from seed and recent unconfirmed experiments indicate that tip cuttings, dipped in a strong rooting hormone and placed under intermittent mist, will form roots.

'Akia (*Wikstroemia uva-ursi*), an endemic species, has very recently become popular locally where it is grown on a fairly large scale. A low, spreading shrub growing to 3 ft in height, 'akia makes an excellent ground cover, bank cover or potted specimen. It is drought-tolerant, salt-and wind-tolerant and grows in virtually any well-drained soil including sand and coral or among lava rocks on difficult planting sites. Small, but plentiful, chartreuse-yellow flowers are followed by a bright-red fruit. It does best in full, hot sun, but will tolerate light shade.

'Akia is readily propagated from seed and with some difficulty from cuttings. Recent trials at the University of Hawai'i have shown increased rooting of cuttings from treatments with auxin and wounding of the cutting.

Kolokolo kahakai (*Vitex rotundifolia*) is an indigenous coastal species whose natural habitat is on sand dunes in the very teeth of salt winds and spray. There it forms a low- growing, spreading ground cover to 2 ft in height. It also performs well inland and will attain a height of 3 ft or more. The strong, grey-green foliage is aromatic. The small but conspicuous flowers are blue-lavender. Kolokolo kahakai is unsurpassed as a ground cover or dune-holder in exposed beach landscapes. It is very easily rooted from cuttings under mist with or without rooting hormones.

The above sampling of valuable landscape species in the Hawaiian flora were selected to show the wide range of environmental conditions in which native species can solve landscape problems and provide visual enhancement. Landscapers in Hawai'i are becoming aware of their value and are beginning to specify their use which will lead to nursery propagation and public appreciation of the unique Hawaiian flora.

QUESTION-ANSWER SESSION

Mike Evans: *How is the Mexican agency that would be the same as our Forest Service promoting either private industry or their own nursery program for reforestation?*

Richard Phillips: Inside of Mexican agencies like our USDA there are forestry researchers and agronomists. Other agencies are responsible for four major areas: reforestation, plantation, urban forestry, and environmental protection. The Army which has very little experience in nursery management has been asked to grow 123,000,000 seedlings. This has been very difficult in some cases, but in others it has succeeded due to personal interests of those involved. To date, there has not been the investment necessary to bring the nurseries up to standards that will be needed to be competitive in the forestry industry.

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Analyze Now or Pay Later: A Role for Testing in the Business of Plant Propagation

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It is amazing how much money is spent needlessly due to the lack of testing. The reasons for not testing are as many and varied as the people who give them. They include "I have no problems," "It costs too much," "I know my business" or "my land," "Testing doesn't work," or "If I wait to test I'll lose too much profit."

Testing services provide information used to make more accurate, less risky management decisions that justify the cost. The point of testing is to prevent problems, to make better business decisions. There are things that can not be known about land, media, or water without some type of testing. Testing services **DO** work. They are based on sound research and years of experience. Some, who don't take the time to test, realize losses not profits. Testing uses a sample of a population to learn something about a population, instead of using the whole population to learn as many people do.

Several examples of problems created due to the lack of testing will be presented. Not all are from the plant propagation industry, but all illustrate a point. Several testing methods will be discussed. Some you can perform easily, while others require specialized personnel or equipment. The testing discussed addresses routine decisions in horticulture. How much nitrogen is needed? Is a particular soil mix suitable? Does the water have too much salt? All are questions that affect the bottom line.

How much do you think is spent on back-support belts. You see them everywhere: delivery people, back rooms of restaurants, and the grocery store. Safety is good business, prevents losses, and makes money. Worker compensation insurance rates should be lower if employees use these belts. Our insurance carrier did not agree. They checked testing results. The belts are no help and may give lifters a false sense of security leading them to bend the back instead of the knees. A lot of money was spent without testing and for no gain.

A Southern California color grower used color plants worth several million dollars to test a new source of sawdust for his growing medium. All were lost, a very expensive test. The grower's new supplier, my client, called to have a third party test the product. Soil mixes made with new and old sawdusts as well as redwood bark were tested. Five species of plants were grown in three media in replicated greenhouse trials. All mixes produced healthy plants of each species; however, growth was not equal. Water-holding properties of the media differed and all were irrigated based upon properties of the media made with the new sawdust. The grower's old media produced inferior plants. Some did not survive. Photographs presented in court provided convincing evidence that the problem resulted from the grower's management, or lack of testing.

Symptoms on plants grown by a propagator of California natives ranged from deficient through normal to toxic. Tissue and media analyses indicated a wide range of nutrient contents. Some plants received far too much while others received little or no fertilizer. Obvious variability of the blended fertilizer product used in the media was detected by visual observation. Blended dry fertilizers made from ingredients having different particle size distributions will separate during handling. That happened in this case. Each bag had a different combination of ingredients. The problem is easily prevented by testing fertilizer ingredients and selecting only those that are compatible.

During the mid-sixties, fertilizer manufacturers changed the particle size distribution of some products. A blender of dry fertilizers, not the one mentioned above, performed an expensive test. The fertilizer components separated as the bin above the bagger was filled and unmixed more as material flowed from the bin into bags causing the grade in individual bags to vary greatly. The California Department of Food and Agriculture found that the firm failed to meet label guarantees and was proceeding to prosecute. State's evidence was discarded when their sampling methods were tested and it was shown that the sampling device used to draw samples was biased. An ingredient and product testing program was put in place resulting in decreased deficiencies. It was this experience that helped with quick diagnosis of the problem at the native plant nursery.

Why test? To make money of course. To obtain information used to make more accurate, less risky management decisions. To check on the quality of a supply or a product. The problem in each example could have been predicted and prevented with a few dollars worth of testing. There are things we do not and can not know without some form of testing. No one can see nitrate in water or water-holding capacity of a soil mix. Tests for these types of things do work. They are based upon sound research and experience.

What should be tested? Anything new, anything unpredictable, and things that change over time or space. While all the examples involved post-decision problems, most of our testing is performed before routine decisions about nutrient, salinity, soil, and irrigation management are made. No examples of pre-decision testing were given because profitable routine decisions don't result in such graphic examples.

Pittenger (1986), evaluated 15 potting soils available in California stores and found that six had less than desirable physical properties and seven had one or more undesirable chemical properties. His concern was that sufficient information was not available on the label for a customer to make a decision. Similar concern by the Australian Institute of Horticulture and the CSIRO Division of Soils led to an Australian Standard (Council for Standards Australia, 1989) for potting mixes. The standards include test methods as well as definitions of properties. Clearly there are differences between products that are worth knowing about, in advance.

What do we need to know? Several physical and chemical properties of growth media are of primary importance in the production of container-grown plants. A soil mix must be light-weight, have a high water-holding capacity, and have adequate aeration when at container capacity. Container capacity is the maximum amount of water a mix will contain when in equilibrium with gravity. Salt content, including salt contributed by fertilizers, must not be so high as to restrict growth and nutrient content must be sufficient to support growth. Physical and chemical analyses as well as bioassays may be involved.

Water quality can have a big impact on productivity. It must have low total salt content as well as low concentrations of toxic elements such as chloride or boron. Nitrate content of water can be a plus. Some constituents precipitate upon evaporation or react with some fertilizers to form insoluble materials and plug emitters. Many growers are required to recycle water presenting a new set of risks. As water is consumed by plants, salts become more concentrated and drain water analysis will help determine at what point it must be discarded.

What can you do? A simple bioassay is easy to plan and execute. For example, a new medium ingredient could be tested in an existing production facility along side the medium it is to replace. The new mix in labeled pots can be randomly placed in normal production. If there is no detectable difference the new mix will be safe to use. If the new mix produces better plants, the new mix may justify a higher price. If the new mix does not do as well, it may need different management or perhaps it should be rejected. Such a test requires little more than normal production equipment and pots or labels so the test mix can be distinguished from normal production.

Such a bioassay integrates all the parameters of a mix that affect plant growth. A key is good planning if results are to be meaningful. Replication and randomization are critical. There is normal variation. No two things or places are exactly alike. Variation occurs. Replication, randomization and statistical evaluation will help prevent interpreting normal differences as though they were differences due to what was being tested.

To evaluate some physical properties on your own, all that is required is a balance or scale and a drying oven. In addition, you will need several pots and one or more small buckets or other water-tight containers large enough to contain a pot, all from your inventory. The procedure that follows will provide total porosity, container capacity, air-filled porosity at container capacity, and bulk density.

1) Determine and record the tare weight of each pot.

2) Determine and record the tare weight of each water-tight container.

3) Fill a tared pot with medium to be tested.

4) Tap the pot on the bench several times to settle the mix.

5) Saturate the material by slowly wetting the mix from the bottom so that air will not be entrapped and structure of the medium is not changed. Leave the medium just barely submerged for 24 h.

6) Quickly transfer the pot to a tared water-tight container to retain the water which will drain rapidly from large pores. Weigh and record the weight.

7) Set the pot aside for 24 h to allow the mix to drain to container capacity.

8) Weigh the pot and record the weight.

9) Place the pot in a drying oven and dry.

10) Weigh the dry material and record the weight.

11) Record or mark the distance from the top of the pot to the top of the dry soil mix.

12) Empty, clean, dry, and line the pot with a plastic bag.

13) Weigh and record the weight of the pot and bag.

14) Fill the lined pot with water to the level determined in step 11.

15) Determine and record the weight of the pot and water.

Calculations are as follows:

$$B = (d - t)/(w - l)$$

Where B is bulk density in g/ml, d is the weight of the dry mix from step 10, t is the tare weight of the pot from step 1, w is the weight of water and lined pot from step 15, and l is the tare weight of the lined pot from step 13.

$$P = (s - c - d)100/(w-l)$$

Where P is porosity as % v/v, s is the weight of the saturated mix from step 6, c is the weight of the tared water-tight container from step 2, d is the weight of the dry mix from step 10, w is the weight of water and lined pot from step 15, and l is the tare weight of the lined pot from step 13.

$$C = (f - d)100/(w-l)$$

Where C is container capacity as % v/v, f is the weight of the drained mix from step 8, d is the weight of the dry mix from step 10, w is the weight of water and lined pot from step 15, and l is the tare weight of the lined pot from step 13.

$$A = P - C$$

Where A is air-filled pores at container capacity in % v/v, P is porosity, and C is container capacity.

This procedure is rough and quick. To more accurately predict conditions that will occur in production, fill the pots and water them three times per week over a 3-week period so the material will settle to the density that would occur in production. After the final watering, allow the mix to drain for 48 h, then resume with step 5.

Excessive moisture is the most critical value. Factors other than aeration play a role in plant health so no exact guideline can be given. It is generally accepted that there should be more than 10% v/v air-filled pores at container capacity. General guidelines are as follows:

Bulk density	0.5-0.8 g/ml
Porosity	80% v/v
Container capacity	60% v/v
Air-filled pores at container capacity	10-20% v/v

More precise determination of water-release characteristics involves placing the medium on a ceramic pressure plate or other low-tension plate connected to a manometer. The manometer allows determination of soil moisture contents at various tensions which is a reflection of pore size distribution. According to De Boodt and Verdonck (1972), ideal media should have porosity of 85%, easily available water-holding capacity of 20% to 30% and water-buffering capacity of 4% to 10%. Easily available water is released between tensions of 10 and 40 cm of water and water-buffering capacity between 40 and 100 cm. It is generally accepted that plants recover little water at tensions above 100 cm.

Salinity and nutrient content of media play an important role. D. D. Warncke (1979) discussed use of the saturated media extract (SME) for evaluating chemical properties of media for container-grown plants. A large sample of media is saturated with gentle mixing. Saturated medium is equilibrated for 2 h followed by determination of pH and vacuum extraction of the soil solution. Nutrients and electrical conductivity are determined on the extract. Interpretative guidelines proposed by Warncke are presented in Table 1. Nutrient balance can be estimated using results from the SME method.

Table 1. General guidelines for greenhouse soil testing nutrient levels and their interpretation (Warncke, 1979).

Soil test	Low	Acceptable	Optimum	High	Very High
pH	5.5	5.5-5.9	6.0-6.4	7.0	7.5
Soluble Salts mmhos	0-0.74	0.75-1.99	2.0-3.49	3.5-5.0	5.0+
Nitrate-N ppm	0-39	40-99	100-179	180-280	280+
Phosphorus ppm	0-3	4-7	8-13	14-19	20+
Potassium ppm	0-59	60-149	150-249	250-350	350+
Calcium	0-79	80-199	200-349	350-500	500+
Magnesium	0-29	30-59	60-99	100-149	150+

Table 2. Guidelines for interpretation of water quality for irrigation (Ayers and Westcot, 1985).

		Degree of restriction on use		
Potential problem	Units	None	Slight to moderate	Severe
Salinity				
EC_w	dS/m	<0.7	0.7-3.0	>3.0
Infiltration				
SAR = 0-3 and EC_w =		>0.7	0.7-0.2	<0.2
SAR = 3-6 =		>1.2	1.2-0.3	<0.3
SAR = 6-12 =		>1.9	1.9-0.5	<0.5
SAR = 12-20 =		>2.9	2.9-1.3	<1.3
SAR = 20-40 =		>5.0	5.0-2.9	<2.9
Specific ion toxicity				
Sodium (Na)				
Surface irrigation	SAR	<3	3-9	>9
Sprinkler irrigation	me/l	<3	>3	
Chloride (Cl)				
Surface irrigation	me/l	<4	4-10	>10
Sprinkler irrigation	me/l	<3	>3	
Boron (B)	mg/l	<0.7	0.7-3.0	>3.0
Miscellaneous effects				
Nitrogen (NO_3-N)	mg/l	<5	5-30	>30
Bicarbonate (HCO_3)	me/l	<1.5	1.5-8.5	>8.5
pH Normal range 6.5-8.4				

Exact interpretation depends upon other factors such as nutrient source, species being grown, and the type of growth desired. Use of slow-release fertilizer will yield lower salt and nutrient concentrations, yet will be adequate. Luxuriant, rapid-growing natives, are not desired for re-vegetation so lower nutrient values may be acceptable.

Water quality is one of the most important tests to be performed by anyone in irrigation horticulture. Water quality and how it is managed determines the salinity of the growing media. Gone is the time when salinity could be offset by using a little more water and discarding the drain water. We are expected to use water more efficiently by recycling the drain water. In addition, the folks downstream don't want what we leave in our discarded drain water.

Increased salt content as expressed by electrical conductivity has the effect of reducing water-holding capacity. Sodium will reduce infiltration rates of many soils. Chloride, boron, lithium, and other constituents are toxic to some species. Bicarbonate will cause unsightly residue on foliage when applied through overhead sprinklers or misters. Table 2 contains general interpretative guidelines. Interpretation varies greatly depending upon leaching fraction, species grown, and other factors (For more detail see Ayers and Westcot, 1985). Iron, manganese, and other constituents, on their own or in combination with some fertilizers can cause emitter plugging.

Whether or not you do the testing or contract for it depends upon four factors. First is the value of your time or the time of your employee. Management and technical personnel in production organizations earn more managing production than by testing. Second, people who test on a routine basis are usually more efficient at testing just as production people are more efficient at production. Third, there are times when more precision or care in the test is required than production people may be able to provide. Fourth, some testing requires more equipment than is available in the normal production facility.

The important thing is that adequate information is available for decisions. Testing can provide useful information, information that facilitates more accurate, less risky, and more profitable decisions.

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The Process of Plant Disease Diagnosis

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ABIOTIC VERSUS BIOTIC DISEASES

Illnesses of plants are caused by factors that are either living or nonliving and that may predispose to each other. For example, overly wet roots may be weakened and more susceptible to biotic root rot, and biotically infected roots may reduce water uptake and cause normally watered plants to suffer from lack of oxygen.

BIOTIC FACTORS.

1) Insects—small ones, such as psyllids, thrips, borers, webworms, midges, mites (arachnids), or larger types—may distort and discolor tissues in many ways resembling diseases.

2) Nematodes may cause general plant growth suppression by damaging roots with galls and distortion.

3) Vertebrates, such as, gophers, mice, rats, deer, or coyotes may feed on plant parts.

4) Diseases by fungi, bacteria, or viruses.

Abiotic Factors. Abiotic factors include, but are not limited to, wind, frost, water excess, water stress, heat excess, sunburn, salt, chemical toxicity, smog, or herbicides. In viewing a plant or plants in distress, these abiotic factors must be identified as potential causes before moving on.

CROP

Crop refers to plants in commercial production or monocultural landscapes.

- Random occurrence of a disease syndrome is indicative of a biotic cause (as in flu infections in a human population.)
- Uniform occurrence of an abnormality suggests an environmental (abiotic) cause.

INDIVIDUAL PLANTS

Overall Symptoms. If the entire above-ground portion of the plant shows abnormal symptoms, an infection is likely in the collar area (region immediately above and below the soil surface), on the roots, or by a virus.

Above-Ground Symptoms. Localized above ground symptoms include burnt leaf margins, leaf spots, leaf blotches, blossom blight, shoot tip blight, dieback, stem blight, cankers, or leaf specks.

Partly Overall Symptoms. Partly overall symptoms are often caused by vascular diseases.

MANAGING CAUSES OF BIOTIC DISEASES

Root Problems. Roots, stolons, or rhizomes are more often diseased in containers than in the landscape except for turf. In the landscape, biotic root diseases more commonly occur with annuals or shrubs than with trees.

- Root rot may be caused by many different fungi, but in southern California, they are mainly *Pythium, Fusarium, Rhizoctonia, Phytophthora*, or *Thielaviopsis*.
- Identification of possible pathogens may be done by a commercial lab.
- With the pathogen identified, selecting materials for drenching or spraying on the foliage is greatly simplified.
- With big landscape trees, bleeding, decline, or death are more often than not water related.

Collar Problems. Infections at the collar are often terminal because the plant may be girdled. These are common in the landscape. The most common pathogen causing collar rot is the fungus, *Phytophthora*.

- Predisposition to infection may occur from excessive moisture at the collar. Reduction of predisposition may be achieved by careful water management.
- In a multiple planting, diseased specimens should be rogued.
- Those not entirely girdled may be surgically helped.
- Fungicides specific for *Phytophthora* control are available.

Crown Disorders. Diseases of the blossoms, shoot tips, leaves, or stems must be diagnosed for cause by either referenced findings or laboratory culturing.

- They may be caused primarily by fungi or bacteria on a local basis. Nematodes also may cause foliar necrosis, while viral symptoms represent systemic infections.
- Environmental conditions are extremely important in the management of crown disorders. "Cool and moist" are the standard favorable conditions described in the literature.
- There are contact and systemic fungicides, but primarily contact bactericides. The latter must be timed to protect the susceptible tissues when conditions are favorable.
- Reduction of favorable foliar moisture conditions may help.

Vascular Diseases. The name is derived from infections of roots by soil-borne fungi that migrate upward in the conductive tissues.

- They may be identified by an unbalanced decline of the crown.
- Darkened vascular tissue may be cultured by a commercial lab.
- Pathogens of vascular diseases are difficult to control.

Virus Diseases. They are systemically spread throughout the entire plant except meristem tissues.

- Symptoms include weakened plants, chlorotic patterns, shothole of leaves, color breaks of blooms, and more.
- Since the virus particles are in most tissues, propagation must be restricted to virus-free stock.

Propagation of Mycorrhizal Plants for Restoration

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There is increasing interest in the propagation of native plants for use in habitat restoration. Mycorrhizae are essential to the survival of most native plant species and a defining feature of functional ecosystems. Native plant nurseries are now being called upon to provide mycorrhizal plants for habitat restoration (St. John, 1993). Production of mycorrhizal plants requires a source of inoculum, care in providing growing conditions favorable for both plant and symbiosis, and an ability to verify successful colonization.

INTRODUCTION

Rampant and often uncontrolled development in southern California has brought about a belated realization that our unique biological communities are almost gone. Habitat restoration—the rebuilding of native ecosystems—is supported by environmental regulations and has now reached the status of an industry. In recent years, Tree of Life Nursery has been supplying mycorrhizal plants for habitat restoration.

Most plant species form the beneficial fungal association known as mycorrhiza. The fungus colonizes both root tissue and soil and acts as a bridge for transport of phosphorus and other nutrients. Mycorrhizal fungi are usually destroyed by grading and other severe disturbances; their propagules are typically slow to re-invade disturbed sites. Thus, uninoculated mycorrhiza-dependent plants may be placed in the field and expected to become self-sufficient without their symbiotic partners.

Mycorrhizal types are defined by structure and kind of host plant. The most common involve aseptate fungi of the order Glomales and are usually called vesicular-arbuscular mycorrhizae (VAM). The structure of VAM is not evident without special staining procedures. Typical VAM host species include most crop and ornamental plant species.

Ectomycorrhizae (ECM) involve fungi of the basidiomycetes and ascomycetes. ECM host plants include pines, firs, and spruce, along with most of the other commercial timber species. Other ECM hosts are oaks, beeches, willows, and the tropical family Dipterocarpaceae.

The Ericaceae and other families have mycorrhizae that are different in structure from either VAM or ECM. A fuller description of all of these types can be found in Harley and Smith (1983).

Mycorrhizae have a number of beneficial effects on host plants, the most prominent of which is improved phosphorus nutrition. Due to the slow diffusion of phosphate ions, much of the supply in the soil is out of reach of unaided roots. Mycorrhizal fungi absorb this more distant phosphate, which is then passed to the root (Tinker 1978).

Mycorrhizae are able to reduce stresses of various kinds (Sylvia and Williams, 1992). In some cases reduced stress is a side-effect of improved phosphorus nutrition. VAM can improve drought tolerance through a combination of improved nutrition and other mechanisms (Hardie, 1985; Nelson, 1987; Safir et al., 1972).

There has been considerable experimental work on the possibility that mycorrhizae confer disease resistance. Linderman (1994) concluded that a large share of the protective effect is due to improved phosphorus nutrition and increased vigor of mycorrhizal plants. Most of the remaining effect, at least with VAM, is probably due to antagonistic microorganisms that often accompany mycorrhizal inoculum. Such protective effects are clearly most effective when both VAM and associated pathogen antagonists are introduced before any pathogens become established.

In many cases the only practical way to introduce mycorrhizal inoculum to a restoration site is mycorrhizal carrier plants: plugs or other inexpensive plants, normally part of the intended flora, that have been made mycorrhizal in the nursery.

INOCULATION IN THE NURSERY

Unless the growing medium contains field soil, it is unlikely to contain propagules of VAM fungi. If the plants are to become mycorrhizal, they must be intentionally inoculated and given growing conditions that favor development of the symbiosis.

Mycorrhizal inoculum, the mixture of roots, hyphae, and spores that give rise to new colonization (Ferguson and Woodhead, 1982; Menge, 1984), can be purchased from commercial sources, collected from the field, or produced in-house. Commercial sources are available for both VAM and ECM. Commercial inoculum is usually of much higher quality than field soil or in-house inoculum. Field-collected soil is a reliable source of pathogens and insects.

Mycorrhizal fungi tend to be non-specific for hosts. That is, most species of fungus can form mycorrhizae with most suitable hosts. However, there is considerable specificity for soil pH and other characteristics (Cordell and Marx, 1994; Mosse, 1975). It is important that the fungi used in the nursery be suitable for both the growing medium and the field soil for which the plants are destined. In some applications, the best choice may be a mixture of fungal species from the site for which the plants are intended.

Some conditions commonly found in nurseries can prevent mycorrhiza formation. The most important of these are low light intensity, excess fertilization, improper watering, extreme temperatures in the root zone, and the presence of root pathogens.

VAM inoculation essentially consists of mixing inoculum uniformly through the growing medium or of placing a small amount of inoculum under a transplant. ECM inoculum may be spores or vegetative mycelium, applied in any of several ways (Castellano and Molina, 1990). Inoculation rate has a significant effect on mycorrhizal colonization and plant performance (Cordell and Marx, 1994).

It is very important that nursery staff realize that inoculum is perishable. The inoculum must not be allowed to heat up in the sun or freeze. If the material was delivered as an air-dried preparation, it should not be stored damp.

The best response to mycorrhizae is usually realized with early inoculation (Abbott and Robson, 1981). For practical reasons, nursery managers may decide to await the first transplant before inoculating.

It is important to verify the success of inoculation, a task that is more difficult with VAM than with ECM. Determination of VAM status requires chemical treatment of roots to remove cytoplasm and selectively stain the fungi (Phillips and Hayman, 1970). The fungal structures in the roots must then be distinguished from any other fungi in the roots. By contrast, ECM are often visible with the unaided eye or a hand lens.

The nursery that intends to undertake a mycorrhizal plant program must be prepared to make some procedural changes. The first decision is the kinds of plants and mycorrhizae required. Most host species form only a single type of mycorrhiza (i.e. VAM or ECM), but cottonwoods and a few other species form both VAM and ECM.

Nursery growing media may have to be changed to accommodate the symbiosis (Cordell and Marx, 1994). It may become necessary to substitute biocontrol for certain pesticides and to choose other pesticides for compatibility with mycorrhizae (Trappe et al., 1984). The customers must be made aware of the need to handle the plants carefully, not over-fertilize, and assure that the roots of bare-root plants are not damaged (Cordell and Marx, 1994).

A very important question is how to verify the success of inoculation. If no one on staff is able to stain and interpret roots, an outside laboratory or consultant may be able to do so. Soil and Plant Lab, Orange, CA, has recently begun to offer mycorrhizal determinations.

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QUESTION-ANSWER FRIDAY MORNING

Barbara Selemon: Will mycorrhizae work with exotic plants? Can mycorrhizae be introduced after the plant has been grown for 1 year?

Ted St. John: It is not too late. You can certainly inoculate after the fact. It's not the best thing to do when plants are in large containers. With special plants or for research purposes, it has been done. For the first question, whether the fungus is suitable, the only real question here is whether your plants are the vesicular-arbuscular type. If they are, then these general fungi are suitable. In fact, the same species are probably found in their home countries. They tend to be globally distributed and there are about 200 species. You do have to make sure it's the right kind of fungus and the fungi tend to be quite specialized for soil although they are very unspecialized with regard to host. The fungus that comes from an acid soil will not work in a neutral or basic soil, for instance.

Christy Alterman: How can you tell the difference between fungus gnat larvae and shore fly larvae?

Karen Robb: If they have a dark brown head capsule it is diagnostic for fungus gnats?

Christy Alterman: Would your potato idea attract shore flies as well or is it specific for fungus gnats?

Karen Robb: The potato slices or cores attracts only fungus gnat larvae.

Andrew Davis: Are mycorrhizae affected by herbicides (e.g., RoundUp) that are applied to the soil around landscape plants?

Ted St. John: No, herbicides are not usually directly damaging to the fungi, although if you were to eliminate the host plant over a long period of time the fungi would gradually die out.

Andrew Davis: How long is long?

Ted St. John: The only answer is, it depends on the host plant, how it propagates itself and the soil. Some fungi have spores that are quite resistant. One to two years there will probably be a significant amount of inoculum, but 3 to 5 years is too long.

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Barbara Selemon: What about propagating from a diseased one-of-a-kind plant? Is it worth taking the chance?

Randy Keim: No problem as you don't propagate from the diseased tissue.

John LaForge: Why do I sometimes not observe an improvement in growth in nursery plants that have been inoculated with mycorrhizae?

Ted St. John: There's a long of list of reasons that make it unpredictable in the nursery. First, if you're fertilizing heavily the plants often don't become mycorrhizal at all. If the plant is receiving plenty of phosphorus then the fungus is not needed. Second, even if it became mycorrhizal it's possible your fertilization program is masking the benefits of the fungi. This difference usually does not appear until after the plants have been transplanted to the field.

Shelley Androse: Are there chemicals we should be careful using when we are inoculating with mycorrhizae?

Ted St. John: Yes, any general biocide, Vapam, for instance. Some systemic fungicides especially if applied to the leaves may slow them down. Drenches may be more hazardous, but it is a bit unpredictable. There are compatible fungicides, Subdue, for instance. Fungicides that kill *Rhizoctonia* will also kill mycorrhizae.

Roger Hollinsworth: We have been using biological control for root weevils. How far from the original pot would be a good idea to put on the biological control (25, 100, 1500 ft.)?

Karen Robb: That's a very difficult question to answer. It really depends on the situation and the seriousness of the infestation. Traps can help determine where most of the infestation is. Recipe recommendations are not a good idea since every situation will be different.

Theresa Lipton: Are there cultural practices that will control ants?

Karen Robb: Cultural ant control is very difficult. I don't know of any cultural control methods.

Nevin Smith: Are there adverse effects of redwood and other barks in container media on the inoculation and growth of mycorrhizae?

Ted St. John: Work that I have done in the past with phenolics and hyphal growth showed that they were not inhibitory. There are many organic components that cause problems and we don't know why. I suspect that phenolics are not a serious problem unless they are at very high concentrations.

Don Dillon: Do excessive amounts of phosphorus that are associated with UC mixes inhibit mycorrhizal activity?

Ted St. John: Large amounts of phosphorus are quite inhibitory in most cases.

Bruce Briggs: If you had to do it over again would you do things any different in relation to your IPPS Work Study Grant?

Becky Jo Summers: I'm very happy with my decision. Everything I did over there (New Zealand) was a new experience for me. The ability to move around was very nice also. I was able to attend IPPS-New Zealand in October and made many contacts. If anyone were to come here that should be made available to them. The whole experience was just wonderful. Thank you.

David South: One thing that has always confused me about quantifying mycorrhizal infection is that it is always done on a root length basis instead of on a per plant basis so that as you increase phosphorus fertilization you might get a bigger plant with more roots and if you actually counted the number of infection points you would have the same number of mycorrhizals per plant as a smaller non-fertilized plant and yet you would conclude that the phosphorus decreased mycorrhizae because of number of infections per cm of root was reduced. Am I stating this correctly?

Ted St. John: Obviously, you're not a newcomer to mycorrhizae. I've written a paper that addresses this very point and would be happy to mail it to you. There is no way of quantifying infection that does not mislead into one direction or another. You made a very important point, one that's overlooked by a number of mycorrhizal researchers and the real answer is that you need both total root length colonized and the percentage colonized to interpret what you're seeing and, in fact, you could go beyond that and say you need something about the intensity of infection within each centimeter that is colonized as well.

Understanding Fog Technology

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Historically, many methods have been used in the attempt to retain moisture in unrooted cuttings. These have included sprinkling, misting, intermittent mist, and more recently micromist and fog. It has long been recognized that large droplets get the rooting medium too wet and soggy and that intermittent application of a fine mist is superior to sprinkling. Intermittent misting works fine for some applications, but it is difficult to control and sometimes results in an environment that is either too wet or too dry. Fog technology can solve those problems, but few people understand that the application of fog technology in propagation is entirely different from that of intermittent misting.

First, it's important to understand the difference between fog, micromist, mist, and sprinklers (rain size drops). The difference to the grower boils down to how wet things get, specifically plants and the growing medium. Big drops hold much more water than tiny droplets, so on a drop-by-drop basis a big drop will get anything it collides with much wetter than a small droplet. But what happens if we apply the same volume of water to an equivalent greenhouse area—in one case with rain or mist size droplets, in another case with fog size droplets? The answer is that all of the rain and mist drops will fall to the ground, and all of the fog drops will stay airborne. With micromist some droplets will fall and some will stay airborne. Sprinklers produce rain-sized drops, low-pressure misters produce mist-sized drops, and high pressure foggers produce fog and micromist. There are also products on the market, called foggers by the manufacturers, that propel low-pressure mist across a greenhouse with high velocity fans.

At low relative humidity, some water will evaporate from any drops that are airborne. With low pressure sprinklers and misters operating in a greenhouse environment, typically about 3% of the water will evaporate. With micromist, if the humidity is less than 50%, typically all of the water will evaporate while the droplets are airborne—if the humidity is 80% or more, then as much as half of the volume of micromist water will reach the ground before evaporating. Fan blown misters have some fall out even in low humidity environments and at high humidity virtually all of the water will fall to the ground. With true fog, if the humidity is less than 100%, all of the water will evaporate while airborne. At 100% humidity, fog droplets will not evaporate, but will still remain airborne. As a rule of thumb, in a greenhouse environment, all droplets smaller than 40 microns will stay airborne, droplets larger than 40 microns tend to settle onto the growing surface, especially if the humidity is high.

The above information leads to one rather obvious conclusion: if you want to irrigate, use misters or sprinklers; if you want to raise the humidity or do evaporative cooling, fog or micromist is better for the job.

FOG TECHNOLOGY

True fog is made by atomizers that produce an array of droplets ranging in size from about 2 to 40 μm in diameter. By comparison a human hair is about 100 μm in diameter. Micron is an expression meaning micrometer, or one millionth of a meter. The most useful measure of fog or micromist is volume median diameter. The volume median diameter of a typical fog is about 15 µm. This means that half of the volume of water in the fog is contained in droplets that are larger than 15 µm, and half is in droplets that are smaller than 15 µm.

The best atomizers used in micromist systems will produce an array of droplets ranging in size from about 2 to 100 µm in diameter. The volume median diameter of such a micromist is about 40 µm, so that half of the volume of water is in droplets larger than 40 µm.

It should be noted that most manufacturers today claim that their devices produce 10-µm droplets. While this might be technically correct, it is a useless statement unless the entire drop size spectrum is investigated. For example, in the micromist system discussed above only about 2% of the volume of water is in droplets 10 µm and smaller. This makes the 10-micrometer claim true, but meaningless.

What is the meaning of drop size? At 50% relative humidity and lower, a 100-micron droplet will evaporate in the 20 sec it takes to settle the 8 to 10 ft typically available in a greenhouse. But, at the higher humidity typical of a propagation area, all droplets larger than about 50 µm will reach the growing bench before evaporating.

PROPAGATING WITH FOG

True fog can be used to create a zero-transpiration environment without overwetting the growing medium. This is because fog drops will not settle and irrigate the medium. When micromist is used for propagation it must be cycled off long enough to allow excess water to drain and evaporate from the growing medium. While the drying time is much less than is necessary for heavy mist, it is still long enough to allow some water to transpire through the stomata.

When fog is used for propagation the usual practice is to keep a light fog around the plants at all times. This foggy atmosphere will be at 100% RH, but that in itself is not enough to guarantee zero transpiration loss. This is because when solar energy is absorbed by a leaf, the temperature of the leaf surface is raised above that of the surrounding atmosphere. This raises the vapor pressure of the plant water, so that some water would transpire and evaporate even in a 100% RH environment.

However, when plants are placed in a fog environment another phenomenon takes place that prevents transpiration loss. Although the fog droplets do not settle significantly, they do migrate and bump into both the upper and lower leaf surfaces. This means that after a short time in a fog environment a plant will be coated with a very thin layer of fog water. Under these circumstances when solar energy tends to increase the leaf temperature it is the fog water, rather than plant water, that evaporates and cools the leaf.

The properties of fog make it very useful for plant propagation. Because fog does not settle, the growing medium can be kept light and fluffy and oxygen rich. This cannot be accomplished with mist, and is very difficult to accomplish with micromist. Only true fog can create a healthy, zero-transpiration environment. The zero-transpiration environment created by fog greatly enhances the chance of rooting hard-to-root varieties. Fog is also useful for starting plants in plug trays, whether from seed or from tissue culture. Fog will not saturate the plug tray, and will maintain a healthy environment for seed germination and for tender tissue-culture plants just out of the test tube.

FOG MAKING SYSTEMS

There are three basic types of atomizers used in fog and micromist systems today: air atomizers, direct-pressure swirl jet atomizers, and impaction-pin atomizers (See Fig. 1 and 2 for examples of the latter two). Air-atomizing devices use the shearing force of an air jet to atomize water. The two types of direct-pressure atomizing devices use high pressure and the velocity of water through a small orifice to accomplish the atomizing.

Air-atomizing fog systems have the advantage of being cheaper to make for small systems requiring only 2 or 3 atomizers. Air atomizers are not practical for large systems because the energy requirements are typically 20 times that needed for an equivalent direct-pressure system. A 3000 ft^3 greenhouse would typically use 1 horsepower for a direct-pressure verses 20 horsepower for an equivalent air system. The water flow through an air atomizer can be varied, but high flow rates produce larger droplets. Caution should be used when evaluating an air system, because the specifications usually list maximum flow and minimum droplet size without making it clear that the two do not go together. A good air atomizer can produce true fog-size droplets, but at water flow rates that are ½ to ¼ that of a direct-pressure fog nozzle, and energy requirements twenty-times as high. Another disadvantage of air atomization is that air compressors designed for shop use are not meant to run continuously as is required in an air fog system. The continuous running greatly shortens the life expectancy of the compressor and increases maintenance costs.

Swirl jet nozzles are considerably cheaper to make than impaction-pin nozzles, but produce micromist rather than true fog. Swirl jet nozzles are less efficient than impaction-pin nozzles because of energy loss caused by friction in the swirl chamber. A swirl jet nozzle with an equivalent orifice size operating at the same

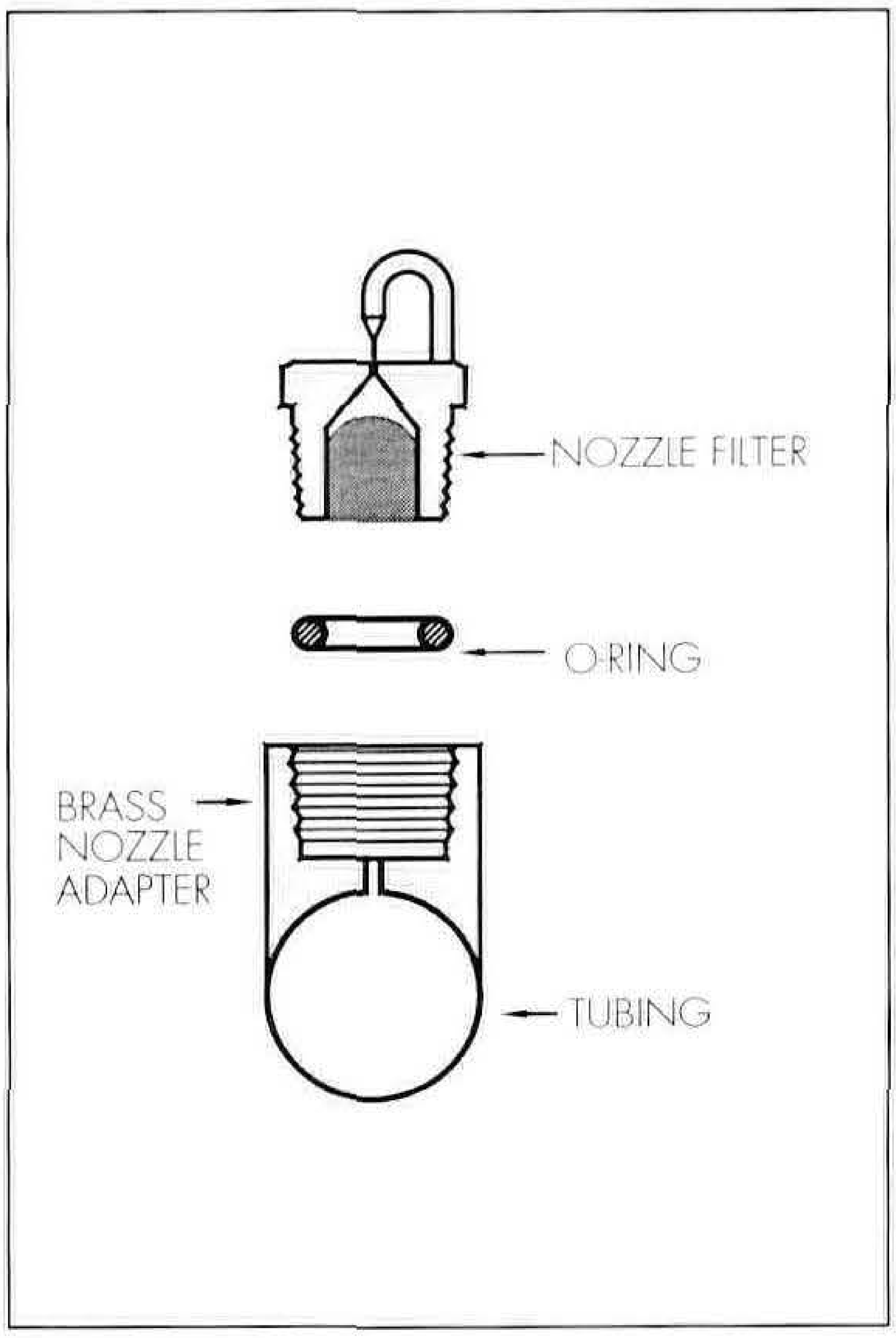

Figure 1. Impaction pin nozzle.

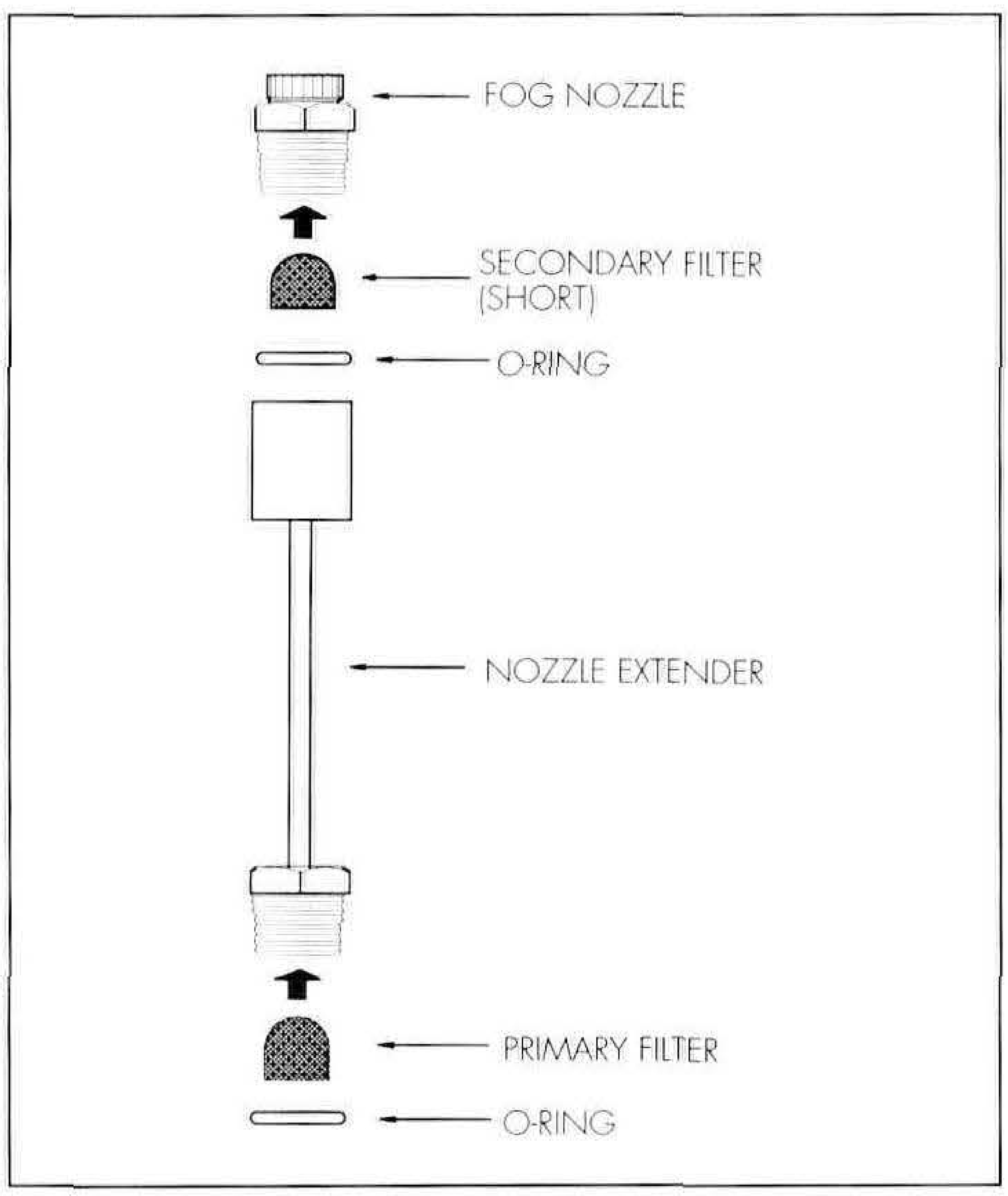

Figure 2. Swirl jet nozzle and extender.

pressure as an impaction pin nozzle, will produce droplets that are approximately 2½ times larger than the impaction pin, with a flow rate that is approximately ½ that of the impaction pin. To get an equivalent drop size and flow rate would require that the swirl jet operate at about 6 times the pressure of the pin nozzle. This would require 6 times the power and considerably more costly pumps and plumbing. Impaction-pin fog systems are the most efficient at producing true fog droplets. To make a true fog, air atomization requires 20 times the energy and swirl jets six times the energy of an impaction-pin system. In addition, the swirl jet system would have to operate at about 6000 psi, and would require much more costly pumps and equipment. Direct-pressure, impaction-pin fog systems typically operate at 1,000 psi, a compromise between equipment costs and small droplet size. These systems are cost effective and practical for use in large areas. Higher pressure would produce finer fog, but would also greatly increase the equipment and operating costs.

SUMMARY

All three basic types of fog systems have advantages and disadvantages. Air atomization systems are best suited for small applications that require only two or three atomizing nozzles. Air systems are impractical for large areas because they become too costly.

Micromist systems are less costly to make than true fog systems and, therefore, might have a cost advantage in applications where the relative humidity does not need to exceed 75% or where wetting is not a problem.

True fog systems are capable of producing droplets that are small enough to stay suspended in the air under all greenhouse conditions. True fog systems offer a tremendous advantage in high-humidity areas where maximum evaporative cooling is required. True fog also offers advantages in propagation situations where zero transpiration loss is desired and where too much wetting would cause problems.

There are a number of fog system manufacturers in the market today. It is impossible to evaluate them by reading sales literature or by listening to sales spiels—all claim to be the best. The best way to make an evaluation is to talk to a grower who has experience using a particular system or, preferably, has experience with more than one manufacturer. There is definitely a difference in quality between systems that seem to be equivalent. Lower cost is not necessarily the most economic purchase. Pay attention to the vendor's ability and reputation for after-sale customer service. All systems need maintenance. Most important, pay close attention to the vendor's knowledge of water chemistry and ability to handle water quality problems. All systems on the market today are subject to nozzle clogging problems and all nurseries have different problems associated with water quality. The vendor's ability to analyze and take care of water quality problems will save many maintenance headaches in the future. When interviewing a grower ask about maintenance costs as well as up-front costs.

The use of fog technology and zero-transpiration environments for propagation is still relatively new to the grower, but it has produced some spectacular results, especially in the propagation of hard-to-root plants.

Some Plant Propagation Methods Used in China

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During 1989, the University of British Columbia Botanical Garden signed a 5-year agreement with the Nanjing Botanical Garden, People's Republic of China, for cooperative programs in research, plant exploration and educational programs. In 1991, I was invited by Dr. He, Shan-An, Director of Nanjing Botanical Garden, to give presentations, and workshops on propagation and new plants with commercial potential.

Besides visiting other gardens, arboretums, and mountain forests, I did have the opportunity to visit some nurseries to see the propagation techniques used. Much of it was very traditional and facilities were well below the standard used in the Western world. Nonetheless, I was impressed with their enthusiasm and skills.

The nursery at the Nanjing Botanical Garden contained a wide variety of plants from their research programs and wild collections. One program is the hybridization of *Taxodium* for urban planting. A number of hybrids were made using *T. distichum* var. *imbricatum* (syn. *T. ascendens*), *T. distichum*, and *T. mucronatum*. The best hybrid was *T.* 'Zhongshan' (purple mountain) which had high resistance to air pollution, salts, and alkalinity. It is propagated by open-ground, whip grafting onto 3-year seedlings of *T. distichum*. Each graft is covered with an individual polyethylene bag, secured just below the graft itself. This provides a humid environment and protection against wind.

Part of the Garden's mandate is conservation measures to protect rare and endangered plants. *Parakmeria lotungensis* (Magnoliaceae) is included in this program. This evergreen tree, growing up to 30 m with large, white flowers, is scattered in sub-tropical areas of China and known for its high-quality wood and potential for horticultural cultivation. *Parakmeria lotungensis* is whip-and-tongue grafted onto *Magnolia denudata* to quickly multiply selected clones from different provenances. Similarly, a rare clone of *Liriodendron chinense* from Sichuan is whip-and-tongue grafted onto *L. tulipifera*. It was a pleasure to observe the Garden's master grafter so carefully cut the tissues to obtain exact matching of the cambial tissues. The method used was identical to the diagrams from the late Robert J. Garner's book, *The Grafter's Handbook*.

Castanea mollissima (Chinese chestnut) is becoming increasingly important as a commercial crop. Different clones are propagated using a rind graft onto *C. mollissima*. Mature, fruiting plants of *Actinidia deliciosa* were being crown-rind grafted to quickly establish new clones for fruit production.

The grafting knives are hand-made from hardened steel—with or without wooden handles. The blades are ground to produce 5 to 10 mm of cut surface. (I was given a gift of these knives and reciprocated with a Tina 606).

Micropropagation of rare and endangered plants is another important method used at the Nanjing Botanical Garden. A natural woodland area is set aside for the endangered plants to be grown. Plants being investigáted include *Magnolia biloba* and *Idesia polycarpa* var. *vestita*. The Hangzhou Botanical Garden is working with the very rare *Carpinus putoensis* and *Disanthus cercidifolius* var. *longipes*. This

Carpinus is in danger of extinction, with only one tree remaining on a mountain in Putuo Island. It will propagate by seed, but its seed have a short longevity. Cutting propagation has been partly successful. The *Disanthus* is found in the Nanling mountains and propagation is by seed, with little or no success from cuttings. Both these species are prime candidates for tissue culture research.

In Nanjing, I visited two or three of the municipal nurseries whose main purpose was to provide plants for city and highway plantings. The plants grown were mainly limited to*Acer palmatum* f. *atropurpureum*, *Juniperus chinensis* 'Kaizuka', *Platanus* ×*acerifolia*, *Loropetalum chinense*, and evergreen azaleas. Particularly interesting was the red-flowered *L. chinense* 'Rubra'. There was considerable variation in the size and color of the flowers, which were most attractive against the new purple-red foliage. Propagation was by cuttings under mist. Due to poor sanitation and the variable water supply, a considerable number of cuttings perished.

Also at the municipal nurseries, crops were raised from seed to provide summer bedding plants. The range of crops I saw was mainly limited to *Calendula* and *Dianthus*. They also grew *Cyclamen* and azaleas for decoration at important festivals.

Low polyethylene tunnels (sun-frames) were made from twisted bamboo and used for rooting of some hardwood cuttings during the fall. Charcoal was used to cover open-ground seed beds of *Berberis* and *Pyracantha*. In general, herbaceous perennials were grown mainly in open-ground beds, with division being used for propagation.

There were definite problems in the varied growth of container-grown plants, due mainly to the poor structure of the potting mixes. A gray clay formed the basis of the mix that included a number of different substances—crushed clinkers from coal-burning fires, rice husks, recycled sewage, and chopped straw. For small plants, perlite was sometimes added. For growing lotus plants, human hair was collected from barber shops and mixed with the clay. For fertilizer, bone meal and other organic matter were mainly used. Once these soil mixes dried out they became very hard, making it difficult to re-moisten the mix.

China is showing much greater interest in joint ventures with western companies to promote plant exports, including davidias, tree and herbaceous peonies, and young bonsai plants—the latter is now a popular export to Europe. Sales within China are mainly to municipal institutions and newly constructed hotels.

Author's Note: An excellent reference book on rare and endangered plants in China is *China plant red data book—rare and endangered plants*, ed. Fu Li-Kuo, Science Press, Beijing and New York.

Mediterranean Plants Under Glass at Longwood Gardens

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INTRODUCTION

Longwood Gardens is a display garden situated on 1060 acres in southeastern Pennsylvania. Longwood is open year-round, attracting visitors to its 200 acres of outdoor displays and 3½ acres of conservatories and greenhouses. Longwood has been incorporating Mediterranean-climate plants into its conservatory displays since the mid 1980s. This was done to maintain lower greenhouse winter temperatures because of the escalating costs of heating fuel and to increase visitation during the winter months by providing the visitors with a kaleidoscope of plants in bloom. Longwood is located in USDA Hardiness Zone 6B, characterized by an average minimum winter temperature of 0 to -5F; as such, relatively few Mediterranean-climate plants are hardy outdoors in our area.

The Mediterranean-climate regions of the world include the true Mediterranean, the California chaparral, parts of coastal Chile, western and southern Australia, and the southwestern cape of South Africa. Mediterranean climates are typified by cool, moist winters that are relatively frost-free, and hot, dry summers. Most of the plants indigenous to these regions are therefore winter-growing, blooming in the late winter to early summer months. The preponderance of the Mediterranean-climate plants utilized at Longwood are South African and Australian in origin, collected during staff trips to each country and from California nurseries and botanic gardens.

Longwood is currently displaying Mediterranean-climate plants in four conservatory spaces: the Garden Path, a 2500 ft^2 garden created in 1986 as a cottage-style display of subtropical and Mediterranean-climate plants; the Silver Garden, opened in 1989 as a 4000 ft^2 garden devoted to the display of silver and grey foliaged plants; the Mediterranean Garden, opened in 1992 as a 3200 ft^2 garden devoted to the display of true Mediterranean-climate plants, and the East Conservatory, an almost 22,000 ft^2 space that currently contains a mixture of permanent and rotating displays of Mediterranean-climate, subtropical, and non-hardy, temperate plants. The roof of this conservatory is slated for replacement in 1997 and preliminary plans include the complete redesign of the displays with probable further incorporation of Mediterranean-climate plants.

CULTIVATION

Both the display areas and research greenhouses containing our Mediterranean-climate plants are maintained in winter months from 42 to 45F by night, warming up 5 to 15F by day. Summer temperatures typically go over 90F by day, cooling off into the upper 60s to mid 70s (F) at night. While our winter solar radiation values do not approach those encountered outdoors in the true Mediterranean regions, we do receive sufficient light to grow and bloom such high-solar-radiation-requiring plants as *Banksia ericifolia*, *Protea cynaroides*, and *Xanthorrhoea quadrangulata*.

Plants are grown both in containers and also permanently planted in conservatory beds. Soil mixtures vary considerably, from conservatory beds containing unamended native soil, which is very high in clay content, to soilless media. The beds of the Mediterranean Garden are filled with a soilless medium composed of 3 haydite : 3 granitic grit #3 (particle size approximately 3 to 5 mm) : 2 Douglas fir bark (¼ inch) : 1 peatmoss (by volume). Our Mediterranean mix was developed based on several cultural and display criteria. The components either do not decay or decay very slowly, minimizing bed shrinkage and settling. Its very high water infiltration and percolation rates with minimal lateral movement allow heavier irrigation of moisture-requiring plants without overwatering adjacent lower-moisture-requiring plants. The excellent drainage and aeration lessen disease problems caused by a saturated soil. The low cation exchange capacity minimizes the risk of excess fertility problems and allows us to apply different fertilizers to adjacent plants. Aesthetically, its dark color contrasts well with the stonework and plant material in the Mediterranean Garden. This medium is used to container-grow most of the backup plants for the Mediterranean Garden, as well as many of the research plants under evaluation.

SPECIFIC PLANT GROUPS

We have perhaps 500 accessions of Mediterranean-climate plants, including annuals, geophytes, and herbaceous and woody perennials. Though the majority of these are from South Africa and Australia, the other Mediterranean regions are also represented. Our two largest groups of Mediterranean-climate plants are representatives of the family Proteaceae and winter-growing geophytes.

Plants of the Proteaceae. We currently have 92 accessions, mostly from the genera *Banksia*, *Grevillea*, *Leucadendron*, *Leucospermum*, and *Protea*. About 24 accessions are on display in the conservatory, with the remainder still under evaluation in the Research Division. We grow Proteaceae plants both in plastic and clay pots. Seedlings and rooted cuttings are planted in our propagation mix, 3 or 4 granitic grit #2 (particle size 2 to 3 mm) : 1 peatmoss (v/v). Plants ready for pots, 10 inch or more in diameter, are planted in our mediterranean mix, 3 haydite : 3 grit #3 : 2 douglas fir bark (1/4 inch) : 1 peatmoss (by volume). All of the containerized Proteaceae are fertilized monthly with Olympic 20-0-20 Hi-Calcium Peat-Lite at 100 ppm N. Chlorotic plants are fertilized biweekly until they green up, then are put back on the monthly schedule. We apply Peters Excel 15-5-15 CalMag at 100 ppm N once in March and once in October, which seems to be sufficient to supply the plant's phosphorus needs. We have observed that the grevilleas tolerate much higher levels of fertilizer, having applied Peters 20-10-20 Peat-lite Special at 200 ppm N to several accessions every two weeks from June through August of this year with no apparent detrimental effects. Following this cultural regime, we have readily grown and bloomed members of all these genera and have experienced very few losses; the one exception to date has been *Leucadendron argenteum*, the silver tree, which does not appear tolerant of our summer heat and humidity.

Geophytes. The term geophyte is more appropriate for what have been called bulb plants, used incorrectly to include true bulbs, corms, and rhizomes. We have about 160 accessions of true Mediterranean-climate geophytes, predominantly from the South African cape region, including the genera *Aristea*, *Bulbinella*, *Gladiolus*, *Lachenalia*, *Ixia*, *Moraea*, *Oxalis*, *Veltheimia*, and *Watsonia*. For the most part, these are winter-growing geophytes that are deciduous during their summer dormancy. We store the dormant bulbs, corms, and rhizomes in their pots in the greenhouse over summer. The Bulbinellas and Veltheimias are syringed about every two weeks, but the other geophytes are stored dry. We begin repotting in mid-August and have all the geophytes repotted and in growth by early October. Depending on corm or bulb size, most are planted in 7-inch standard clay pots containing 3 grit #2 : 1 peatmoss (v/v) or some similar sharply draining mix. The corms or bulbs are watered in after repotting then kept fairly dry until shoot growth is evident when watering is increased. The geophytes are grown over winter in 45 to 55F minimum temperature greenhouses that warm up 5 to 15F by day. Most of the geophytes do not receive any fertilizer application until flowering has commenced, which, depending on the species, will be from December to May. Once in bloom, the plants are fertilized with Peters Excel 15-5-15 CalMag weekly at 200 ppm N until foliage begins to die down in late spring to early summer. The South African cape geophytes as a group have proven very easy to cultivate and propagate. Most set seed readily, and reach blooming size from seed in two growing seasons. Our major problem has been the presence of potyviruses, which are vectored by aphids and through mechanical means. To deter the spread of virus, we vigorously screen our accessions by utilizing Agdia (Elkhart, Indiana) monoclonal antibody Potyvirus test kits and destroy any plants that test positive. We collect seed and regrow accessions when possible and also tissue culture propagate virus-free plants.

PROPAGATION METHODS

Seed Propagation. Many of the Mediterranean-climate plants we have were obtained as seed from commercial sources or other botanical gardens. We attempt to duplicate natural conditions as closely as possible in the sowing and treatment of seed. As most Mediterranean-climate plants are winter growing, we sow seed from these regions in the autumn, typically from mid-September through November. Any seed received after early February will be held in storage until the following autumn. Seed are sown in our propagation medium consisting of 3 or 4 granitic grit #2 : 1 peatmoss (v/v). This is a well-drained medium with a low pH and minimal risk of pathogen problems. For seed containers, we use 1-gal nursery pots for deep-rooting herbaceous and woody perennial species, and 3 inch × 12 inch × 16 inch propagation flats for annual and geophyte species. Seed containers are placed in a shaded greenhouse that, during the winter months will cool down to 48F nightly and warm up to nearly 75F daily. Fluctuating temperatures have proven to stimulate the germination of South African Cape species (Brown et al., 1993). Seed are watered either by hand or by intermittent mist.

Cutting Propagation. We propagate a wide array of Mediterranean-climate plants from cuttings. Cuttings may be taken any time of the year depending on the species. Terminal stem cuttings are preferred; generally, the lower leaves are stripped and the growing tips left intact. In the Research Division we use liquid formulations of KIBA dissolved in water to treat cuttings. Soft to semi-firm, herbaceous cuttings of plants such as *Boronia heterophylla*, *Lechenaultia biloba* 'Moora' (syn. 'Royale'), and *Prostanthera* species are dipped for 5 sec in 2500 ppm KIBA. Greenwood cuttings of woody plants such as *Echium candicans* (syn. *E.*

fastuosum), *Leucospermum* cvs., and *Protea neriifolia* are dipped for 5 sec in 5000 ppm KIBA. Other plants will receive different auxin treatments as determined by either literature search or through trials. For example, we have determined that a 5-sec dip in 500 ppm KIBA appears optimal for South African *Erica* species. Cuttings are stuck in 3 inch × 12 inch × 16 inch propagation flats containing 3 or 4 granitic grit #2 : 1 peatmoss (by volume). Cuttings taken from September to May are placed under intermittent mist controlled by a 24-h time clock and a programmable 1-sec-interval relay switch. Cuttings taken from June to August are placed under fog generated by a 1 HP Humidifan Turbo 1000 or a combination of mist and fog. The Humidifan is controlled by a 24-h timer and a two-stage thermostat, the flow rate of water being manually adjusted with climatic changes. The Humidifan is set to oscillate 180 degrees, which creates a drier zone below and behind the fan. This has proven ideal for weaning freshly rooted cuttings and seedlings from higher to lower relative humidity. Many of the plants we propagate are not tolerant of an overly wet propagation medium and must be removed from mist or the wetter fog zones as soon as roots are established. Fog propagation of Mediterranean-climate plants has, therefore, been very effective as the propagation medium remains drier with fog compared to mist. The propagation greenhouse is ventilated and from May to October provided with about 50% shade.

Tissue Culture Propagation. We have a small tissue culture laboratory capable of maintaining about 2400 culture tubes. Species are selected for tissue culture propagation based on their lack of availability, difficulty in seed or cutting propagation, and the number of plants needed for display. Based on these criteria, Mediterranean-climate plants we have investigated in tissue culture include *Erica fastigiata*, *Eriostemon* (Ault, 1994), and numerous South African geophytes. Many of these geophytes are not commercially available, or when available are often very expensive, and may be infected with various potyviruses such as Ornithogalum Mosaic Virus. We screen our stock for potyviruses prior to and after tissue culture propagation by utilizing Agdia monoclonal antibody Potyvirus test kits. Very often we have a limited amount of stock available for tissue culture propagation; therefore, we use leaf tissue as the explant source to avoid sacrificing the bulbs. We have successfully tissue culture propagated *Lachenalia arbuthnotiae; L. bulbifera; L. purpureo-coerulea; L. pustulata; Veltheimia bracteata*, both a yellow-flowered clone and 'Rosalba'; and *V. deasii* (*V. capensis* var. *deasii*) utilizing this approach.

Mediterranean-climate plant material has become an important part of Longwood's conservatory display. These plants have filled a role not satisfactorily met by other plant groups by providing winter flower interest, often proving easy to cultivate, and tolerating cooler growing temperatures, resulting in energy conservation. The public has been very receptive to these plants, as most of our visitors are not familiar with Mediterranean-climate flora. We anticipate the further incorporation of these plants into our current and future conservatory displays.

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Innovations in Growing using Retractable Roof Greenhouses, Cold Protection, and Shade Houses

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INTRODUCTION

Most growers, given the opportunity, would prefer to grow their plants outside. Not only is the outside environment the natural environment for all plants, but it also requires less capital to grow outside than in a greenhouse structure. However, due to the fluctuation in the outdoor environment from day to day and season to season, it became obvious that some sort of structure would be required to precisely control the growing environment. As a result, growers began to build greenhouses to protect their plants from adverse outside conditions.

While inside a greenhouse, the plants are protected against adverse conditions outside. However, when outside conditions warm up and dry up, and the sun comes out, the greenhouse environment becomes too hot and too humid. During these sunny, hot conditions, most growers experience some or all of the following problems when growing in a greenhouse:

- Plant stretch
- Higher incidence of pests and disease due to higher heat and humidity
- Poor plant growth due to excessive leaf and soil temperatures
- Differences in the rate of plant growth, due to temperature variations as a result of improper ventilation
- Lack of control over crop timing, due to inability to cool the crops
- Poor plant performance after being moved to an outdoor finishing area or into a garden, due to the plant being poorly acclimated to outside light and wind conditions.

This poses a dilemma for growers. If they grow their plants outside they could be exposed to cold and rain. If they grow their plants in a greenhouse they would have to contend with the problems listed above.

Many different types of equipment were developed to help cool and ventilate the greenhouse environment in the summer, like shading systems installed inside or above the greenhouse, fog systems, gutter vents, roll-up sidewalls, etc. These different systems did help moderate the daytime greenhouse environment, but they could not create true outdoor growing conditions inside the greenhouse. The plants were still exposed to a greenhouse environment regardless of the weather outside.

Similar problems occurred with growing plants in shade houses. The plants only needed shade for 5 to 8 h per day, but they were shaded for 24 h per day. Having the shade cloth overhead 24 h per day restricted air circulation, thereby creating high temperature and humidity levels that caused poor plant quality and higher incidence of disease.

GIVE THE PLANTS WHAT THEY NEED, WHEN THEY NEED IT!

In order to maximize crop quality and quantity, it became evident that the plants need the proper growing environment, 24 h per day, regardless of the weather outside.

One solution is to have a roof covering that can protect the plants when they need protection from the outside elements, but then could be retracted when the outside environment is suitable for the plants. This way the plants are in a protected environment when they need the protection, but are in the outdoor environment when it is suitable to the plant.

There are now three types of retractable roof structures available, each providing a different level of protection when the roof is closed, namely:

- Shade houses
- Flat-roof cold-protection houses
- Greenhouses

Shade Houses. Retractable roof-shade houses can increase plant growth by 15% 30%, as compared to fixed-roof houses, simply by optimizing light levels and by properly reducing the plant leaf and soil temperatures. The retractability of the shade allows for a darker shade to be used for proper cooling during excessive light and temperature conditions, since the shade is retracted during low light conditions.

However, since black shade cloth is porous, it is very difficult to get significant cold protection or rain protection, since the rain will pass through the shade cloth. However, the shade cloth can be used to break up the larger rain droplets to create more of a mist. This type of retractable roof shade house is used primarily where shading and cooling are most important.

Cold-Protection Houses. Flat-roof cold-protection houses with a retractable roof are similar in design to a shade house, with the only difference being that a woven, white polypropylene covering is used instead of black shade cloth. This covering allows water through, but allows minimal air passage. This house is used primarily for cold protection, but can be used also for some shading in the summer for crops that are heat sensitive. This is especially beneficial for situations where soil temperatures in the pots get too high, resulting in plant stress and eventual shutdown.

This type of house is used in the south for foliage and nursery-type plants and in the north for nursery and perennial production. Since the covering is horizontal the rain does pass through the covering, so the plants will get wet when it rains. This house should not be used for rain-sensitive plants, like bedding plants, but is ideal for perennial production, especially since the automatic retraction of the roof allows for a snow cover to fall on the perennials for added insulation and protection.

With the cold protection and shade house, if proper planning is done ahead of time, the posts used for these two house designs can be used to attach a greenhouse roof at a later date.

With respect to snow, the cold protection house can be designed to hold a 7 to 10 lb ft^2 snow load when the roof is closed. For situations where greater snowfalls may occur, either supplemental heaters can be used to melt the snow, or a snow sensor can automatically retract the roof when it begins to snow.

Greenhouse with a Retractable Roof. A greenhouse with a retractable roof provides the greatest degree of protection to plants in that it can keep plants both warm and dry, like a conventional greenhouse. The main difference is that a conventional roof vent only opens up 25% of the roof, whereas in a retractable roof greenhouse the greenhouse roof retracts 90% of the way in less than 3 min. Not only does this create a massive roof vent, but, more importantly, it allows for the plants to receive direct, unfiltered sunlight. It is becoming apparent that direct ultraviolet light is nature's most effective growth regulator and is critical to growing properly acclimated plants. With this house the crops can be exposed to outside conditions any time the outside temperatures exceed the desired minimum and it is not raining. This means for many locations the roof would be retracted 50% to 70% of the time.

These houses are essentially the same as a conventional fixed-roof greenhouse, with the exception of ventilation capacity. This means that all standard equipment that is typically used in a conventional greenhouse can be used in a retractable roof greenhouse, such as:

- Typical heating systems
- Irrigation booms
- Hanging baskets
- Additional curtain system for shading, cooling, and heat retention
- Fog systems
- Roll-up side walls or side vents for added cross ventilation.

Retractable roof-type greenhouses are ideal for bedding plants, containerized ornamentals, vegetables, tree seedlings, specialty cut flowers, or any other plant that prefers to be grown outside. A good rule of thumb is that if it is going to be sold and then planted outside it would do extremely well in this type of house.

Plant Benefits. When the roof is retracted on any of these three types of retractable roof houses:

- Plants receive outside light, temperature, and humidity levels.
- Leaves dry off quickly, due to the wind and direct sunlight.
- Plants grow more compact and are properly acclimated.
- Plants are more disease resistant, since they are grown healthier and are exposed to less stress.
- Plant growth is more uniform throughout the range, since there is no temperature differential throughout the range.

Other Benefits.

- Better temperature and humidity control will result in reduced chemical fungicide and growth regulator usage.
- Roof can be closed to help contain chemical applications
- Roof can then be retracted after applications have been completed to allow for purging.
- Growers can manage larger growing areas, since it is easier to grow plants when you have proper control over the environment.
- When plants are rain-tolerant, growers have the opportunity to conserve water by retracting the roof when it is raining.
- There is no limitation to the length of a greenhouse due to fan ventilation limitations.
- Larger greenhouse ranges can be constructed as a result, which makes it easier to monitor workers' activities.
- Eliminates the need to buy, operate, and maintain fans.

The most important benefit, however, is that the crops will be of a more consistent, higher quality and better acclimated, which is becoming a major issue with the mass merchandisers. Not only that, if the consumers enjoy higher quality plants our entire industry will benefit.

QUESTION-ANSWER SATURDAY MORNING

John LaForge: Have you seen any fog systems inside these retractable-roof houses for propagation?

Richard Vollebregt: At this point, not yet. We have only been promoting this for production ranges. As growers become more aware of it we see fog used in propagation. We have seen it in Arizona were people have flat-roof houses and they were using the fog simply for cooling whereby they would have a retractable shade to reduce the light level and then the fog system would be used to supplement the cooling of the air temperature.

Marge Sweeney: In your Mediterranean house, what was your watering system?

James Ault: Everything is being manually watered in there right now. Since we move plants around so much, trickle irrigation systems have been difficult to use. The soil mix in there is well-drained and you can have a plant that has a high water requirement next to a plant that has a low water requirement and not have problems with irrigating either one.

Ross Merker: How do you manage pest management when you have large numbers of people going through your facility?

James Ault: We have 800,000 people visit and we are open 365 days a year so that is a real concern. We have a full-time integrated pest manager and it is his job to figure this out. We do use some biocontrols. We use a lot of soap and oil that works very well under glass. We avoid including plants in our displays that have serious insect problems.

Patti Kreiber: When do you expect Volume 2?

Bruce Macdonald: It is about 25% complete.

Jim Conner: Under high wind conditions and the curtains are open, what happens to the crops?

Richard Vollebregt: The roof systems have been designed whereby they can be operated at any point in time without regard for wind. The structures, as a general rule, are designed to be exposed to 80 MPH winds when the roof is in a closed or covered position. The roof can be retracted if you want, but our philosophy is that you spent this money to buy a structure to protect these plants and you have to be able to accomplish that objective no matter what the environment is like. If you have to retract the roof to protect the structure because of 50 MPH winds, you shouldn't buy the structure. The horizontal retractable roof systems have been in operation for the last 10 years and have never had a wind-related failure. The main reason for this is that the covering is suspended below stainless steel wires that provide support in up-lift conditions that would occur in a strong wind. The retractable roofs are controlled strictly by light, temperature, or rain.

The most important benefit, however, is that the crops will be of a more consistent, higher quality and better acclimated, which is becoming a major issue with the mass merchandisers. Not only that, if the consumers enjoy higher quality plants our entire industry will benefit.

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Bruce Briggs: How do you feel as a displayer of carefully walking the line between selling a product and providing needed information to inform growers?

Richard Vollebregt: The last thing we (sales people) need is another trade show. In order for us to sell anything we have to educate because we are trying to tell people that there are different ways of doing things. At trade shows you never get a chance to sit down and talk in detail like we were able to do here. With the understanding that this is not designed to be a commercial forum, I'm more relaxed and I think the people here are more relaxed because the focus is education. My perception is that it would be taboo for it to be anything else.

Motivating Plant Growth With Your Heating System

Jim Rearden
BioTherm Hydronic, Inc., P. O Box 750967, Petaluma, California 94975

INTRODUCTION

Plants exist in several temperature microclimates simultaneously. A microclimate is defined for this paper's purpose as a small environment that is confined by the structure of the greenhouse, the structure of the plant, and the root zone.

The primary aim of this paper is to heighten the reader's awareness of the existence of these microclimates and to outline the tools that are available today to control the temperature in each. It is essential to understand that providing the optimum temperatures to all the plant's microclimates is essential to achieving maximum quality and production.

To create a reference point for this, I suggest that you try to understand the way a specific plant evolved in nature. Very often this simple approach will yield a very good recipe for creative use of the tools that are available for this purpose. To illustrate the impact microclimate temperature control can have, I asked several growers for feedback as to what effect this approach has had on their production.

Example 1: A well known orchid grower found that, "By controlling our soil temperature at 70F with an air temperature of 63F, we were able to eradicate a major root-fungus problem, called *Pellicularia filamentosa*, that had been rampant when we only controlled air temperatures. . . "

Example 2: A cut rose grower found that, "By heating our plants from below, and letting the warmth move up through the plant, we've seen more bottom breaks, bigger heads, and much less chemical usage. . . "

Example 3: A potted foliage plant grower discovered that, "By elevating our soil temperatures above 68F we have seen much higher production and an elimination of iron chlorosis..."

All three of the growers were exercising a very simple cultural practice—they were creating temperature microclimates that mimicked the environments that their particular crops had adapted to naturally. Simply taking a step back and objectively asking yourself "If I could think like a plant, what would I want for temperature control?", may be the most important practice you could make.

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TEMPERATURE CONTROL "TOOLS"

There are basically three commercially viable ways to deliver heating energy to your crops: (1) hot air convective systems, (2) infra-red radiation systems, (3) hot water distribution systems.

Interestingly, hot water as a medium can be applied to your production facility in many different ways these include:

- Under bench or perimeter pipes
- Under bench or perimeter finned pipes
- On-bench systems
- Under floor systems
- On floor systems
- And, of course, as hot air!

Steam systems are no longer an affordable medium of heat delivery, because of high maintenance and high initial cost. Here is a reference chart that outlines the advantages and disadvantages of each system.

Advantages	Disadvantages
Hot air	
Inexpensive	Expensive to operate
Easy to install	High maintenance
Helps humidity control	Uneven distribution
Infra-red	
Energy saving	High initial cost
Dry foliage	Descending soil temps
	Even-heating can be "black magic"
	Hard to control
	Casts shadows
	Won't adapt to all potential areas
Hot Water	
Placement of BTUs very flexible	Initial cost
Combination conduction, radiation, and convection heating	Installation can be time consuming
Combustion takes place away from greenhouse in boiler room	
Not tied to any particular fuel	
Many zones in same house	

The best application of each system described above is shown below:

- Hot air—Bedding plants, freeze protection, supplemental heat
- Infra-red—cut flowers, vegetables, blooming house plants
- Hot water—propagation, bedding, holiday crops, vegetables, germination.

Keep in mind that each system has its own inherent "skills" and that your "ultimate" system may actually be a combination of systems. This may be the answer to creating ideal conditions for your specific situation. As an example, very often growers will choose a hot water system for media and plant warming from below, and install a forced air system overhead for overall air temperature, snow melting, and humidity control.

TECHNICAL ADVANCEMENTS

Technology is advancing in all heating product segments, at an increasingly rapid pace. These enhancements are being driven by a demand for higher efficiency equipment, pressures being brought to bear by environmental protection agencies for cleaner burning equipment, and the customer's desire for less frequent maintenance intervals. The enhancements include:

Hot-air systems	Separated combustion Higher efficiency Tubular heat exchangers
Infra-red systems	Temperature uniformity Reliability Corrosion problems reduced
Hot-water systems	Low-mass boilers with pressurize combustion Sealed (separated) combustion Better distribution (heat delivery) materials.

COST ANALYSIS

The three systems discussed in this paper have varying initial costs which vary according to the complexity and size of the installation. The following serves as a cost reference for systems in a 10,000 to 40,000 ft^2 greenhouse application.

Hot-air systems	30¢ to 50¢ per ft^2
Infra-red systems	\$1.50 to \$2.00 per ft^2
Hot-water systems	\$1.00 to \$2.50 per ft^2

ANNUAL OPERATING COSTS

Annual operation costs for each system vary as well. The following chart provides operating costs for systems installed in a typical northern greenhouse:

Hot-air systems	$1.00
Infra-red systems	60¢
Hot-water systems	60¢

To summarize, the tools you need are available and affordable. You can mimic almost any environment to optimize production, if you take time to research your plants actual requirements and apply the tools creatively.

POSTER ABSTRACTS

Information Available on Native Hawaiian Plants

Fred D. Rauch
University of Hawaii, 3190 Maile Way, Honolulu, Hawaii 96822

A number of extension publications have been developed to inform the public about some of the more common native Hawaiian plants. Those currently available include:

Information sheets

Plant	Publication number
Wiliwili	10
'Ohi'a lehua	11
'Akia	12
Ma'o (Hawaiian cotton)	13
Beach Naupaka	14
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Bulletin

Native Hawaiian Plants for Landscaping, Conservation, and Reforestation, Heidi L. Bornhorst and Fred D. Rauch, Univ. of Hawaii Res. Ext. Series 142. 1994.

The Eugenia Psyllid

John Kabashima and Linda Farrar
University of California Cooperative Extension, South Coast Research and Extension Center, Irvine, California

The Eugenia psyllid (*Eugenia myrtifolia*) is a pest on the ornamental shrub Australian brush cherry, *Syzygium paniculatum*. Eugenia psyllid was introduced into California from Australia in 1988. The adult females lay tiny golden eggs along the edges of the leaves. The nymphs then crawl to the underside of the leaf surface and form their characteristic pits.

Dr. Don Dahlsten from U.C. Berkeley and Dr. Donald Kent from Walt Disney collected parasites from Australia and selected *Tamarixia sp.* for release in California. The *Tamarixia* adult females deposit their eggs in the pits under the psyllid nymphs. Upon hatching *Tamarixia* larvae feed upon the mummified psyllid. Adult *Tamarixia* will live approximately 6 weeks and lay eggs in numerous psyllid nymph pits. Adults also feed on unparasitized nymphs.

Tamarixia seems to have established in several areas of California and will hopefully provide a level of control that will keep the psyllid populations from seriously damaging Eugenia foliage.

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Eucalyptus Long-Horned Borer (*Phoracantha semipunctata*)

John Kabashima and Linda Farrar
University of California Cooperative Extension, South Coast Research and Extension Center, Irvine, California,

Eucalyptus long-horned borer (ELB) was first reported in 1984. This beetle is a devastating pest of Eucalyptus plants. ELB is a native of Australia. In Australia, the beetle appears to be controlled by a complex of natural enemies that attack all life stages.

Systemic insecticides are not effective and contact insecticides are not practical because of the size of the trees. Therefore, cultural controls, such as, proper irrigation and pruning practices and the planting of resistant species are the recommended control strategies (Table 1).

Table 1. *Eucalyptus* spp. that are resistant or susceptible to the *Eucalyptus* long-horned borer.

Resistant species	Susceptible species
camaldulenses	*diversicolor*
cladocalyx	*globulus*
robusta	*grandis*
sideroxylon	*nitens*
x*trabutii* (syn. *E. rameliana*)	*saligna*
	viminalis

Drs. Tim Paine, Jocelyn Millar, and Larry Hanks (UC Riverside Dept. of Entomology) are conducting research to establish parasites in infested counties. The natural enemies of ELB are small wasps that are highly specialized parasites, but entirely harmless to other species. *Syngaster lepidus* parasitizes the larvae of the beetle. Two species of *Jarra* parasitize the larvae of the beetle. *Avetianella* *longoi* parasitizes the eggs of the beetle.

State-of-the-Art Research and Demonstration Greenhouse

John Kabashima and Linda Farrar
University of California Cooperative Extension, South Coast Research and Extension Center, Irvine, California

Suzy Sakaske
Rogers Gardens, Costa Mesa, California

In April of 1994, volunteers from University of California Cooperative Extension, the nursery industry, Orange Coast College, and the greenhouse manufacturing and supply industry helped remodel an existing greenhouse at the South Coast Research and Extension Center (SCREC). State-of-the-art features include: rolling benches, ebb and flo benches, positive-pressure coolers, and starfin radiant heat systems.

Complex experiments, such as the effects of different fertilizer rates and irrigation regimes on the growth of New Guinea impatiens, are made possible by the computer software's capabilities to monitor, log, and control all aspects of the greenhouse and its environment. The QCOM computer uses inputs from various sensors to operate the cooling, heating, and retractable shade systems. Tensiometers are used to monitor soil moisture tension, and sensors monitor light, humidity, and temperature.

The Center for Urban Horticulture: An Overview of its Academic and Affiliated Programs

Barbara Selemon
University of Washington, Center of Urban Horticulture, GF-15, Seattle, Washington 98195

The poster lists the various facilities and the significance each provides to the Center for Urban Horticulture, a division of the University of Washington Campus in Seattle.

Facilities listed:

Douglas Research Conservatory
Ecological Research Area
Entry Shade Garden
Marilou Goodfellow Grove
Elisabeth C. Miller Horticultural Library
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Douglas Hyde Hortorium

The Center offers academic programs to undergraduate as well as graduate students. Pamphlets provide specific information on the following programs:

Bachelor of Science (B.S.)	Forest Resources (Urban Forestry)
Master of Forest Resources	Urban Horticulture
Master of Science	Urban Horticulture
Doctor of Philosophy	Urban Horticulture

Additional pamphlets provide specific course information:

Urban Forestry Curriculum in College of Forest Resources and Academic Courses in Urban Horticulture, Ecology and Forestry, 1994-1995.

Research programs in wetland ecology, natural land restoration, genetic plant evaluation, and plant-people relationships are also being conducted at the Center for Urban Horticulture by various research faculty.

Public outreach programs are offered to the community from beginning gardeners to those in the professional industry. In addition to the quarterly newsletters of *ProHort* and *Urban Horticulture Presents*, which provide program information and schedules. Public Outreach conducts courses, lectures, seminars,and symposia.

Wastington Park Arboretum is a 200-acre site managed cooperatively by the University of Washington's Center for Urban Horticulture, City of Seattle's Parks and Recreation, and the Arboretum Foundation, which is a private, non-profit organization giving support in various arenas to the arboretum.

Myoga Ginger Production in New Zealand

J. M. Follett
New Zealand Institute for Crop and Food Research, Ruakura Agricultural Centre, Private Bag 3123, Hamilton

INTRODUCTION

Myoga (*Zingiber mioga* Roscoe) is a member of the ginger family and a native of Japan. It is grown commercially for the spring shoots and subterranean flower buds it produces in autumn. Myoga flower buds (often called hanamyoga) are used in soups, tempera, pickled, and as a spice with tofu or bean curd. The young shoots are used mainly for making soups (Follett, 1986). Production is strongly seasonal and as a result high quality shoots and flower buds supplied out of season can fetch high prices on the Japanese markets. In order to take advantage of these high prices, a number of New Zealand growers are in the early stages of myoga production. Their first commercial crop of flower buds will be available for export in late Summer and early Autumn 1995. Currently there is little interest in the production of myoga shoots for export.

PRODUCTION CYCLE

Although not botanically related, myoga has a similar production cycle to asparagus. Both crops overwinter as underground rhizomes with spears emerging in early September (spring in New Zealand) when soil temperatures start to rise. The shoots continue to grow during the spring until the foliage is 1.0 to 1.5 m tall. In midsummer, subterranean flower buds start to form. In the Waikato, the buds are ready for harvest in late February If allowed to develop, the buds appear at ground level, producing an attractive carpet of pale yellow petals in early autumn. After flowering, the foliage senesces and is killed by winter frosts.

SOIL

Myoga prefers a well-drained, friable soil. Soil prone to water-logging will reduce myoga production and increase the incidence of root disease (Douglas and Follett, 1992). The free-draining, silt loam soils of the Waikato region, derived from volcanic ash, have proved ideal.

CLIMATE

Myoga prefers an equitable climate with warm summers and cool winters. Excessive wind can cause lodging of the foliage in late summer which can hamper harvesting, while insufficient soil moisture during bud formation can reduce bud size. The winter must be cool enough to ensure that the plant goes into winter dormancy. Without a winter dormancy period, flower initiation appears to be erratic and random. Myoga would probably grow over most of New Zealand, however, the far north may have insufficient winter chilling for commercial production, and in colder areas out of season frosts could decimate leaf growth. Most commercial development is taking place in South Auckland, the Bay of Plenty, and the Waikato. Myoga has also been successfully grown in Canterbury in the South Island.

SHADE

In New Zealand, myoga will not grow without shade. If grown in full sun, the leaves become chlorotic, then bleached, before finally dying. Fifty percent shade is generally recommended for good growth (Douglas and Follett, 1992).

PROPAGATION

Myoga can be propagated by root cuttings or tissue culture. Root-cutting production has to date been the only means of commercial propagation in New Zealand. Rhizomes are lifted in winter, washed and divided into 20 cm lengths, with each length containing at least two nodes. The root cuttings are then dipped in a fungicide and cool-stored at approximately 4C for a minimum of 6 weeks (Follett, 1991). At no stage should the cuttings be allowed to dry out, with exposure to the sun at any time likely to affect plant survivals.

PLANTING

Planting should be carried out in early spring, directly from cool storage, or from established beds. In wet seasons or with irrigation, plantings as late as December have been successful. Cuttings are lined out at the base of 10- to 15-cm deep trenches or furrows. Alternatively, for small areas, cuttings can be individually planted with a spade. Myoga can be planted in beds or rows. As the plant spreads radially, it soon grows into vacant areas. At Ruakura, we have recommended that plants be spaced 40 cm apart in rows 1.5 m apart to allow for this expansion. By the second season the rows are continuous while still allowing pickers access between rows.

PESTS AND DISEASES

Compared to many horticultural crops, myoga has to date appeared relatively pest and disease free. Rhizoctonia rot on flower buds has proved to be a minor problem, while greasy cutworm can damage young shoots emerging in the spring. Wet ground rots have also been a problem when the myoga has been grown in poorly drained soils. By far the most debilitating problem in terms of reducing yields has been cucumber mosaic virus. This ubiquitous virus is spread by aphids from weeds in waste areas. Infected plants must be destroyed, with crop hygiene being the main control method.

WEED CONTROL

Myoga is a vigorous crop and once established has few major weed problems. All perennial weeds, particularly rhizomatous grasses and broadleaf weeds, should be controlled before the crop is established. This can be followed after planting, with a pre-emergent herbicide to control annual weeds. Once the crop is established, a winter clean-up (desiccant) spray followed by a pre-emergent herbicide and mulching required for the production of high quality flower buds will control most weeds.

CROP MANAGEMENT

Mulching. Mulching is an essential part of crop management, as it keeps the developing flower buds clean and prevents the buds turning green. It also helps reduce weeds and conserve soil moisture. In Japan, rice husk straw is commonly used, but New Zealand growers have used sawdust and wood shavings. Research at Ruakura comparing barley straw and sawdust found significant yield increases from using sawdust. Indications from this research also suggested that a 20-cm compared to a 10-cm deep mulch is preferred. The mulch is applied in the winter when the crop is dormant.

Fertiliser. There is little indication that myoga requires high rates of fertiliser, although few trials have been carried out in New Zealand. Conversely, anecdotal evidence indicates that excessive nitrogen promotes foliage growth at the expense of flower production. Research at Ruakura, evaluating phosphate fertiliser rates, found no differences in flower production. Current recommendations are that unless there is a known soil nutrient deficiency, fertiliser rates should be conservative, especially with regard to nitrogen.

Vigour Control. In northern New Zealand, the growth of myoga is vigorous. The plant expands radially with most flower production occurring where the plant is expanding. If left untended, plants quickly grow into one another, reducing the ease of access for harvesting.

Controlling this vigour is seen as a major problem for the New Zealand industry. Possibilities include both mechanical and chemical thinning.

Harvesting. In the Waikato, myoga flower buds can be first detected in late January and early February. The buds continue to increase in size until the end of February. From about early March on, the mature buds start to produce petals and become unmarketable. Harvesting is carried out by fossicking through the mulch until harvestable buds are found. They are then plucked by snapping the stem. Research has shown that buds with a minimum diameter of 15 mm will have reached a marketable size of at least 6 g.

Research indicates that yields of between 6.0 to 13.0 t/ha are possible, depending on the age of the plant material and management practices.

MARKETING

Horticultural Export Authority (HEA). A Myoga Product Group, under the auspices of the HEA, has been established. This product group, controlled by growers, has been established under New Zealand law to control and regulate the efficient export of the crop. Funding for the group is achieved by levies imposed on growers. Growers are required to be registered to grow this crop for export.

Grade Standards. Among the responsibilities of the Myoga Product Group is the establishment of grade standards. Currently a myoga flower bud suitable for export must be larger than 6 g and be mostly rouge in colour with no more than 20% of the bud green. The stem should be no more than 10 mm long and inflorescence or petals must not be present. The buds must also be clean, fresh, turgid, free of disease, and capable of attaining a phytosanitary certificate.

Transport. Although myoga flower buds have a reasonable shelf life, common sense management precautions should be taken. Field heat should be removed from the buds as soon after harvesting as possible, with cool storage at all stages from farm gate to market. Currently the only transport option from New Zealand to Japan is airfreight.

CONCLUSIONS

Myoga flower bud production is a very new industry to New Zealand, established to provide product during the Japanese off-season. It is seen as a small niche market that could easily be destroyed through oversupply. The Myoga Product Group regulates the production and supply of myoga to the market. At present, it is not known how large the market is for off-season production.

Myoga production in Japan is an old industry carried out on small family plots. In New Zealand the industry tends to be on a larger scale, with many of the traditional production techniques being unsuitable in the New Zealand context. Research by both growers and Crop & Food Research is ongoing.

It is an exciting beginning, with trial plantings establishing and growing well, but the long-term viability of the industry will depend on the market, and the ability of New Zealand growers to adapt Japanese small-scale farming techniques to their own circumstances.

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Closed, Plant-Production System—Update

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Since initiation of the research in 1990, diverse plants from 42 families (68 genera, 72 species) have been grown in the closed, insulated pallet system (CIPS). Greater growth has occurred in various embodiments of the plant-driven CIPS than in the open container system (OCS) control. Branching of roots, and of shoots of some plants, is greater in CIPS. *Phytophthora cinnamomi,* a plant root pathogen, does not spread from inoculated to noninoculated root pouches in CIPS. In the greenhouse, tomato plants are more tolerant of saline irrigation water, and production is more profitable in CIPS than in the OCS.

INTRODUCTION

The closed, insulated pallet system (CIPS) is a low-maintenance, resource-conservative production system. Description of the CIPS, methods of plant production in

CONCLUSIONS

Myoga flower bud production is a very new industry to New Zealand, established to provide product during the Japanese off-season. It is seen as a small niche market that could easily be destroyed through oversupply. The Myoga Product Group regulates the production and supply of myoga to the market. At present, it is not known how large the market is for off-season production.

Myoga production in Japan is an old industry carried out on small family plots. In New Zealand the industry tends to be on a larger scale, with many of the traditional production techniques being unsuitable in the New Zealand context. Research by both growers and Crop & Food Research is ongoing.

It is an exciting beginning, with trial plantings establishing and growing well, but the long-term viability of the industry will depend on the market, and the ability of New Zealand growers to adapt Japanese small-scale farming techniques to their own circumstances.

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INTRODUCTION

The closed, insulated pallet system (CIPS) is a low-maintenance, resource-conservative production system. Description of the CIPS, methods of plant production in the CIPS, and past research are described in several publications (Blackburn, 1992; Briggs and Green, 1991; Green and Briggs, 1992; Green et al., 1993; Hayter, 1992; Hughes, 1992; Kaplan, 1992; Roberts, 1991; Wijchman, 1991). The following is an update of research not previously reported.

RESEARCH UPDATE

Intermixed Plants in Plant-Driven System. Growth of diverse plants from 42 families (68 genera, 72 species) has been better in CIPS than in OCS. In several experiments, plants with diverse water and fertilizer requirements and growth rates were planted in the same root pouch or in individual root pouches within the same pallet. Growth of plants sharing common water and fertilizer reserves in CIPS was comparable or greater than that of plants in individual OCS. In the "trough" experiment, planted in Sept. 1992 at Briggs Nursery, increases in height and stem diameter of cutleaf European birch, *Betula pendula* 'Laciniata', with 3-liter root-media volume were greater in CIPS than in OCS—90 cm height and 1.3-cm stem diameter in OCS and 124 cm height and 2.2-cm stem diameter in CIPS on 28 June 1994.

In CIPS, after water adsorption on root medium particles and filling of capillary pores has reached equilibria, further flow of water from the underlying reservoir and from the medium, is in response to plant root uptake to support growth and transpiration. Water-flow upward from the reservoir is plant driven to meet that plant's specific requirements. Water in the plant-root medium is moved upward into the medium from the water reservoir. It is held in the medium by adsorptive and capillary forces that are greater than the force of gravity. There is no downward gravitational movement of water through the fertilizer or root medium to the water reservoir in the pallet base.

Fertilizer moves downward from the fertilizer reserve on the top surface of the media by chemical diffusion. Plants within the same pouch share a common fertilizer reservoir at the top surface of the media. Rate of movement of fertilizer to the roots of the individual plants is related to the rate of fertilizer uptake by each root. Fertilizer diffusion rate increases as plant uptake causes an increased gradient between the fertilizer reservoir and the plant root surface.

Because of the plant-driven movement of water from the basin reservoir and plant-driven increase in movement of fertilizer from the fertilizer reservoir at the top surface of the medium, large quantities of fertilizer and water may be added to the reservoirs at the grower's convenience. For example, a quantity of water adequate for a year or more can be placed and stored in the pallet reservoir when water is readily available. Also, a quantity of coated fertilizer could be placed and stored in the fertilizer reservoir once or twice a year.

The plant-driven increase in movement of fertilizer and water in the CIPS enables intermixing plants with different growth rates (different water and fertilizer requirements) within the same planting pouch or pallet. The uptake rate of each individual plant will affect the rate of diffusion of water and fertilizer from the reservoirs to that plant's roots.

Plant Growth and Development. Growth and branching of roots, and in some cases of shoots, of plants grown in CIPS in pouches having an inner surface coating of copper hydroxide, is greater than that of plants grown in OCS. For example, 220 days after *Photinia* ×*fraseri* 5.7-cm liners, were planted into CIPS and OCS, plant shoot gdm (75.3 gdm/CIPS, 46.8 gdm/OCS), shoot height (153 cm/CIPS, 98 cm/OCS) and shoot branching (4 branches/CIPS, 0 branches/OCS) were significantly greater in CIPS than in OCS. Similarly, 90 days after *Daphne* ×*burkwoodii* 'Carol Mackie' liners were planted into CIPS and OCS, shoot dry weight was significantly greater for plants grown in CIPS (3.3 gdm/CIPS, 1.39 gdm/OCS). Greater shoot branching in CIPS may be due to warmer root temperatures and a more positive difference between the root and shoot temperatures (DIFRS) in CIPS than in OCS. Several researchers have reported increased numbers of axillary shoots of unpinched plants when root temperatures are warmer than shoot temperatures (McAvoy, 1992; Merritt and Kohl, 1982; Wulster and Janes, 1984). Further research on effect of DIFRS on growth and development of various plants is planned. Equal or greater plant response may be attained with warm root temperatures within the closed, insulated pallet and lower greenhouse air/shoot temperatures. If so, then significant reductions in energy expenditures for greenhouse heating will be realized.

***Phytophthora cinnamomi* does not Spread Within CIPS.** The potential for spread of *Phytophthora cinnamomi* (root rot) from pouch-confined, inoculated root systems to noninoculated roots of plants sharing a common water reservoir in pallet base was evaluated.

Phytophthora cinnamomi inoculated and noninoculated plants were grown in root pouches with or without an inner surface coating of copper hydroxide. At the end of the experiment, *P. cinnamomi* was recovered from inoculated but not from noninoculated plant roots nor from the common water reservoir. The copper hydroxide interface was not the factor preventing spread of *P. cinnamomi* from inoculated to noninoculated root pouches. The lack of movement of *P. cinnamomi* from one plant to another in CIPS is attributed to the lack of movement of water from one pouch to another. In CIPS, water movement is always upward from the water basin into the root medium and there is no splashing.

Tolerance of Saline Water in CIPS. In order of importance, the greatest differential incidence of blossom-end rot (BER) was related to genotype (45% BER/variety 1; no BER/variety 2) followed by salinity (50%/saline irrigation; 31%/nonsaline), nitrogen form (45% BER/ammonium fertilization; 33%/nitrate), and production system (45%/OCS; 38%/CIPS). Plant growth (plant shoot gfw) was most affected by the production system (359 gfw/CIPS; 187 gfw/OCS) followed by water salinity (386 gfw/nonsaline; 266 g fresh wt/saline). In looking only at growth of the 'Santiam' tomato cultivar, greatest growth and yield and least BER occurred in CIPS with nonsaline water.

Plant growth and yield and BER incidence in CIPS with 4500 ppm salinity irrigation water were not significantly different from that of OCS plants irrigated with nonsaline water. When 4500 ppm salinity irrigation water was used in both CIPS and OCS, significantly greater yield and less BER occurred in CIPS compared with OCS. CIPS is more amenable than OCS to use of saline irrigation water. Additional research using salt-tolerant tomato rootstocks and using halophytic companion plants in the same pouch with the tomato plant is planned. The halophytes that will be evaluated remove salt from the container media and store it in shoot and leaf tissues.

Cost analyses and sensitivity analyses of the contemporary Dutch greenhouse nondeterminant tomato production system, and the proposed greenhouse determinant tomato production in CIPS, with one-time harvest/crop cycle were done by Strik et al. (1993). In CIPS, three crop cycles (110 to 120 days/cycle) or harvests occur annually per given pallet with continuous planting and harvesting of pallets occurring throughout the year. The CIPS was less sensitive to changes in fruit market price, labor costs, and interest rates and was over seven times more profitable.

CONCLUSIONS

Research has established the economical and technical feasibility of CIPS as an alternate system for outdoor production of container-grown nursery plants and for greenhouse tomato production.

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Selection and Evaluation of Native Plants

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New Zealand's nursery people have the good fortune to be surrounded with a unique and varied flora. This flora, separated by the oceans for the past 100 million years, give this country a distinct character and a wealth of material to be discovered and enjoyed. This uniqueness is in part a result of the vast range of landscapes and climates—from alpine tundras to swamps, volcanic landscapes to humid coastlines—found in a relatively small country. Just imagine the awe and wonder those first botanists felt as they ventured through kahikatea forests (*Dacrycarpus dacrydioides* syn. *Podocarpus dacrydioides*), discovered the pohutukawa (*Metrosideros excelsus*), nikau palms (*Rhopalostylis sapida*), and the hundreds of other species that make up our landscape. Apart from attempting to keep body and soul together, and perhaps earning a living, native-plant nursery people can find much of their motivation from the joys of handling such a marvelous and unique range of plants. Propagation of these plants has ensured that we do not lose species, as their habitats are manipulated and lost. New habitats, however, occur in local gardens, parks, and reserves. The pace of discovery of new species may have slowed down over the last century, but our natives are still evolving and changing in response to their environment. The plant propagator, as a multiplier of plants, has a huge responsibility to maintain and strengthen the genetic quality of the natives they grow. When sourcing seed the form and features of the parent plant should be studied, the same goes for propagation by cuttings. Is it true to type? Is it a male or female form? Is the vigour, flower quality, and leaf form the best available? Strengthening the forms we grow now is important, but we can also take advantage of the continual evolution of our plants to have the excitement of discovery of a new form.

At C. H. Simpson Nurseries in Nelson, Cam Simpson has been growing New Zealand natives for the last 37 years. Inspired by the beauty and range of our landscape and flora, Cam has brought into production many plants that may have been otherwise lost and never appreciated. Cam has also striven to uplift the genetic quality of the natives he grows. Part of this is seeking new forms that will be an improvement on those already grown. It was with this need in mind that Cam started looking for an improved green-leaved *Pittosporum tenuifolium*. This shrub has many cultivars of various colours and shapes. The species type is propagated by seed. One batch of seed from New Plymouth gave eight plants that showed interesting forms. Propagating these by cuttings, growing them on both in the nursery and in a variety of garden sites, Cam began the evaluation process. Is this form stable and distinct? Does it maintain the vigour of the parent type? Is it prone to pest and disease attack? Many factors need consideration to eliminate all but the best forms. The results of this evaluation were the introductions, 'Waimea', 'Wai-iti', and 'Wairoa', named after local rivers. All three have a dense bushy shape and respond well to trimming. 'Waimea' has a fresh lime-green appearance, leaves smaller than the type but held on bright green stems. 'Wai-iti' has foliage with a larger leaf and a stronger green color and reddish-brown stem. 'Wairoa' has darker, glossy foliage and a more open habit.

Lophomyrtus ×*ralphii* 'Pixie' and 'Lilliput' were also chance seedlings. The seed, most probably a cross between *L. bullata* and *L. obcordata,* was collected from a garden near the nursery. Two of these seedlings had a particularly dwarf form and were grown on over the next 4 years and evaluated as to their merits. They performed well and were subsequently named 'Pixie' and 'Lilliput'. 'Pixie' makes a compact dwarf bush to 20 cm, with small mahogany coloured leaves. 'Lilliput', a larger growing form to 70 cm, has wine-coloured, rounded leaves.

A wildling of *Carpodetus serratus* also showed unusual form. Instead of the usual upright growth, in which the branches grow in flattened tiers, this seedling stayed low growing and spread out sideways. This makes an interesting shrub, however, evaluation will not be complete until this juvenile form reverts to its adult state.

Elaeocarpus hookerianus 'Moana', another juvenile form, was selected for its highly attractive foliage with unusual glossy brown leaves. Normally a seldom asked for native, propagation of this interesting form has led to many more plantings of this tree.

Lophomyrtus ×*ralphii* 'Matai Bay' was discovered while Cam was taking a break from the rigours of fishing in the Marlborough Sounds. A walk into the bush at Godsiff Bay revealed a particularly large-leaved form of *L. bullata.* This has maintained its size and colour through evaluation.

Extremes in the environment put pressure on a plant to evolve. The hunt for dwarf forms can often begin in windswept places where the low-growing survive well. Evaluation is important in these cases as the plant may revert away from its dwarf form once placed in a sheltered, fertile site.

Leptospermum scoparium is a shrub that hybridises freely and has many colourful forms. From seed sourced at Pillar Point at the base of Farewell Spit, Cam selected a prostrate manuka that maintains its compact weeping habit. The white flowers in summer are only part of its charm, fresh, green leaves that maintain their vigour throughout the year are another.

Looking for a plant in its preferred habitat can reveal gems. *Pseudowintera colorata* is a shrub found from the Mamaku Plateau in the north, to Stewart Island in the south. The green foliage is flecked with purples and reds. Again on the hunt for a better form, Cam went to the Ellis Basin at the base of Mount Arthur in northwest Nelson. *Pseudowintera* thrives in the limestone rock and sheltered aspect on the eastern side of the basin. Cuttings were taken from several particularly dark-red forms from which an outstanding type, now known as 'Winter Fire', emerged. By catching the eye of the customer, we can stimulate interest in planting New Zealand natives.

Seedling grown natives are important for the diversity that they give, and often the ease of propagation. However, in the case of *Clematis indivisa* (syn. *C. paniculata),* a stunning spring-flowering climber, by propagating cutting-grown male forms, the quality and size of the flower is improved.

Each distinct form that is found may, eliminate another lesser form in the market, add to the variety of recognised plants, or be superseded and never seen on a trade list. The evaluation of nursery plants is a perpetual, ongoing task.

To survive and make a living in the industry, the nursery person is called on to perform many roles: a marketer, accountant, mechanic, and lawyer. However, the role of the plants person is critical to the industry. The range and quality of plants we grow must only ever improve. The heart of this profession, should always be to appreciate and share our landscape and flora.

Propagation of Radiata Pine Plants for Plantation Forestry

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Bareroot seedlings of radiata pine (*Pinus radiata* D. Don) are the main planting stock used in New Zealand at present. These are produced using open-pollinated seed from clonal seed orchards. Control-pollinated seed of the best progeny-tested families is also now being commercially produced. However, since this seed is expensive and still in short supply, vegetative propagation methods have been developed to amplify available planting stock.

Many tree nurseries grow rooted cuttings, either using juvenile stool beds to raise cutting material or making field collections of cuttings from young plantation trees. Stool-bed cuttings are more expensive to produce than seedlings, if the cost of seed is ignored, because of the cost of maintaining the stool beds and of manual collection and setting. Currently, however, the high cost of control-pollinated seed makes stool-bed cuttings cheaper to produce than seedlings. Improvements in stem form have been demonstrated with cuttings compared with similar genetic quality seedlings, particularly with field-collected cuttings planted on fertile farm sites. This has created a demand for field-collected cuttings, even though they cost nearly double the price of stool-bed cuttings.

One New Zealand company is using micropropagation to produce plantlets for establishing clonal plantations, and embryogenesis technology is being evaluated by another company. Currently, these technologies are expensive, but can give high multiplication rates, and also have the advantage that juvenility can be maintained by cold storage or cryopreservation during clonal field testing.

Integration of these tree improvement and propagation technologies is allowing New Zealand to advance towards clonal forestry with radiata pine.

INTRODUCTION

The area of plantation forest in New Zealand now exceeds 1.3 million ha. The planting rate has varied over the years, with planting booms in the late 1920s, early 1930s, 1960s, 1970s, and 1980s (Ministry of Forestry, 1993). The rate of new planting decreased in the late 1980s due to increased land values, the sale of state forest assets, and taxation changes. However, new planting has since increased again, and the area of new forests planted in 1994 probably exceeded 100,000 ha.

Radiata pine has been the main species planted, followed by Douglas-fir, hardwoods, and other softwoods (Table 1). This general trend is expected to continue, although there is increased interest in Douglas-fir, eucalypts, cypresses, and acacias.

Plantations have traditionally been established using seedlings raised in bareroot nurseries. For radiata pine, sufficient seed for New Zealand use is produced in seed orchards, while for other species, most seed is collected from seed stands or imported. More than 7000 kg of open-pollinated radiata pine seed was collected from seed orchards in 1993 (Vincent, 1993). A limited quantity of better genetic quality seed is produced by control-pollination amongst the best progeny-tested families in the breeding programme, but the amount available is less than 5% of the total seed collected (Vincent, 1993). This seed is also very expensive, and so vegetative propagation methods have been developed to amplify plant numbers, so that a larger forest area can be planted with this superior material. There are a number of amplification options available, which differ in multiplication rate, time required to produce planting stock, and cost (Menzies et al., 1985a). Cutting options available include both the use of juvenile stool beds to raise cutting material and field collection of cuttings from young plantation trees. These methods are used by a number of nurseries in New Zealand to produce more than 10 million cuttings annually. Another option is to use micropropagation (Horgan and Aitken, 1981; Aitken-Christie and Thorpe, 1984; Smith, 1986), and one company in New Zealand is using this technology to produce up to 3 million plants annually, as well as using cuttings (Gleed, 1991). Embryogenesis is a more recent technology and methods developed at New Zealand Forest Research Institute (NZ FRI) are now being evaluated in pre-commercial production by a New Zealand forest company. These techniques will be discussed in this paper.

Table 1. Area of stocked exotic forest in New Zealand as at 1 April 1992.

	All estate area (ha)	%	Age class 1-5 yr
Radiata pine	1,176,539	90	93.0
Douglas-fir	66,625	5	3.4
Other softwoods	38,717	3	0.7
Hardwoods	25,760	2	2.9
Total area	1,307,641	100	100.0

Source: Ministry of Forestry (1993)

PRODUCTION OF BARE-ROOT SEEDLINGS

Most seedling crops in New Zealand are raised as 1-year-old crops, with seed being sown in spring (Oct.-early Nov.) and the seedlings being lifted the following winter (June-Aug.).

The two most critical aspects affecting quality of nursery-grown seedlings are spacing in the nursery bed and conditioning by root pruning. Nursery machinery has been developed in New Zealand to mechanise these aspects and ensure that high quality plants can be reliably produced (Menzies et al., 1985b). Spacing is controlled by use of a precision vacuum-drum seed sower, while root conditioning is done with an undercutter/wrencher and a lateral root pruner. The undercutter/wrencher is used to cleanly sever the taproots in summer at a depth of 10 cm. This encourages lateral root growth while slowing down top growth. A wide tilted blade on the undercutter/wrencher is used subsequently at monthly intervals to break off any sinker roots growing down below the undercutting depth and at the same time aerating the soil. Lateral roots growing across the rows are severed by the rolling coulters of a lateral root pruner once or twice during the wrenching period. This conditioning concentrates new root growth close to the seedling root collar and results in a "balanced" seedling in terms of root to shoot ratio.

Other machinery includes equipment for distributing solid fertiliser accurately between the rows of seedlings and boom sprayers for application of liquid fertilisers, herbicides, fungicides, and insecticides.

This mechanisation means that all nursery operations can be done from the back of a tractor except for the final lifting operation, where hand lifting is preferred.

Lifting and handling practices now include careful hand lifting to minimise root damage, and trimming of lateral roots to 10 cm long. Roots are kept moist by spraying or dipping them in water. Seedlings are packed into rigid containers on the nursery bed, rather than in a packing house, to avoid prolonged exposure. Packing seedlings on their sides prevents tap root damage. The cardboard containers act as storage containers, and also planting boxes out in the field, so the seedlings are not exposed from the time of lifting until they are planted. Seedlings should be stored for no more than 72 h at cool temperatures (2C to 4C).

PRODUCTION OF STOOL-BED CUTTINGS

Production of stool-bed cuttings has been described by Menzies, et al. (1985a) and Dibley and Faulds (1991). Seed is sown as early in the spring as possible. Stock plants are topped in Feb., when they are 4 to 5 months old. The side shoots subsequently develop into stem cuttings, with an average of four cuttings per plant. In subsequent years, the hedged seedlings are topped with a hedge trimmer in late spring, at a height of between 100 mm and 300 mm. Stock plants have been maintained for up to 5 years at the NZ FRI nursery.

Cuttings from stool beds are generally set in raised beds for the production of bareroot plants. They are collected and set in early to mid-winter. The optimum cutting size is 70 to 100 mm in length and >3 mm in diameter. No rooting hormones are required. Smaller cuttings can be set but, because they may be subject to frost lift and soil splash, are best protected with 30% shade cloth.

Cuttings wilt after setting and need irrigation in hot dry conditions. They recover within 4 weeks and begin to gain height and elongate in spring before rooting in early summer. Commencing in mid-summer, the cuttings are conditioned by undercutting, wrenching, and lateral root pruning. The rooted cuttings are ready for planting in winter, 1 year after setting. A yield of at least 80% acceptable plants can be expected.

FIELD-COLLECTED CUTTINGS

Production of field-collected cuttings has been described by Menzies et al. (1985a). Cuttings can be propagated readily from 3- to 4-year-old radiata pine trees in the forest. Plantations suitable for cutting collection have been established with seedlings from special seedlots from the best open-pollinated seed orchard clones (Arnold and Gleed, 1985) or from control-pollinated crosses. Collection from field trees also allows some selection of vigour and form of the parent tree. Tips of lateral branches with a length between 100 and 150 mm, a minimum diameter of 6 mm, and dense, fully-elongated, healthy needles are collected.

The cuttings are collected and set in early winter during the period of slowest growth, and before the photoperiod starts to lengthen. They are set outside at a depth of 5 cm in raised nursery beds. Overhead irrigation is necessary during warm or dry windy weather, particularly during the first few weeks after setting.

Rooting of field-collected cuttings occurs in spring, a little later than with stool-bed cuttings. Slightly fewer will root successfully, with about 75% forming acceptable root systems.

In trials, field-collected cuttings have performed as well as or better than seedlings of similar genetic quality. On fertile sites, cuttings have shown similar growth rates, but better form than seedlings, providing the physiological age of donor trees has been less than 5 years old. These differences have shown up especially with cuttings taken from donor trees aged 3 years or more, but also with cuttings from stool beds (Fig. 1). The better form of cuttings from field-collected plantations has led to an unsatisfied demand for this type of planting stock.

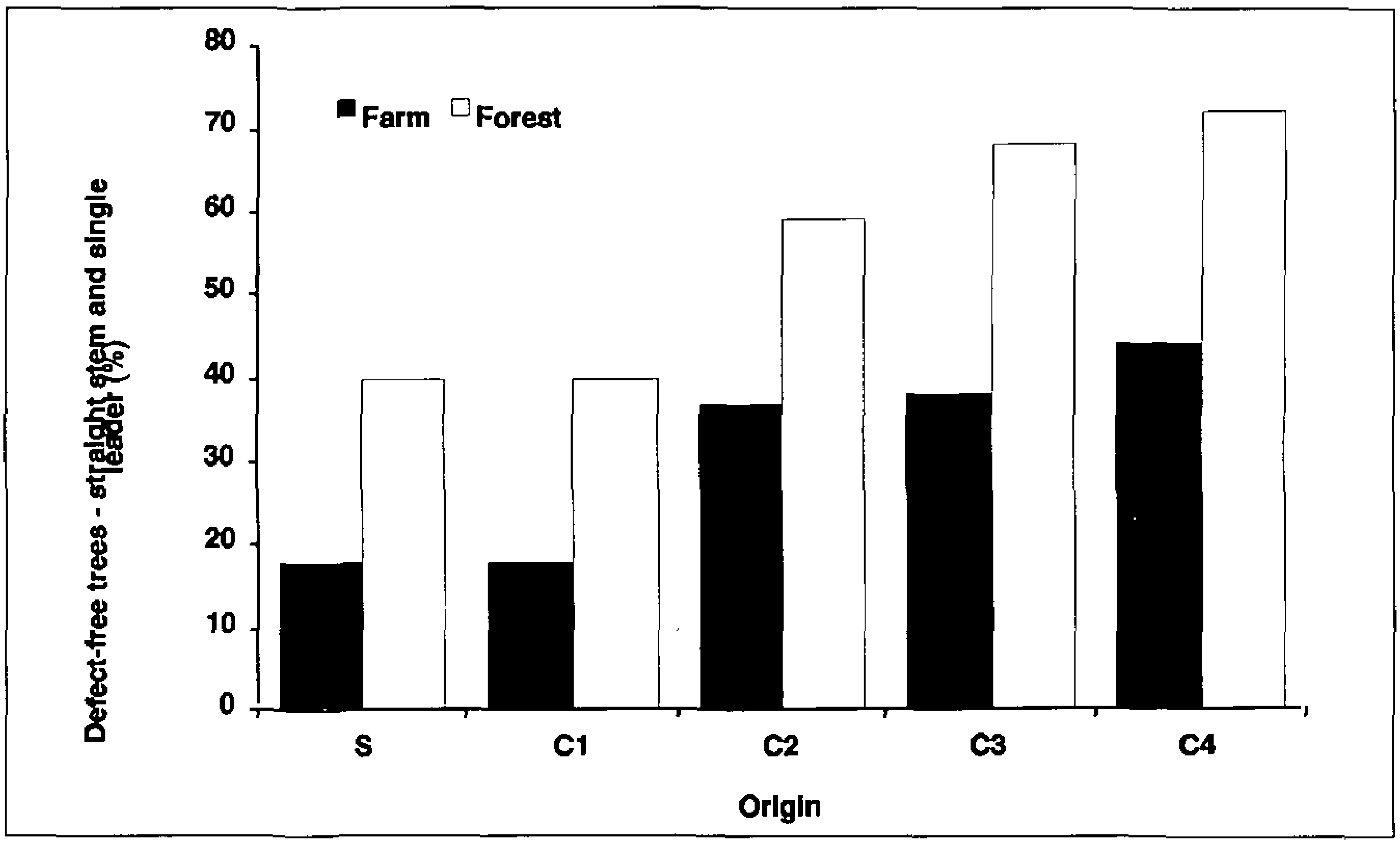

Figure 1. Percentages of defect-free trees at the low pruning stage grown from (a) cuttings from 1- to 4-year-old parent trees and (b) seedlings, on farm and forest sites (Menzies et al., 1991). S = seedling; C1 = cutting from 1-year-old donor tree; C2 = cutting from 2-year-old donor tree; C3 = cutting from 3-year-old donor tree; C4 = cutting from 4-year-old donor tree.

JUVENILE MICROPROPAGATION (ORGANOGENESIS)

While macropropagation methods require the use of large pieces of tissue, micropropagation employs very small plant parts, tissues, or cells. Micropropagation methods include induction of adventitious buds on cultured cotyledons and entire embryos, induction or stimulation of adventitious or axillary buds on cultured shoot tips, regeneration of adventitious shoots and complete plants from unorganised callus and cell cultures, or outgrowth and division of the seedling shoot (epicotyl).

Micropropagation methods have been developed for a variety of radiata pine explants, including embryos, cotyledons, and seedling shoot tips (Horgan and Aitken, 1981; Aitken-Christie and Thorpe, 1984; Smith, 1986). There are four main stages: shoot initiation, shoot elongation, shoot multiplication, and rooting. Tissue is kept sterile through all stages except the last, and is grown in containers on an agar medium containing all the necessary nutrients, hormones, and other substances to support growth. The containers are kept in a controlled environment with artificial lighting. When the shoots are large enough, they are given a hormone treatment to stimulate rooting and set as small cuttings in containers in a greenhouse to form roots. After rooting, they can be lined out in a nursery bed and grown on like seedlings or cuttings (Menzies et al., 1985a).

Tissue-cultured plantlets are currently expensive to produce for two reasons: transfers to fresh media are done manually and the plantlets need to be grown in sterile controlled conditions.

EMBRYOGENESIS

Another propagation technology which is being developed is embryogenesis. Embryogenic cell lines are established from immature seed, and millions of immature embryos of individual genotypes can be multiplied from each seed. These embryos will develop and mature under appropriate conditions, and then can be germinated like natural embryos. The efficiency of this process needs further improvement, but the technology has the potential to produce unlimited quantities of embryos of desirable genotypes, at costs cheaper than current control-pollinated seed prices.

DISCUSSION

There is a wide variation in multiplication rate, time taken to produce planting stock, and cost of the various methods of vegetative propagation. For example, a kilogram of seed will produce enough seedlings to plant approximately 18 ha of

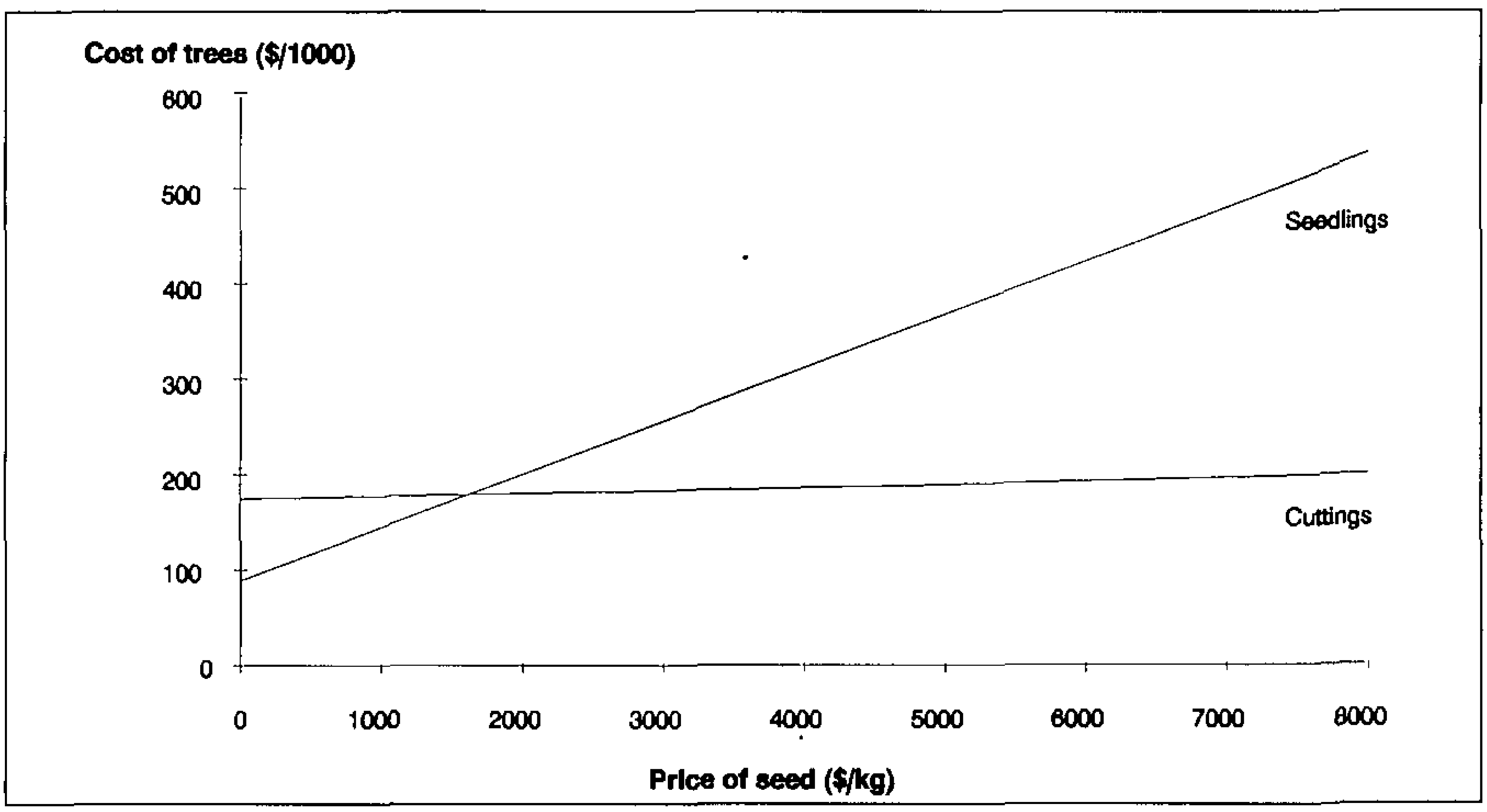

Figure 2. Effect of varying seed prices on the growing cost of seedlings and cuttings (adapted from Dibley and Faulds, 1991).

forest, while the same amount of seed will produce enough cuttings for 360 ha, and enough tissue-cultured plantlets for 3600 ha. However, cutting stool beds will take about 2 years to develop sufficiently to produce this number of cuttings, and a similar laboratory time would be needed for tissue-cultured plantlets.

The approximate growing costs for different options are shown in Table 2. The difference in production cost for open-pollinated and control-pollinated seedlings is the cost of the seed. Disregarding the cost of seed, stool-bed cuttings cost 1.5 to 2 times more than seedlings to produce. However, when the cost of control-pollinated seed is included, stool-bed cuttings of equivalent quality are cheaper to grow. The price of control-pollinated seed has exceeded $6000/kg for the last 2 years and would need to decline to about $1600/kg before seedlings become cheaper to grow than the stool-bed cuttings (Fig. 2).

Table 2. Comparison of growing costs of nursery plants (1994-95).

Stock type	Cost (NZ$)/1000 plants
Seedlings (open-pollinated seed)	110
Seedlings (control-pollinated seed)	460
Cuttings from stool beds (control-pollinated seed)	200
Cuttings from field collections	370
Micropropagated plantlets	~700[1]
Cuttings from plantlets	220

[1] Based on Gleed (1993).

Field-collected cuttings are expensive because of the extra costs involved with travel and collection time from plantation trees, and the lower rooting success. However, the form advantages of field-collected cuttings (Fig. 1) have led to an unsatisfied demand for this type of planting stock, despite their higher cost.

Micropropagated plantlets are very expensive because the process is capital and labour intensive. The process does have an advantage of high multiplication rates and this allows the establishment of clonal plantations. Micropropagated clones can be maintained in a juvenile state by cool-storage, while clonal testing is done in field trials (Davies and Aitken-Christie, 1991), and this has the potential to avoid problems of physiological aging. The effective cost of the process could be reduced by using plantlets as stool plants for the production of cuttings (Table 2). This would delay the delivery of planting stock from seed but would increase the multiplication rate with the extra propagation step.

CONCLUSIONS

Reliable methods for vegetative propagation of radiata pine have been developed. These are increasingly being used by forest growers in an effort to establish forests of the best genetic quality at a faster rate than is currently possible with seedlings. At present control-pollinated seed prices, stool-bed cuttings are cheaper to produce. Improvements in stem form have been demonstrated with cuttings compared with similar genetic quality seedlings, particularly with field-collected cuttings planted on fertile farm sites. This has created a demand for field-collected cuttings, even though they cost nearly double the price of stool-bed cuttings. Micropropagated plantlets are being used by one New Zealand company to establish clonal plantations, despite their high cost.

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Fire and Its Use in Propagation—Inferno Combustion

Terry C. Hatch
Joy Plants, R D.2, Pukekohe East

The process of burning off areas of scrub to promote regrowth has been practiced for a great number of years by "farmers", if they can be called that, in some of the warmer, drier regions of the world. Indeed, it has been taken to the extreme by Australians and Californians, if the news is anything to go by. This practice is also used to clean fields of daffodil foliage and other bulb crops; indeed, I burn off the dead foliage from my nerines each autumn before they start into growth.

I have noticed, as well as other observers, that there is a pronounced effect on the way that the bulbs flower following the fire. There are many references to very good flowering seasons after bush fires, especially in the bulb rich areas of South Africa.

The effects of clearing all shrub and other plant materials must be to let light in, plus the ash will be adding potash which bulbs enjoy. In addition, there must be chemicals in the smoke which trigger dormant bulbs into growth. Many bulbs will have been dormant for a considerable time period—some quotes from South Africa mention 40 years without seeing many of the species found after a fire.

We often stumble along for many years, seemingly in a "cloud of smoke," not really knowing why we are carrying out certain practices. Although a good burn-off on my bulbs does save many hours of cleaning dead foliage, keeps fungal infections to almost nil, wipes out snails and the odd mouse, plus the hairs on my legs, all this aside there is more. After burning off, tremendous numbers of seedlings appear, mostly weeds in cultivation, but in the wild an extremely wide number of species will grow after the first rains. In cultivation, it has been suggested and tried that a layer of leaves be spread over the sown seed of some species, i.e., *Anigozanthos, Erica, Helichrysum,* and many others, too numerous to mention. This is set on fire, sometimes germination results can be good, although this is not over-reliable, and it is not advisable to use plastic trays!

After a recent trip to South Africa and a brief conversation with Dr. Nevil Brown of Kirstenbosch Botanic Gardens, about the "smoke subject", and the research that he and others had been doing, I resolved to undertake further trials on returning to New Zealand. The method most smokers are using seems complicated. It involves sowing the seed in trays, making a poly tent, and filling the tent with smoke, via pipes and tubes from a large metal combustion chamber. Other experiments involved making fire water—most of us know how quickly a billy of water is tainted by smoke when hung over a bush camp fire for tea—which is used for watering the seeds. In addition to this, the South Africans have perfected and patented "Dehydrated Smoke Water", which comes in packets and can be re-hydrated and used to water seeds.

My own experiments at first were to put the seed into a small metal kitchen sieve, light a small smokey fire, and gently roll the seed around in the smoke for 30 min. No great heat reaches the seed, as the flames are kept to a bare minimum, and after smoking, the seeds were sown and watered. The results were outstanding and the seedlings, of species I have never been able to germinate before, grew thick and fast.

The type of material used for burning, I believe, must have a fairly wide range of chemical make up and I use a combination of *Eucalyptus, Leptospermum, Erica, Restio*, and Proteaceae. These all emit a good smell when burning, giving one a smoked fish aroma, and hereby hangs a tail! We have now started using a large fish smoker which can take four full size seed trays—this is an excellent method of quick smoking any amount of seed. The herbage is loaded into the bottom of the smoker and a fire set outside on the ground, this can be ordinary firewood or a gas flame. This vapourises the material, giving a good strong smoke without much heat. The trays get a 30-min treatment which seems adequate for all species.

Record Keeping, An Aid To Quality

Ann Fair
Omahanui Native Plants, 1343 Oropi Road, R D 3, Tauranga

INTRODUCTION

What is the meaning of **Quality**? the *Collins Dictionary* defines it as—"the basic character or nature of something" and the *Oxford Dictionary* defines it as—"A degree or level of excellence".

Why do we strive for quality?: "job satisfaction" (pride in our work) and "to succeed in business" (quality is producing what the customers want and when they want it) are two reasons.

Whatever the reason, keeping track of quality control is important, and records are necessary.

We at Omahanui Native Plants have devised a system which I wish to share with you, and which may help in your recording system.

All seeds and plant material brought into the nursery are entered in a register by using the last two digits of the year collected, followed by a numeral, e.g., 94103. This registration number follows the plant throughout its cycle in the nursery on the back of each label. Our registration book has headings for "species", "date collected", and "where collected and by whom". This could be used for plants for regional genetic purity or a particularly nice form which we have chosen to bulk up.

Seed and cutting information was in the past maintained on cards with all the relevant information available at the "flip of a card". Now with the computer age, we had to devise a simple way to identify different batches of plants.

THE INVENTORY CODING SYSTEM

A maximum of 13 spaces can be used for plant codes. This includes a maximum of six letters:

3 or 4 letters for genus	CORO	*Corokia*
2 or 3 letters for species	COROBU	*Corokia buddleioides*
Or 2 letters for double cultivars	COROFC	*Corokia* 'Frosted Chocolate'

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In Propagation. Seeds are registered, but do not appear in the inventory system until the pricking out stage.

Cuttings are stuck into flat trays according to the following system:

Identifying code for this group	2	Cuttings
Maximum of 6 letters for plant name	2COPRUG	Cuttings of *Coprosma rugosa*
Container code-1 letter	2COPRUG F	Cuttings in flats
Date; month-2 numerals/year 1	2COPRUG F122	Cuttings done Dec. 1992

Tubes, plugs, and pricking out trays use the same system as above but with 3 instead of 2 as prefix. Root trainers use the same system but with 5 as prefix. The following container codes are used: F = flat tray, T = tube, P = plug, H = Hillson (root trainer)

When potting, the first prefix is discarded and the pot size code is added. *Coprosma* 'Taupata Gold', in PB5, that were potted in September 1992, would have a code COPTG 5092.

Metrosideros 'Maungapiko', in 6-litre pots, potted February 1993, would have a code METMAU 6L023.

With this system we can follow the plant's progress, checking on quality and questioning:

- Was the cutting taken at the right time?
- When is the flowering time?
- When is the best time to market the batch?
- Are we giving quality at point of sale?

For Propagation. We have forms (all forms are colour coded for easy visual identification) recording:

- Seeds—collection, storage, sown (Fig.1).
- Cuttings—into trays, tubes, plugs, root trainers, pricking out (Figs. 2 and 3).

For Post Propagation. A potting sheet includes the code from propagation, registration number, number of plants, size of pot or PB, Ronstar granulated, location to be put in nursery, special requirements—if any, number potted, and the new code (Fig. 4).

As the number from propagation may be different from what was potted, a Reject Analysis form is filled in, giving us important information on why it was rejected (Fig. 5). All plants at the final stage of the nursery are recorded if not despatched or thrown out, so the computer records are kept up to date (Fig. 6). All these records are totalled at the end of each month, giving us information from each department.

New Plant Trials. These are assessed and recorded with registration number, nursery location, and the stage of the assessment, all with the same coding system. Contracted plants are registered with additional alphabet code. These have a monthly progress checksheet and are recorded as to progress, condition, nursery location, required date and number, an easy visual aid when a phone caller inquires as to the stage his/her plants have reached.

PROP/DR1/013
SEED COLLECTION & STORAGE RECORD

SPECIES	REG NO	DATE COLL	PRE-STORAGE TREATMENT	DATE STORED	PRE-SOWING TREATMENT	DATE SOWN	NO TRAYS	RESTORE

Figure 1. Seed collection and storage record.

PROP/IRPR/1292
OMAHANUI NATIVE PLANTS – Trays of cuttings

DATE ________

PLANT NAME	REG NO	NUMBER UNITS	TREATMENT	INVENTORY CODE	OFF

Figure 2. Records of cuttings into trays.

PROP/IRPR2/1292
OMAHANUI NATIVE PLANTS

TUBING CUTTINGS/PRICKING OUT/PLUGS/DIVISIONS/ROOT TRAINERS
DATE ________

PLANT	PRESENT PROP. NO	REG	CONT TYPE	QUANTITY REC	QUANTITY POT	REJECTS	REASON	INVENTORY CODE	BATCH FINISHED Y/N	OFF

Figure 3. Records of cuttings into tubes, plugs, root trainers, and pricking out.

POTTING RECORD SHEET
OMAHANUI NATIVE PLANTS
WEEK ENDING ________ BATCH ENTRY NO ________ DATE ENTERED ________
SIGNATURE ________

PLANT NAME	PROP CODE GOL SOURCE	REGSTR NO	NO FROM PROP	POT PB	RG	LOC	SPECIAL REQUIREMENTS	NO POTTED	NEW CODE

Figure 4. Potting record sheet.

PROP/PSL/0193
OMAHANUI NATIVE PLANTS

POTTING REJECT ANALYSIS
REJECT CODES – RECORD NUMBERS REJECTED FROM POTTING SHEETS

DATE	PLANT CODE	SURPLUS S	OLD O	SMALL SM	DISEASE D	SHAPE SH	ROOTS R	TOTALS	PERCENT REJECT

Figure 5. Potting reject analysis.

PROP/PSCT2/0193
OMAHANUI NATIVE PLANTS

REJECT ANALYSIS – POST PROPAGATION
REJECT CODES – RECORD NUMBERS REJECTED FROM THROW OUT SHEETS

DATE	PLANT CODE	PAST SALE PS	DISEASE D	DIED DD	REASON FOR DEATH	POOR QUALITY Q	TOTAL

Figure 6. Reject analysis: post propagation.

DATA BASE

A data base is now being prepared for all the plants we grow—a big job—but it will be a valuable aid to our production planning, quality, and marketing. The data base will contain the following information:

Plant Information. Stock Code, botanic name, common name, and description.

Primary Propagation.

Seed: Source, collection time, cleaning, storage, sow, pre-sow treatment, container, and germination.

Vegetative: Means, source, collection time, cutting treatment, and container.

Secondary Propagation. *Container, trimming, spray schedule, and mix.*

Potting. Time, container, mix, watering method, herbicide, spacing no.(M2), frost rating, trimming, spray schedule, top dress, time of maturity, flowering, and marketing.

With the help of all these records, we can become totally committed to quality production and keep improving our business. So, record keeping is definitely an aid to quality.

Breeding of New Zealand Native Plants at the Auckland Regional Botanic Gardens—Commercial Potential of our Native Flora

Jack Hobbs
Auckland Regional Botanic Gardens, 102 Hill Road, Manurewa, S Auckland

Hebes possess many characteristics which make them desirable garden subjects, including abundant flowering, attractive foliage, and ease of propagation. Despite the horticultural merit of *Hebe,* and a vast gene pool with which to work, little breeding work has been undertaken to produce improved hybrids.

A *Hebe* breeding programme commenced at the Auckland Regional Botanic Gardens in 1982 with the objective of producing outstanding cultivars of superior appearance and improved garden performance. The susceptibility of hebes to disease, particularly in nursery conditions, has restricted their commercial potential. Initially our main aim was to produce hybrids with reduced susceptibility to septoria leaf spot (*Septoria exotica)* and downy mildew (*Peronospora grisea*). *Hebe speciosa,* one of our most important parents as the source of bright floral colours, is susceptible to both of these diseases. Species which generally remain free from such disease problems (e.g., *H. diosmifolia)* were introduced into the programme with the intention of imparting some degree of disease resistance to their offspring. Generally this strategy proved to be reasonably successful, although complete freedom from diseases under nursery conditions has proven to be difficult to achieve.

Other objectives for the breeding programme included:

- Increased flowering periods.
- Repeat flowering (several flushes per year).
- Increased flower quality.
- Greater flower colour range, with particular emphasis on blue, pink, purple, and magenta shades.
- A range of flowering times.
- Attractive foliage.
- Compact symmetrical plant habit.
- Reliable garden performance.
- Acceptable nursery performance.

In 1990 and again in 1993, I visited Denmark to look at the production of *Hebe* on the island of Funen. Subsequently, and as a result of having consulted with growers in this country, the objectives of our breeding programme were expanded. New considerations include:

- The commercial requirement that flower colour should be appropriate for the particular season.
- The requirement for new variegated cultivars in Europe.
- The importance of cultivars in which flowering time can be predicted and controlled. This is a problem for those cultivars in which flowering is triggered by exposure to cold, as it is not possible to always predict how low mean temperatures will be in a particular winter.

Therefore, it is preferable that flowering should be initiated by exposure to a period of warmth as, although relatively expensive, this can be controlled. Danish hebes are despatched when in flower to the markets by lorry, and they often spend up to three days without light. It is necessary that their flower colour does not fade in these conditions.

Selection of elite material from the wild for introduction into the breeding programme has been fundamental to its success. Often great variation occurs within a wild population. Selected plants are asexually propagated, then grown and evaluated. Those which exhibit desirable characteristics may then be used as parents. With few exceptions F1 hybrid seedlings have exhibited characteristics which are intermediate between those of their parents. This is not, however, true of complex hybrids, which can in fact be extremely variable. This presents opportunities for breeders to extend further the previous limits of this genus.

Attempts to produce new variegated clones have been made both genetically and by using irradiation techniques. Only genetic methods have proven to be successful so far, although we have yet to produce a commercially viable variegated cultivar. Seed has been irradiated at various levels in an attempt to induce variegation. At 10 kilorads, albinoism has been induced in seedlings, but these lacked vigour and died. Currently a level of 2.5 kilorads is being tested.

Each year several million hebes are produced in Denmark for the European market. About 2.5 million *Hebe ×franciscana* 'Variegata' plants are grown in 10-cm pots. Most of these are sold during July and August. They are used mainly as outdoor pot plants, in window boxes, as house plants, bedding plants, and particularly in Germany for decorating graves. Generally they are discarded once they cease to be attractive.

Several other native genera present great potential to breeders. Graeme Platt, Terry Hatch, and others have now collected several outstanding forms of *Metrosideros excelsus*. The opportunity exists to use this material to produce hybrids with different characteristics.

Our kowhai (*Sophora tetraptera* and *S. microphylla*) have been largely neglected, with few worthwhile selections from the wild available and no breeding programme.

Arthropodium cirratum (rengarenga) is another species with great horticultural merit. We have now selected and assembled elite material in association with Graeme Platt. This material includes superb horticultural forms with large wide-arching foliage and dense candelabra-like inflorescences. These have the potential with breeding and selection to produce a strain with outstanding foliage and flowers. They could even eventually rival hostas in appearance, and they would undoubtedly exceed them in performance.

Divaricating shrubs are predominantly native to New Zealand, but it is overseas where they are now becoming hugely popular. *Muehlenbeckia complexa,* in particular, has been accepted in Europe where it is being produced in vast numbers. A hybrid *Muehlenbeckia* has recently been introduced there, and the European market would welcome more hybrid divaricating plants.

The above are just a few examples from our abundantly rich native flora which could be made more commercially viable by breeding and selection.

The Influence of Nutrition on Foliage Growth and Tip Necrosis on Container-grown *Chamaecyparis lawsoniana* 'Ellwood's Gold'

Michael B. Thomas, Brent A. J. Richards, and Mervyn I. Spurway
Department of Plant Science, Lincoln University, Canterbury

Container-grown *Chamaecyparis lawsoniana* 'Ellwood's Gold' were evaluated for the influence of N, P, and liming levels on tip necrosis and growth responses using a three factor central composite design. Plant height, spread, and foliar dry matter production increased strongly with added N and P, particularly when both were added at high levels. Liming depressed growth while tip necrosis primarily occurred at low or nil N, especially when combined with nil P. Rates equivalent per month to 80 to 90 g N m-3 and 40 g P m-3, along with nil or low lime (pH 4.5) were recommended to maximise growth rates and minimise tip necrosis.

INTRODUCTION

The *Chamaecyparis lawsoniana* 'Ellwood's Gold' is a commonly grown ornamental golden conifer. A nutritional trial was set up to investigate the problem of tip burn or necrosis which had been noted on a South Island nursery.

Large growth responses to added N, with a range of small conifers grown in outdoor beds, were reported by Benzian (1965). In a trial carried out with a range of soilless media using *Chamaecyparis lawsoniana* 'Ellwoodii', the largest plants were observed at the highest level of fertilisation equivalent to 675 g N/m^3 of 5-6 month slow-release fertiliser (Anon, 1993). However, Istas et al. (1986) reported little affect on growth when comparing several fertilisers at 3 or 4 kg m^{-3} on *C. lawsoniana* 'Columnaris'. A similar trial was used by Anon (1990) to look at the response of the latter species to different fertilisers, but growth was relatively poor in response to various mixtures of slow-release fertilisers.

Hawkins (1992) reported that rooted cuttings of the yellow cypress (*C. nootkatensis*) exposed to very low levels of nutrients were less tolerant of low N than low P or K, although plants survived very low additions if given balanced nutrient levels. Nutrients provided in excess resulted in luxury consumption and eventually resulted in plant death. However, there were clonal response differences.

Field work conducted on *C. lawsoniana* 'Alumii' resulted in a recommendation of 1.7% to 1.9% foliar N content for good plant growth and quality (van der Boon, 1986). Winter injury, as evidenced by browning, was more serious in the plants with higher N contents. Container research conducted by Thomas (1984) resulted in the conclusion that the ×*Cupressocyparis leylandii* (Leyland cypress) requires medium to high N fertiliser levels but prefers an acid mix with a pH of about 4. High liming coupled with low N rates was particularly unfavourable for growth. This contrasts with other work (Anon, 1990) when researchers found that this species preferred a pH of 6.5, while superior results occurred at pH 5.5 for *Juniperus* ×*media* and *Taxus baccata*, and pH 4.5 for *Thuja plicata*.

An experiment was carried out to evaluate the influence of N, P, and lime on the foliage growth of *C. lawsoniana* 'Ellwood's Gold' so as to provide a fertiliser recommendation for future production.

METHODS AND MATERIALS

The experiment was a three factor response surface Box-Hunter design by Cockram and Cox (1957) of the composite second order type with incomplete blocks. The three factors were N, P and lime, with 20 treatments arranged in four blocks, i.e., there were four replicates per treatment.

A medium of 4 medium-grade composted *Pinus radiata* bark : 1 washed crusher dust sand (< 5 mm) (v/v) was used. Rates of N, P, and lime were supplied by using Osmocote 23N-0P-0K, Osmocote 0N-18P-0K, and dolomite lime ($MgCO_3/CaCO_3$), respectively. The N and P fertilisers were applied in two split applications, at the start of the trial and after 8 months. All treatments included a basal application of Osmocote 0N-0P-37K (supplying 37% K) at 893 g m^{-3} and Micromax (trace elements) at 300 g m^{-3}. The formulations of Osmocote were all of 5 to 6 months duration.

The media and fertilisers were well mixed and transferred to PB 6½ (3.9 litre) planter bags. Even grade rooted cuttings (i.e., 7-cm tubes) of *C. lawsoniana* 'Ellwood's Gold' were bagged up with one plant per bag.

The trial was set up in June 1992 and plants were arranged in blocks outside in a sheltered area. Plants were watered by overhead sprinklers.

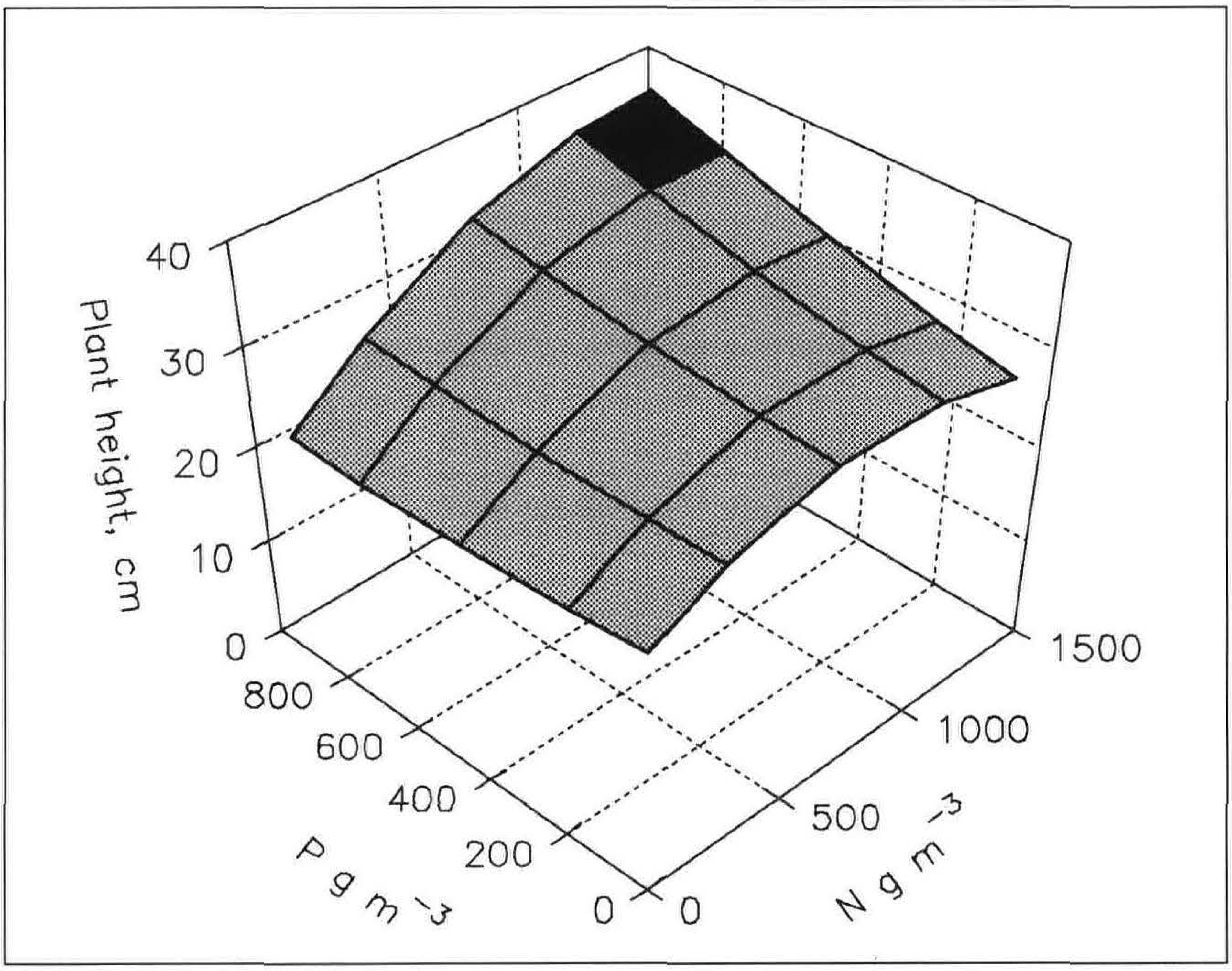

Figure 1. Influence of P and N on height.

Assessments were carried out during the running of the trial as well as foliar and media analyses which were done at 7 months. Visual ratings of foliage necrosis were carried out using a grading system to assess the amount of tip burn or necrosis (1 = severe tip necrosis to 5 = no tip necrosis). Slight necrosis was judged to be evidenced by white or severely chlorotic tips deemed not to be natural colouring for this cultivar. Media analyses indicated levels (mg/litre for all) of 3, 1, 18, 4, 10, 6, and 10 for NO_3-N, NH_4-N, P, K, Ca, Mg, and Na, respectively for the treatment with the middle rate of N, P, and lime. The next lower rate of N and P recorded levels of 1 and 16 mg litre^{-1} of NO_3-N and P respectively, while the second to highest rate of these two nutrients showed levels of 21 and 55 mg litre^{-1}, respectively. The NH_4-N levels were found to be at 1 mg litre^{-1} for all three treatments. Final measurements and harvest were carried out in Sept. 1993 after the trial had been running for 14½ months. Tops were dried and weighed.

RESULTS

Measurements taken at the completion of the trial showed that the height of the conifers was influenced by all the fertiliser and lime additions and this confirmed recordings taken earlier. On each occasion the tallest plants were those supplied with the highest rates of N and P (Fig. 1, earlier data not shown). The response to N was quite strongly dependant on high levels of added P. The additions of N and P were also important for the spread of the plants; this interaction is shown in Fig. 2 for final measurements. The shape of the surfaces that predict height and spread

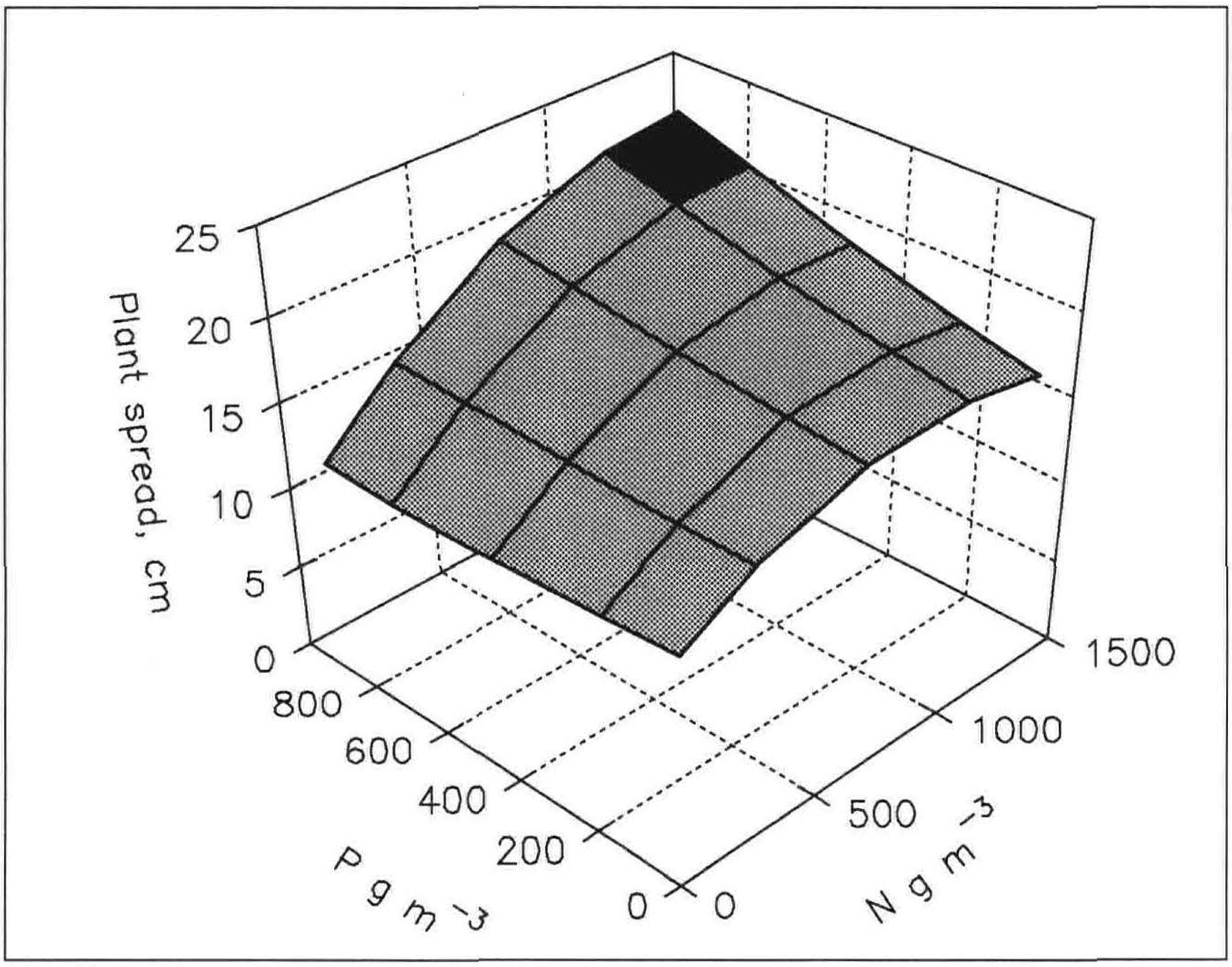

Figure 2. Influence of P and N on spread.

in response to N and P are similar. Fig. 3 shows the interactive effects of N and liming on plant spread. In this case lime had a negative effect, with the widest plants receiving the highest rate of N fertiliser but no added lime.

The foliage of the plants was rated for tip necrosis at 6 and 13 months after potting-up and just before final harvest. Early indications were that N deficiency was the most serious cause of tip burn although high rates of P, especially in the absence of lime, were also detrimental (data not shown). Plants rated just before harvest confirmed the earlier observations. Tip necrosis was most severe at nil N and P (Fig. 4). This was also predicted to be moderately severe at nil N and with increasing levels of P or when N and P were both at their highest levels. Necrosis at high levels of N and P did not confirm early observations when no tip necrosis occurred at these levels (data not shown). Therefore, the most consistent factor inducing tip burn was N deficiency.

The most significant aspect of the foliar nutrient levels, measured at about the half-way point in the experiment, was that the N content was 1.3% at the second lowest rate of N fertilisation but increased to nearly double this concentration when the plants were supplied at the second highest rate of N (Table 1).

Foliar dry weights confirmed the height and spread measurements. Dry matter production of foliage was predicted to be strongest at the highest levels of N and P (Fig. 5). These predicted figures relate well to the observed or actual weights, since the six plants with the greatest dry matter production all had the combination of high levels of N and P fertilisation. The foliar weight of plants when given high N

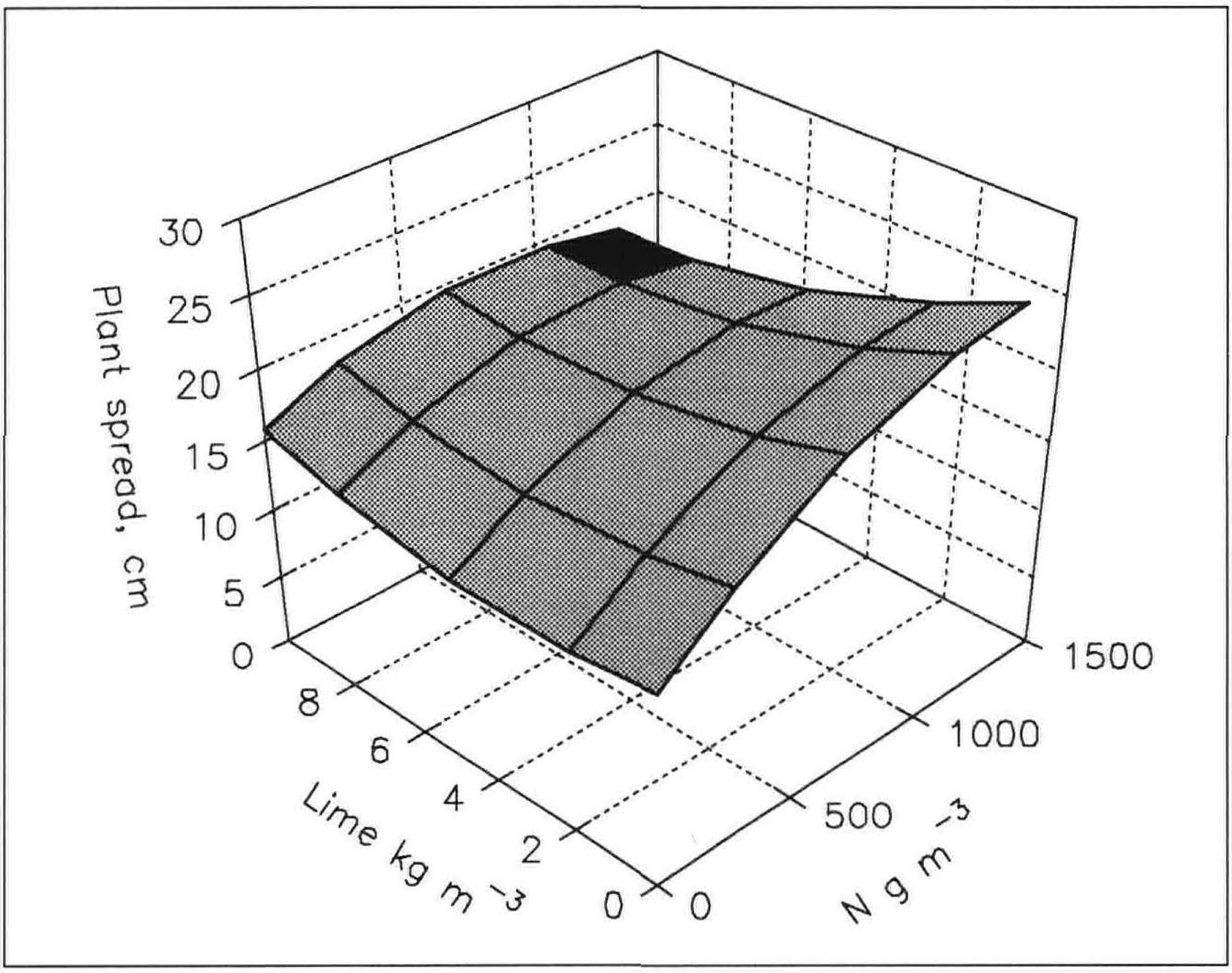

Figure 3. Influence of lime and N on spread.

with low P were predicted to more than double if the highest P rate was also applied. However, increasing lime levels reduced foliar dry weights except at low N (Fig. 6). Liming also depressed predicted foliar dry weights at nil or low P, but greatest predicted dry matter production was when both P and lime were at highest levels together (Fig. 7).

Table 1. Foliar nutrient levels.

Treatment Nutrients (g m^{-3})			Foliar nutrients %						$\mu g\ g^{-1}$				
N	P	Lime	N	P	K	S	Ca	Mg	Fe	Mn	Zn	Cu	B
267	178	2030	1.3	.41	1.7	.14	.97	.26	131	192	90	6	22
659	439	5000	2.1	.47	1.6	.17	.83	.24	113	108	61	7	18
1052	696	7970	2.3	.46	1.3	.11	.98	.23	213	87	74	11	17

DISCUSSION

High N levels were shown to be particularly important in ensuring good growth and minimal tip burn. Nitrogen levels have been shown to be a key aspect in the

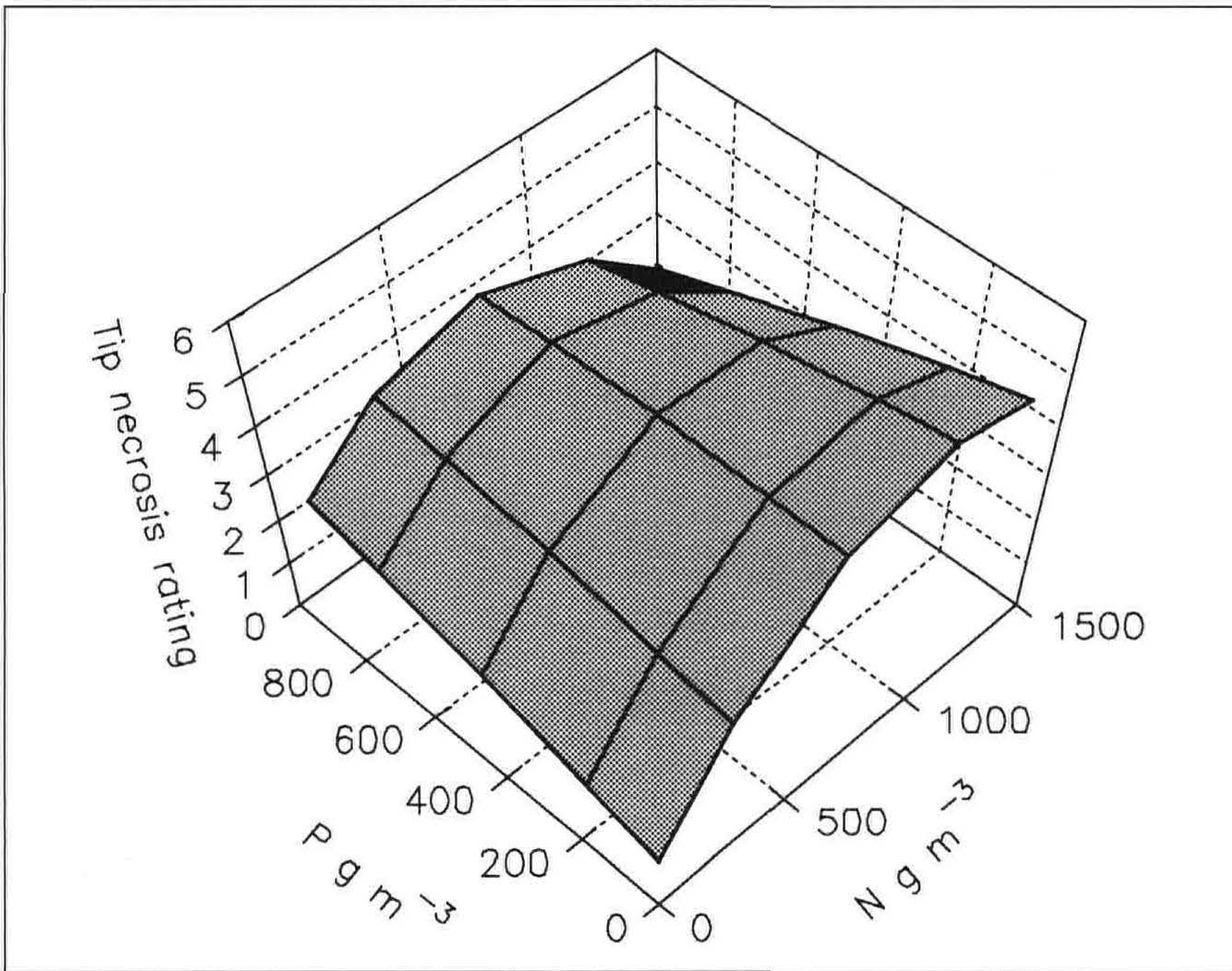

Figure 4. Influence of P and N on tip necrosis.

nutrition of container-grown plants in soilless media (Thomas and Baird, 1983) and can be expected to give large growth responses in small conifers when grown in forestry seedbeds with adequate watering (Benzian, 1965). Another feature of the results was the strong value of adding high P along with high N rates. It has been observed that pot plant crops like *Ficus macrophylla* (Thomas and Teoh, 1983) and herbaceous plants respond strongly to added P, whereas a range of trees and shrubs were found to be relatively unresponsive (Thomas, 1981).

Liming was found to generally reduce foliage growth even at high N levels, where this fertiliser addition would have been expected to have depressed the pH. This indicates a preference for acid conditions since N fertilisation would be expected to lower the pH of the medium. This was in full agreement with similar work on Leyland Cypress (×*Cupressocyparis leylandii*) which grew strongly in response to slow release N at a rate equivalent to about 100 g N/m^3, yet plants had their greatest spread and height at nil added lime (Thomas, 1984). Benzian (1965) had noted, from the examination of soil samples from over 100 nurseries, that conifer seedlings grew poorly when soils were neutral or only slightly acid. A further aspect about liming could be the reduction of available P due to the formation of insoluble calcium phosphates, and would account for poor foliage growth when P was at nil or low levels, coupled with high rates of liming (Fig. 7). High lime rates were, however, not predicted to be a problem if high rates of P are used along with high liming.

Two other potential causes of tip burn are frost damage and cypress canker (*Monochaetia unicornis*). No assessment was made on the effect of these factors,

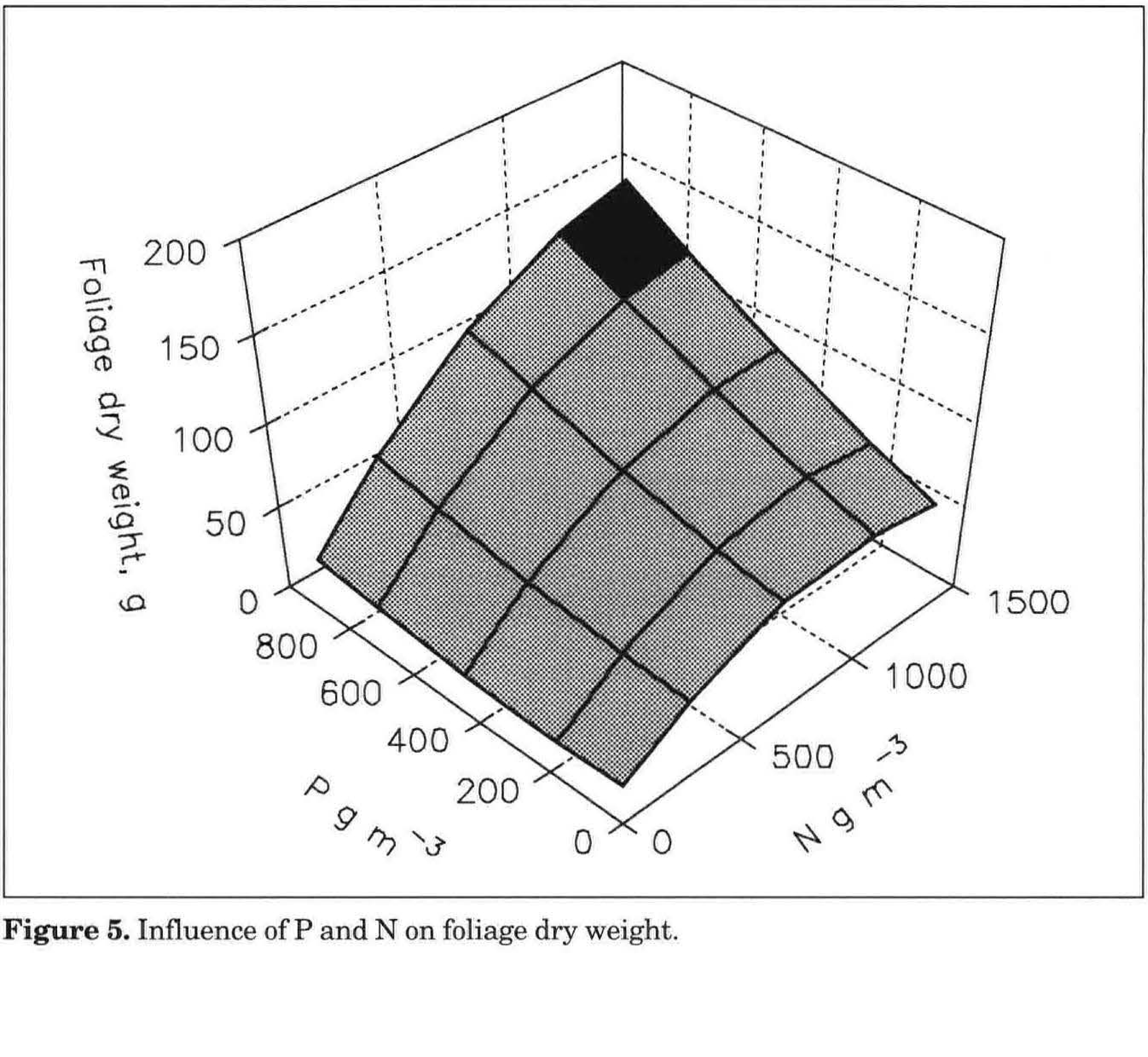

Figure 5. Influence of P and N on foliage dry weight.

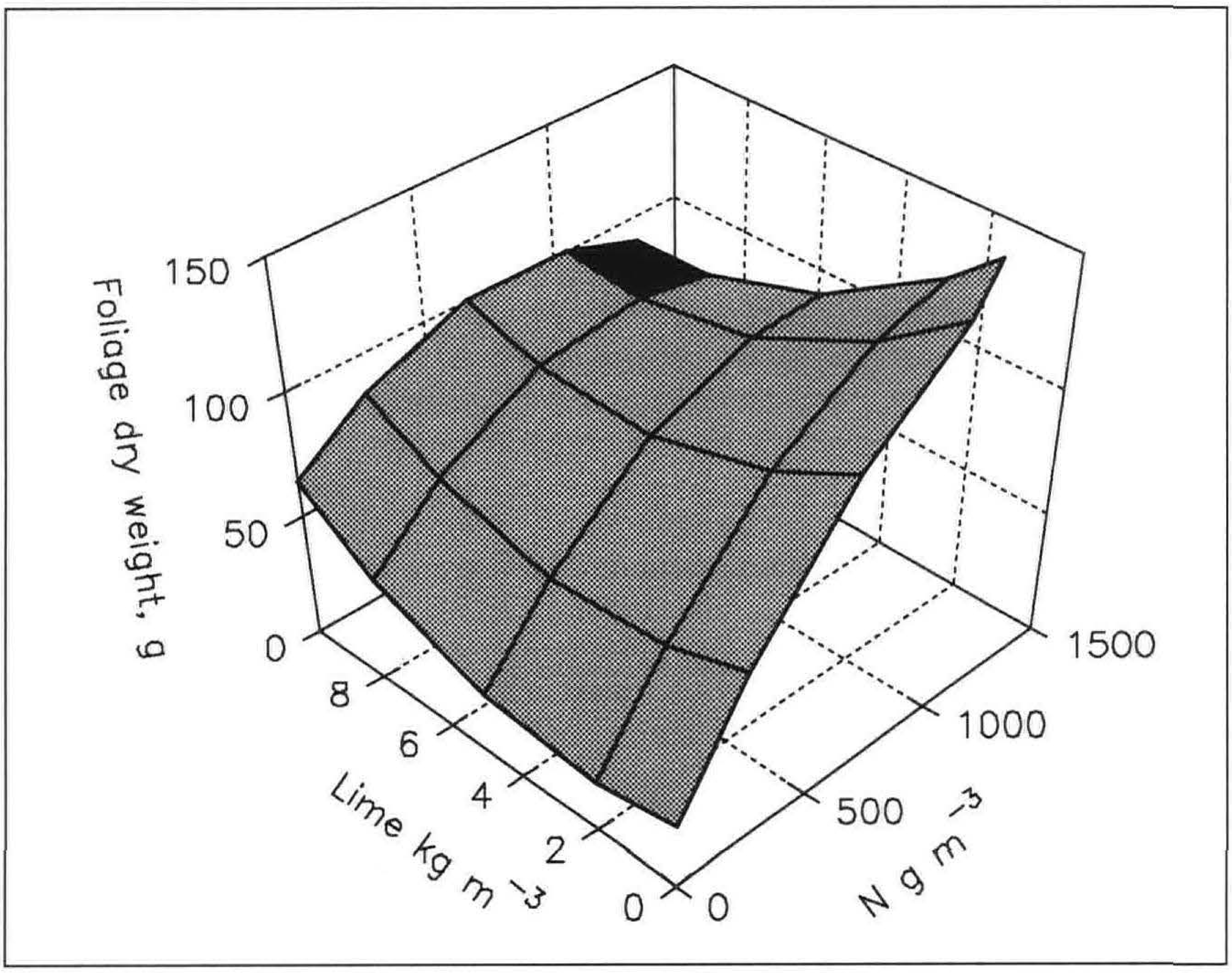

Figure 6. Influence of lime and N on foliage dry weight.

however, van der Boon (1986) noted that frost damage occurred at high N rates while the results reported here showed least tip burn at this level.

CONCLUSION

In conclusion, it is suggested that high N (1200 to 1300 g N/m^3) coupled with medium levels of P (600 g P/m^3), and little or nil added lime are recommended. Monthly nutrient release rates based on the equivalent of about 80-90 g N m^{-3} and 40 g P/m^3 for slow-release fertilisers and a pH for the medium of about 4.5 are suggested. It is proposed that these additions should help to promote growth and quality with minimal tip necrosis in this species.

Acknowledgements. We thank Wallis's Nurseries Ltd., Mosgiel for the supply of plants and funding of media and plant tissue analyses. We also thank Gilbert Wells for help with computing work and Grace Sierra for the supply of Osmocote single nutrient formulations.

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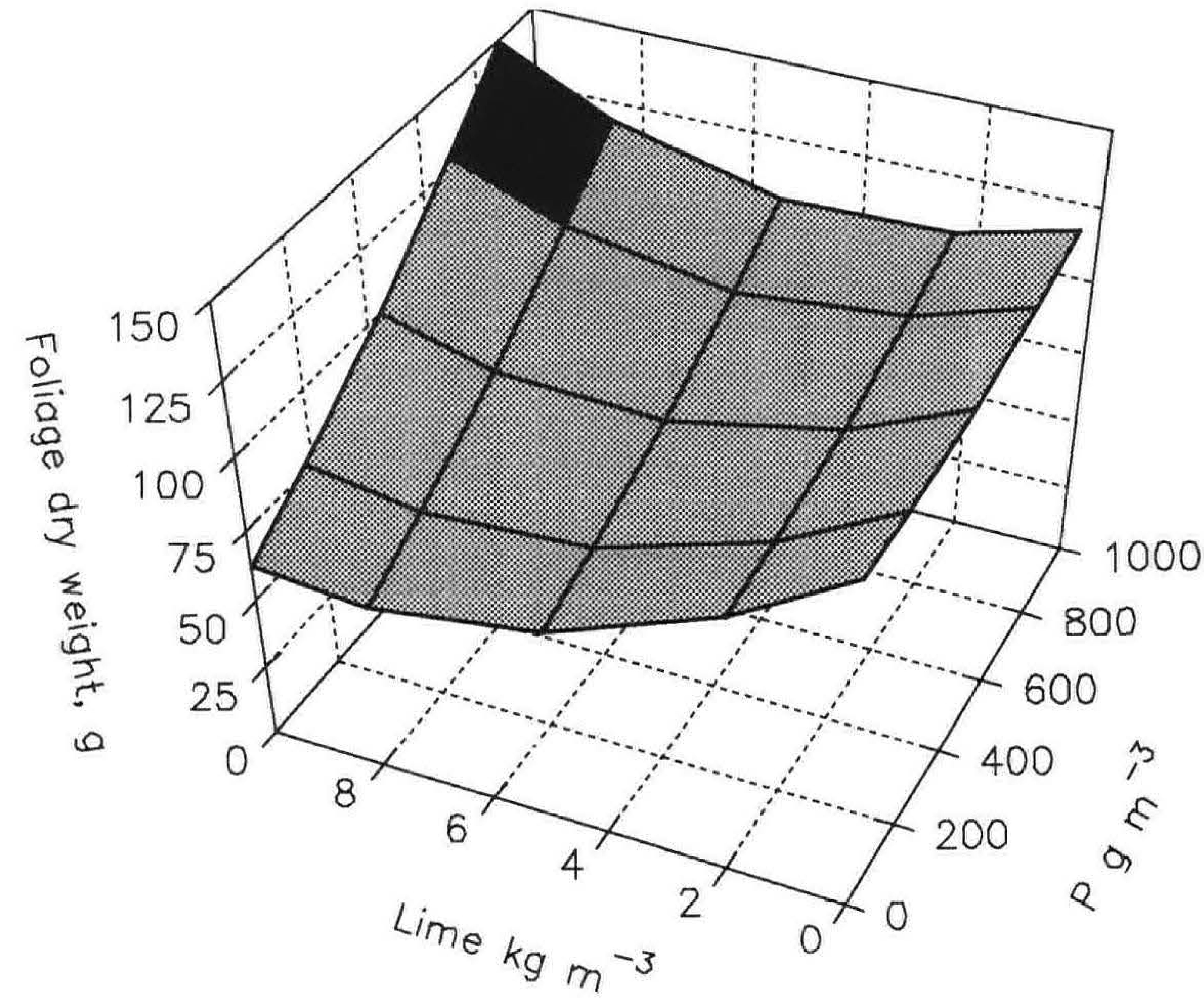

Figure 7. Influence of lime and P on foliage dry weight.

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Root Control Systems

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There are three pot designs which I wish to discuss; they are the Root Maker Pot, the SpringRing™ container, and the root control bag.

When I stumbled across a book entitled *Production of Landscape Plants* by Dr. Carl Whitcomb, I was excited about his concepts. He had done research on this very problem and had come up with some new ideas in pot designs. His work centred around the concept of air root pruning to produce trees with a high number of lateral roots originating from the root stem interface, and no root circling.

He came up with the Root Maker Pot which provides a means of air root pruning the taproot, thus stimulating secondary root growth and creating a fibrous root system without any circling.

It is recommended that direct seeding or cuttings only be employed when growing a tree, as pricking out can create kinking in roots which negates any further efforts at creating a well developed root system. Once a well-structured, fibrous root system has been initiated with the Root Maker Pot; it is essential that this be allowed to continue as the tree is potted into a larger container. The SpringRing™ container is also based on the work of Whitcomb (but since developed further by Ronneby Tree Farm) and also involves the air pruning principle. It is made of UV stabilised, high-density, polyethylene with deep open-ended cusps to which the root tips are guided as they grow out toward the container wall and are thus air pruned.

Ronneby Tree Farm (Victoria, Australia) are the second largest advanced tree nursery in Australia. They have been using the above systems most successfully for the growing of specimen *Eucalyptus* and many other trees, difficult to achieve using traditional, conventional pot methods.

The root control bag is another concept first established by Whitcomb, but since altered and developed over many years by Ronneby Tree Farm. This is an in-ground bag system, using the on-site soil as the growing medium. The Ronneby root control bags are made of a geotextile of great strength, in fact, the strongest on the world market as far as root control bags are concerned. It allows roots to penetrate the bag wall and grow out into the surrounding soil. Growth of root diameter is limited by the constriction of the geotextile wall and floor (typically 3 mm). Roots become limited in length (typically 2 m outside the bag) but they continue to source water and nutrients. The immediate benefit of root restriction is a reduction of apical dominance within the root, leading to profuse growth of vigorous lateral roots. Longer term benefits flow from starch-charged nodules which form on either side of the restriction. The root control bag, in effect, self-wrenches the tree; no other form of wrenching is necessary. After transplanting (when the bag is removed), roots develop from behind these nodules quickly. We use this system extensively on our own advanced tree nursery and our experience has shown that there is negligible transplant shock. This system allows harvesting on an almost year-round basis and I consider it has revolutionised specimen tree growing.

The Role of Botanical Gardens in the Green Decade

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Botanical Gardens are generally not well understood places. While most everyone would know that they have something to do with plants, few would know what is done and why. Perhaps this is because over the past four centuries the term has, at times somewhat cavalierly, been used to describe a broad spectrum of public and private institutions. At one end are the classic botanical gardens like Kew, Missouri, Sydney, New York, and Berlin with clearly defined missions, policies, and programmes. At the opposite extremity are a host of gardens which may be superb ornamentally, but which are devoid of any meaningful scientific or educational programming, and often lack even basic plant documentation and labelling systems. The legitimacy of the latter could be argued, but since there are no enforceable rules governing what can or cannot be called a botanical garden, such discussions are probably best left to coffee or cocktail time. Even among the acknowledged great botanical gardens there are significant differences of focus and personality. It is the unique character and individual strengths of each which contribute to the richness of the international botanical garden community. True botanical gardens are in a sense living museums, and like traditional museums or art galleries, display their carefully documented collections to the public. What distinguishes botanical gardens from these other cultural agencies, is that unlike institutions whose collections are comprised of inanimate objects, the "living" collections of a botanical garden do by definition change in the fourth dimension, both cyclically with the seasons and linearly with time. This dynamic nature of a botanical gardens' collections demands that they receive constant and consistent care. In times of financial constraint they cannot be simply put into storage only to be dusted off and returned to display when things improve. As with any cultural institution, there are a number of economic, social, political, and even personal factors, which influence a botanical garden's direction, evolution, and consequent role in society. Just as a botanical garden's collections change with time, so can its mission.

It is generally acknowledged that the first botanical garden in the western world was founded in Pisa in 1543. This was closely followed by others in Padua and Florence in 1545. Later came Zurich (1560), Leiden (1577), and Oxford (1621). These earliest botanical gardens, often called physic gardens, were developed to cultivate medicinal plants or "simples" as they were then known. They were small, walled gardens normally associated with a university and served both for the production of medications and as a training ground for medical students. They were definitely not public places.

Concomitant with the colonial expansion of the 18th and 19th century, the role of botanical gardens began to shift. In Europe, gardens began to focus on plant taxonomy, as there was need to classify the thousands of plants and samples being collected during global exploration. Many of these plants were tropical and thus would not survive as outdoor collections in Europe. Glasshouses were built to accommodate modest living collections of these, but perhaps more importantly, large herbaria and libraries were established at places like the Royal Botanic

Gardens-Kew, to facilitate longer-term study. These facilities continue to grow and remain a valuable resource for taxonomic research. To further their expansionist plans, countries began to establish gardens in their tropical colonies or along trade routes. The local flora was investigated and exploited to feed the local population (many of them plantation slaves), fill the larders of passing ships, and hopefully discover plants which would provide substantive economic value to the empire. History has shown the latter to be particularly significant. The British, for example, were responsible for introducing vast quantities of plants including tea, rubber, and sugar cane to South-East Asia, thus forever changing the agriculture of the region.

It was also during this time that the notion of using plants for ornament and pleasure crept into the botanic garden scene. Initially this was primarily an amusement for royalty and wealthy merchants, who regularly engaged in a game of botanical one-up-man-ship. Eventually however, the public was invited to share these exotic botanical treasures and with this, elements of design were introduced to the garden. Taxonomic research continued, and the rigorously arranged family-order beds remained, but display became increasingly important. One only has to think of Victorian bedding schemes to see how far and quickly this aspect of botanical garden programming developed. These gardens became places where the average family could visit, simply to enjoy beauty and tranquillity. As the urban landscape continues to coalesce, this botanical garden role of being a place for passive recreation will become even more vital.

How then would we define a botanic garden today? The Botanic Gardens Conservation Strategy published in 1989 by the International Union for Conservation of Nature and Natural Resources (IUCN) and the World Wildlife Fund (WWF), defines a botanic garden as "a garden containing scientifically ordered and maintained collections of plants, usually documented and labelled, and open to the public for the purposes of recreation, education, and research". This rather broad definition works reasonably well and would be accepted and understood by most people associated with botanic gardens, but how is the institution viewed from outside?

In a 1994 visitor survey we (Royal Botanical Gardens—Hamilton) asked our visitors what they felt was the main role of a botanical garden.

- "To teach about the environment"—29%
- "To teach and educate about plants"—27%
- "To display plants in a pleasing manner"—26%
- "To conduct scientific research"—7%

The perception that scientific research is not a main role is an interesting one. It may be due to the fact that much of the research is either conducted behind the scenes, or in the case of plant evaluation, is integrated into display gardens and thus is not readily apparent. It could also be a result of the nature of the sample population, who we would describe as tourist visitors, and as such would probably not be looking for scientific activity. The responses are, however, generally consistent with the IUCN definition. Unfortunately, what this suggests is that when it comes to the world of plants, botanic gardens should be "all things to all people". In an ideal world, this may be possible, but when "reality" is factored into the equation, the picture changes significantly and it becomes necessary to set priorities. While these are likely to vary from garden to garden, it is never an easy nor pleasant process, and inevitably leads to conflict among competing visions.

Regrettably, in the 1990s most priority decision making is financially driven, at least this is true of our organisation and, from what I gather from colleagues elsewhere, seems to be quite universal. Most botanical gardens rely on government funding in one form or another for at least part of their budget. Recessions, public debt, and changing political agendas, can at best result in funding inconsistencies and at worst, some horrific shocks. At one time, cultural institutions may have been funded more for their intrinsic value to society, but now are measured in terms of their potential for funding in more prosaic ways, chief of which is an estimate of the number of individuals who actively become involved in the services and programmes of the institution each year. For those who see a botanic garden as a scientific and educational institution dealing with the basic issues of quality of life and planetary well-being, and truly believe that it is upon these that credibility rests, the thought of becoming a market-driven visitor attraction may be repugnant. Difficult though it may be to accept, for many gardens it is a matter of survival. The challenge then becomes one of how to reconcile these seemingly competing visions. Is it possible to become a major visitor destination with all the associated trappings, and still retain scientific and educational credibility? Clearly the answer must be yes. Indeed rather than being mutually exclusive, the visions can and must become mutually supportive.

The 1990s have been coined the green decade. Among developed countries public awareness and concern for the environment has never been greater. Issues revolving around sustainable development, renewable resources, global warming, depletion of the ozone layer, and biodiversity, virtually unknown less than a generation ago, are now common journalistic topics, and the centrality of green plants to the health of the planet is accepted. Botanical gardens are well positioned, and must be prepared to accept the lead in dealing creatively and responsibly with these sorts of issues. Remember that nearly one-third of our 1994 visitors viewed "teaching about the environment" as our primary role. In doing so, a balanced fact-based approach avoiding corporate dependency or environmental paranoia, is essential. This does not however mean that botanical gardens should retreat behind the garden walls that isolated them from their community 4½ centuries ago. On the contrary, they must continually forge partnerships with industry, government, and interest groups, and wherever possible act as facilitators to promote mutual understanding and cooperation.

Since their inception, botanical gardens have been involved in plant exploration, whether in search for new medicinals, agricultural crops, or ornamentals. Facilitated in recent times by the easing of political barriers, and spurred by a renewed interest in the medicinal potential of plants, such expeditions have enjoyed a renascence. Once obtained, it is normally the botanical garden, often in concert with the local horticultural trade, that identifies, evaluates, and develops propagation and production procedures for the plant. Today many gardens, again with the support of the trade, also become involved in the promotion, marketing, and licensing of new plants.

The importance of industry support, both moral and professional, but most importantly financial, for botanical gardens cannot be overstated. Governments and other funders look very critically at the support a garden receives from its closest stakeholders as a measure of relevance.

Of all of a botanical garden's roles, perhaps the most important is that of demonstrating and interpreting the world of plants, its relationship with humanity and the rest of nature through public education. Traditionally, this was done primarily through formal courses, field study, and seminars. These are all still valid but we live in an age where technology and hence information delivery change very quickly, as do the expectations of the user, in this case the visitor. If a botanical garden is to be successful as a visitor attraction, it must use current and sophisticated methods of way-finding and information delivery, to control the visitor experience and message. In addition to plant labels, interactive exhibits, carefully scripted interpretive signs, videos, computers, and audio tours are now found in many good gardens. Festivals, special events, and participatory activities, are not only an effective means of attracting visitors, especially the young to the garden, they can provide very useful teaching opportunities.

In North America, gardening is the number one leisure time activity. Each year homeowners spend several billion dollars on their gardens and landscapes. In 1993, 15% of the population in the U.S.A. visited public gardens, this is more than twice the number that attended all professional football games combined. At one time it was thought that the typical visitor to a botanical garden was a retired person belonging to the local horticultural society. If this ever was the case it has changed. In 1994, 40% of the summer visitors to RBG-Hamilton were aged 21 to 40, the next 25% were 41 to 65, and only a scant 9% were over 65 years of age. When compared to other statistics and demographics, it becomes clear that there is a relationship between age, disposable income, and interest in botanical gardens. This is further supported by anecdotal evidence about the profile of the type of person registering for lectures and seminars. When multiplied by the several million annual visitors to North American botanical gardens, the marketing potential, both for the garden and the horticultural trade, suggested by these statistics is exciting. Botanical gardens are one of the most effective generic marketing tools available to the nursery trade. Modern horticultural consumers however are both astute, and very value, rather than merely price, conscious. Botanical gardens are good for business, and should be looked upon and supported by the horticultural trades, as an investment not just a charity or another programme to be supported by the government.

Botanical gardens are complex and multi-faceted cultural institutions which serve varied constituencies and are influenced by many stakeholders. They cannot be "all things to all people", but in the good ones "something for everyone can be found", whether that is a much sought after herbarium specimen, information on a new perennial for the garden, propagation stock of a recent introduction, or simply cool shade on a summer afternoon. Never have they been more relevant and potentially valuable to such a broad cross-section of society. If not neglected, they will continue to evolve and make scientific, educational, and recreational contributions throughout the green decade and beyond.

Cutting Propagation of *Juniperus procumbens* 'Nana'

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IBA at 8000 ppm was shown to produce the best rooting percentage with cuttings of *Juniperus procumbens* 'Nana' in a series of experiments which evaluated IBA, NAA, IBA + NAA combinations, and KIB. The practice of resetting unrooted, callused cuttings at the time of potting rooted cuttings, allowed the majority of the cutting crop to remain in the cutting flats for a shorter period of time without effecting the overall rooting percentage.

INTRODUCTION

Juniperus procumbens (Endl.) 'Nana', the dwarf Japanese garden juniper, is widely grown for use in the landscape. Plants generally form a low mat or mounding ground cover, approximately 1 ft in height and 4 ft in diameter, a size well adapted and readily maintained (with minimal pruning) in home gardens and in containers. Older plants can mound up to 2 ft in height and spread to 10 ft in diameter. Plants also adapt readily to training up a stake to create a cascading effect, as well as traditional bonsai and other trained forms.

The dense, overlapping branching habit and blue green foliage are characteristic of this cultivar. Plants are especially attractive in the spring during the flush of new, bright-green growth. Plants generally perform best in full sun, although some afternoon shade is of benefit in hot, dry areas.

Juniperus procumbens 'Nana' was originally introduced from Japan by the D. Hill Nursery Company in Illinois, during the 1920s.

Juniperus procumbens 'Nana' is commonly propagated by cuttings (generally made during the winter months), although grafting is sometimes used to produce special forms, such as patio trees.

MATERIALS AND METHODS

The experiments contained in this report were conducted over a period of several years, in an attempt to optimize the rooted-cutting yield of this crop. Experiments centered on the effects of selected types and concentrations of rooting hormones, as well as the duration of the auxin treatment and the practice of resetting (resticking) callused, unrooted cuttings.

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

Propagation material was collected from 1- and 5-gal container plants during early winter (late Dec. and Jan.). Cuttings were prepared approximately 4 to 5 in. in length, such that the outer tissue on the main stem of the cuttings was brown at the base and green above. Side branchlets on the cuttings were trimmed as needed so that all cuttings were of an overall uniform size. The bottom branchlet was stripped from the cutting.

Prepared cuttings were washed by immersing them for 5 sec. in a water bath containing 15 ppm chlorine. Cuttings then received a quick basal dip in their respective hormone treatments and were stuck into pasteurized flats of a rooting medium, consisting of 9 coarse perlite : 1 peat moss (v/v). Cutting flats were placed on outdoor heated concrete rooting beds, in full sun, with an average bottom heat temperature of 62F. Intermittent mist was provided during the daytime for 10 sec every 12 to 30 min, depending on weather conditions. Results were evaluated and rooted cuttings were potted 5 to 6 months after sticking the cuttings.

Experiment 1 compared the standard treatment of 3000 ppm IBA (used for a wide assortment of juniper cuttings), with 6000 ppm IBA, 8000 ppm IBA, and 16,000 ppm IBA (the first three in solution form and the latter as a powder).

Experiment 2 re-compared the standard treatment of 3000 ppm IBA with 8000 ppm IBA (the treatment producing the best rooting percentage in Experiment 1) on a larger scale.

Experiment 3 compared the new standard treatment of 8000 ppm IBA with selected hormone treatments containing moderate to high concentrations of NAA, combinations of IBA and NAA, and KIB (all in solution form).

Experiment 4 compared the standard treatment of 8000 ppm IBA with solutions containing 8000 ppm IBA and varying concentrations of NAA.

Experiment 5 examined the effects of the duration of the hormone treatment (the standard quick dip compared with a 15 sec and 30 sec dip).

In the final trial, rooted cuttings were potted after 15 weeks (rather than after the standard 5 to 6 months), with any callused, unrooted cuttings saved to be retreated with the standard hormone treatment and restuck in the perlite/peat medium in flats to allow for further rooting. An earlier potting date for the majority of the rooted cuttings, was desired in order to shorten the production time for the crop and reduce potting mortality, by removing the rooted cuttings from the propagation flats before the root systems became too extensive. The reset cuttings were evaluated and potted after an additional 12 weeks.

RESULTS

Table 1. Experiment 1: Effects of selected IBA treatments on the rooting of *Juniperus procumbens* 'Nana'.

Treatment	Average number rooted per flat ±std. error†	Rooted (%)
3000 ppm IBA	106.0±5.5 a‡	53.1
6000 ppm IBA	94.5±3.5 a	47.3
8000 ppm IBA	113.0±2.9 a	56.5
16,000 ppm IBA powder	110.5±10.0 a	55.3

† 200 cuttings per flat, four flats per treatment.

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

Table 2. Experiment 2: Re-evaluation of two selected IBA treatments on the rooting of *Juniperus procumbens* 'Nana'.

Treatment	Average number rooted per flat ±std. error†	Rooted (%)
3000 ppm IBA	91.2±2.6	45.6
8000 ppm IBA	120.0±1.5	60.0

† 200 cuttings per flat, 100 flats per treatment.

Table 3. Experiment 3: Effects of IBA, NAA, and KIB on the rooting of *Juniperus procumbens* 'Nana'.

Treatment	Average number rooted per flat ±std. error†	Rooted (%)
8000 ppm IBA	116.0±8.9 a	58.0
3000 ppm NAA	68.6±7.5 bc	34.3
3000 ppm IBA + 3000 ppm NAA	61.8 ±3.1 bc	30.9
6000 ppm IBA + 6000 ppm NAA	51.2±26.0 bc	25.6
12,000 ppm KIB	47.8±8.5 c	23.9
16,000 ppm KIB	100.4±10.7 a	50.2

† 200 cuttings per flat, five flats per treatment.

Table 4. Experiment 4: Effects of IBA and NAA combinations on the rooting of *Juniperus procumbens* 'Nana'.

Treatment	Average number rooted per flat ±std. error†	Rooted (%)
8000 ppm IBA	106.5±8.8 a	53.2
8000 ppm IBA + 100 ppm NAA	89.0±12.6 ab	44.5
8000 ppm IBA + 500 ppm NAA	93.3±10.2 ab	46.6
8000 ppm IBA + 1000 ppm NAA	110.7±8.7 a	55.4
8000 ppm IBA + 2000 ppm NAA	63.7±8.3 b	31.8

† 200 cuttings per flat, five flats per treatment.

Table 5. Experiment 5: Effects of IBA treatment duration on the rooting of *Juniperus procumbens* 'Nana'

Treatment	Average number rooted per flat ±std. error †	Rooted (%)
8000 ppm IBA, quick dip	106.3±9.5 a	53.1
8000 ppm IBA, 15 sec dip	112.9±20.5 a	56 5
8000 ppm IBA, 30 sec dip	87.6±12.6	43 8

† 200 cuttings per flat, five flats per treatment.

Table 6. Resetting cuttings of *Juniperus procumbens* 'Nana'.

Treatment	Number rooted†	Rooted (%)
Original cuttings after 15 weeks	4686/10,000	46.9
Plus available resets (callus only)	1841/10,000	18.4
Reset cuttings after 12 more weeks	996/1841	54.1
Combined results	5682/10,000	56.8

† 200 cuttings per flat, 8000 ppm IBA.

DISCUSSION

In Experiment 1, 8000 ppm IBA (liquid) and 16,000 IBA (powder) produced slightly higher rooting percentages than the standard (control) treatment of 3000 ppm IBA, although the differences were not significantly different.

Based on these results, 8000 ppm IBA was again compared to 3000 ppm IBA on a larger scale (Experiment 2). In this case, 8000 ppm IBA did produce a significant improvement in rooting, and so became the new standard treatment. (Re-comparison of the 16,000 ppm IBA powder was left for another time, as the use of powders tends to be more costly than the use of liquids.)

In Experiment 3, solutions of NAA, IBA + NAA, and KIB were compared to the standard, in concentrations often used for moderate to difficult-to-root conifers. In this case, the standard treatment continued to produce the best results.

The inclusion of varying concentrations of NAA into the standard formulation of 8000 ppm IBA, again produced no significant improvement in rooting percentage (Experiment 4).

In Experiment 5, extending the duration of the hormone treatment from a quick dip to a 15-sec dip, produced a slightly higher rooting percentage. However, the difference was not statistically significant; neither did the slight increase warrant the additional labor required.

Finally, the evaluation of the re-setting (resticking) of callused, unrooted cuttings after 15 weeks (at which time all rooted cuttings were potted), produced a rooted cutting yield equivalent to that normally obtained when rooted cuttings are potted after approximately 6 months. This earlier potting procedure features the advantages of reducing the production time on a major portion of the crop, as well as reducing the transplant loss sometimes experienced with rooted cuttings which have remained in the cutting flats for an extended period of time.

Presently, we are using a commercial formulation of 16,000 ppm IBA powder (which was evaluated in Experiment 1), as crystalline IBA is no longer available to us for formulation of our own IBA solutions. The re-setting of unrooted, callused cuttings after 15 weeks also continues as our standard practice, yielding good results.

Vegetative Propagation of *Gevuina avellana* Mol.

Brent McKenzie
New Zealand Institute for Crop & Food Research Ltd., Invermay Agricultural Centre, Private Bag 50034, Mosgiel

INTRODUCTION

Gevuina avellana Mol. belongs to the Protaceae, and is related to *Macadamia,* producing similar nuts with edible kernels. This plant is a source of cosmetic oils and the timber is used for joinery and turning. Several common names are used for the plant, including Chilean nut and Chile hazel. The latter gives rise to the mistaken belief that the plant belongs to the genus *Corylus. Gevuina avellana* grows to form an attractive native tree in the Valdivian forest in Chile. It is known in Great Britain as an ornamental and is grown in the milder areas of Cornwall and Devon.

Our research shows that this plant has been grown in New Zealand since the 1940s, although poor types with small nuts have meant that it has only been grown as an ornamental. Tolerance of frost to -8C makes *G. avellana* hardier than *Macadamia,* thus making it of interest as a potential new crop for New Zealand. Roasted nuts are sold in Chile at prices of about NZ$7 per kg (Crop & Food Research, 1993, Halloy et al. 1993).

We have introduced several new accessions of *Gevuina* into New Zealand from South America. These are being screened for hardiness and will be compared with plants grown from trees already in the country. Once plants attain fruiting size, the quality and size of nuts can be compared. To provide plants for trials, and to be able to grow plants once an elite cultivar has been selected, trials were conducted to assess the feasibility of propagating *Gevuina* by stem and leaf-bud cuttings.

MATERIALS AND METHODS

Propagation trials were carried out in a twin-skin polycarbonate-covered greenhouse at Invermay Agricultural Centre, Mosgiel. Thermostatically controlled heating cables embedded in sand provided a mean basal cutting temperature of 22C. Air temperature was maintained at a minimum of 18C. Misting was controlled by an electronic leaf sensor. No artificial lighting was supplied.

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At the time of taking cuttings, most plants were growing under glass in pots to produce cutting material. This tended to force plants into growth and produce another batch of cuttings in a season, whereas plants outside, had one main growth flush in spring. Cuttings were taken from a total of 13 accessions, although the number of cuttings varied depending on the number of stock plants available. Some cutting material was from second generation plants. Parent lines within each accession were also maintained so that any variation within each accession can be identified. This is particularly relevant when an accession has been obtained as seed, as there can be genetic variation between seedlings.

Cuttings were from either apical or axillary shoots and varied in length from 140 to 160 mm. They were dipped for 5 sec in 5000 ppm indolebutyric acid (IBA) potassium-salt formulation and stuck in plastic pots or trays. The medium was 1 peat : 1 sand (v/v).

When cuttings were trimmed to length in the past, excess material was discarded. The high rooting percentages obtained, and the manner in which roots were formed, suggested that this material should be tested as cuttings. It was made into leaf-bud cuttings, by cutting stems 10 mm above and below the nodes, leaving stem sections about 20 mm long. The leaflet of each cutting was trimmed depending on size. Cuttings were then treated in the same way as above. Care was taken to ensure that the small stem sections were secure in the medium, but that the buds were not covered so that rotting could not occur.

Cuttings were taken in summer (Feb.) and winter (June), with one accession in spring (Sept.). The internodal cuttings were taken in winter (June).

Phytophthora has caused problems in the past, so cuttings and parent plants were treated with Aliette (80% fostetyl-aluminium) at 5 g/litre as a drench.

A comparison was made between the rooting ability of stem and leaf-bud cuttings, both taken in winter, as well as the length of time from sticking to potting, in stem cuttings taken in both summer and winter. No comparison was made between the rooting ability of apical and axillary stem cuttings.

RESULTS AND DISCUSSION

The results of these trials confirmed that *G. avellana* can be rooted from stem cuttings. In addition, propagation from leaf-bud cuttings was also successful. Significant root structure on stem cuttings had developed after 18 days in previous work. In this trial, from a sample of 143 cuttings taken in summer (Feb.), three accessions showed sufficient root development for potting to occur after 34 days. The percentage of rooted cuttings was 24% in accession 557, 64% in accession 63, and 100% in accession 545 (average 62% rooting for this sample). Unrooted cuttings, or those with insufficient roots for potting, were restuck. These were potted on 27 April 1994 and 5 July 1994.

For stem cuttings taken in winter, root development was noted from 22 days, but growth was slow and time to potting (78 days) was longer than for cuttings taken in summer. This longer root growth period for winter cuttings may be illustrated by a more recent batch of cuttings; of 492 cuttings taken on 5 May 1994 from 11 accessions, only 15 (3%) had developed sufficient roots for potting by 6 July 1994 (62 days).

Table 1 compares leaf-bud cuttings and stem cuttings taken in winter and early spring. Leaf-bud cuttings rooted well, but with a lower rooting percentage than stem cuttings. Subsequent growth was equivalent to that of a stem cutting. More care is required with leaf-bud cuttings. It seems to be important to allow buds to break into growth before potting. Some very small buds have not yet broken into growth. The days to rooting indicates when good roots had developed. Potting occurred on 2 Sept 1993 (at 78 days) for all accessions except 1339, which was done on 24 Nov. 1993 (at 76 days).

Table 1. Leaf-bud cutting and stem cutting comparison (winter and early spring).

Accession	Date cut	No. cut	No. rooted and (%)	Days to rooting	Cutting type
293/6-93	16/6/93	7	7(100)	24	stem
293/6-93	16/6/93	7	6(86)	25	leaf-bud
277/6-93	16/6/93	3	2(66)	28	stem
277/6-93	16/6/93	3	1(33)	30	leaf-bud
294/6-93	16/6/93	10	10(100)	22	stem
294/6-93	16/6/93	22	19(86)	25	leaf-bud
1339/9-93	9/9/93	15	15(100)	30	stem
1339/9-93	9/9/93	21	14(66)	33	leaf-bud

It appears that both the physical stage of development of the cutting material and the time of year that the cuttings are taken are important factors. Of 87 softwood cuttings made on 26 Nov. 1993, 57 collapsed and died within a 3-week period of sticking. No root development had occurred.

CONCLUSIONS

- *Gevuina* can be successfully grown from leaf-bud cuttings and apical and axillary stem cuttings.
- The period from sticking to potting was shorter during summer months.
- Losses can occur with rooted leaf-bud cuttings if potting is carried out before bud break.
- Cuttings taken from semihardwood material during summer can make good root growth from 18 days on, with the potting stage usually reached at about 35 days.
- Further work needs to be carried out to determine optimum times for leaf-bud cuttings.

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Control of Woody Root Systems using Copper Compounds

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INTRODUCTION

In the past 30 years in Australia there has been a major swing away from the production of woody plants as a field production system in favour of producing plants in containers. A container production system has many operational and marketing advantages over field production. The climate of Australia is more conducive to the production of woody plants in containers. The lack of any real winter dormancy over most of the country is a major factor in this country-wide trend to container plant production with woody plants.

THE NATURE OF THE PROBLEM

The shape and the relatively small size of nursery propagation containers have been major causes of serious root distortion in container-grown plants, especially large woody plants. In the woody nursery industry in Australia, a small, round container with a top diameter of 50 mm (the ubiquitous 2-in. tube), is extensively used as the first propagation container for both cutting propagation and for transplanting of woody plant seedlings.

Table 1. Causes of root deformity due to propagation and planting procedures (Moore, 1985).

Procedure	Aspect of procedure causing deformity		Kinking	Circling
Propagation	1) Depth of germination tray		x	
	2) Pot	(a) shape		x
		(b) diameter		x
		(c) depth	x	x
	3) Pricking out		x	
	4) Potting on		x	x
Planting	1) Hole	(a) shape		x
		(b) diameter		x
		(c) depth	x	x
	2) Twisting as planting			x
	3) Depth of planting		x	

Harris (1983) outlined the major root distortion problems of container-produced woody plants as:

1) Kinking of Roots. This form of distortion involves a bending or doubling back of the young main or tap root at an early stage in the nursery production process.

2) Circling or Girdling of Roots. This distortion is a response of the root system to the shape and size of the growing container. The roots will circle or spiral around the inside of the container, and after a period of time growing in the container, the whole root ball will assume the shape of the growing container.

In an examination of container-grown plants selected randomly in the VCAH Burnley Nursery in Victoria by Moore (1985), it was determined that the extent of root distortion problems was extremely high with many woody plant species. In this study, up to 100% of the plants of some woody plant species exhibited severe root distortion problems. There is no reason to suppose that the extent of root distortion problems in the commercial nursery industry across Australia is any less severe. Table 1 provides an overview of the extent to which nursery container production procedures influence root distortion.

Work carried out by Whitcomb and other researchers in the U.S.A. has supported the results obtained by Moore in Victoria. Whitcomb (1989) demonstrated that long-term root development of container-grown trees was heavily influenced by the container and the nursery production practices imposed on the plants during nursery production. In the nursery industry world-wide, it is now widely accepted that woody plants, particularly fast-growing seed-raised types, are extremely vulnerable to serious root distortion problems.

These root distortion problems are most severe when the seedlings are transplanted into small, round, plastic containers. The 50-mm plastic tube is probably the worst transplant container that nurseries can use. Its small volume, combined with the smooth inner surface, causes extensive spiralling of the roots around the interface between container and growing medium. If the plants are transplanted from the tubes before significant spiralling of roots occurs (i.e., at the optimum time for transplanting), the problems will be minor. However, if the plants are allowed to remain in the container for longer than the optimum period, severe root distortion will occur and the long-term development of the plants will be seriously impaired.

KINKING OF THE ROOT SYSTEM

Kinking of the roots usually occurs as a result of poor pricking out technique. It results from a doubling back of the main root during the pricking out process. Kinking of the roots is not perceived as a problem in the short term. The regular watering and fertilising programs carried out in the nursery allow the seedlings to grow quite normally.

The major impact of kinking of roots does not appear until well after the plant has been planted out into its final growing position. Cellular expansion of the woody roots in the vicinity of the kinked area causes enormous stresses in the kinked area. These stresses, combined with reduced availability of water, often result in sudden death of the plants. Most horticulturists will be familiar with this situation in many forestry and landscape situations. However, it is also a problem with many woody plants in plantation-style floriculture.

The prevention of root kinking can be very difficult for nurseries as it is largely a problem caused by poor operator technique. Many forestry nurseries are attempting to overcome this problem by eliminating pricking out of seedlings from their production systems. Direct seeding into tubes, using vacuum seedling equipment to plant one seed per tube, is now becoming widely used. The seed germinates and grows on in the tube without the need for pricking out, and the potential for root kinking is therefore reduced.

SPIRALLING OF ROOTS

Root spiralling is largely a response to the size and shape of the growing container. When a plant is potted into a container, the roots will grow outwards (and downwards) until they come into contact with the walls of the container. In the case of round, smooth plastic containers, the root will be deflected by the inside wall of the container and will grow round and round in a circular shape until removed from the container and planted out.

The consequences of severe root spiralling usually do not show up until well after the plants have been planted in their final growing position. Undoubtedly the small circular containers used in most nurseries are the principal cause of root spiralling. The smaller the container, the more serious the spiralling will be. In extreme cases where severe root spiralling has occurred in the nursery, the plants may die through strangulation of the base of the stem by the spiralled roots. This extreme situation usually occurs as a result of root spiralling in small propagation containers, such as 50-mm tubes.

After planting out, plants with spiralled root systems may respond in a number of different ways:

a) Reduced Growth. The efficiency of the root system will be impaired, and this reduces its ability to forage successfully for water and nutrients. Poor and often unsatisfactory growth results.

b) Poor Root Anchorage. The inability of the roots to grow out in the normal way leads to an inability to withstand strong winds, and affected plants are frequently blown over and lost.

c) Strangulation of the Stem. As outlined earlier, when spiralling has been allowed to occur in very small propagation containers, secondary thickening of the stem base and the woody roots often leads to a severe stem constriction, which eventually means that the tree is strangled by its own root system.

PREVENTION OF ROOT SPIRALLING

There are three main strategies that can be used to reduce or eliminate the degree of root spiralling which occurs with small plants in nursery containers:

Avoid Leaving Young Plants in Nursery Containers for too Long. Keeping plants in the nursery for excessive periods of time inevitably leads to severe root binding. This is a serious operational problem for many nurseries and it requires a serious decision to destroy plants with badly spiralled roots, rather than to pot them up into a larger size container. Potting up of plants with spiralled roots does not solve the problem; it merely masks the problem.

Use Nursery Containers which are Designed to Minimise or Eliminate spiralling of Roots. There have been many examples of nursery containers which have been designed specifically to redirect the growth of roots so that spiralling does not occur. Examples of these include:

1) The Speedling Tray. The Speedling Tray, or Todd Planter Flat, is a multi-celled polystyrene tray with the cells configured as an inverted pyramid shape, with one central drainage hole in the base of each cell. The cell shape directs the developing roots vertically downwards and out through the basal drainage hole. The growing benches on which the trays sit have no base, and the young roots grow out through the base of the container into dry air beneath the bench. This results in a drying off and death of the root tip immediately below the base of the tray. Lateral root development occurs from further back along the root system, and the net result is a more branched root system with all roots growing vertically downwards. This concept of root pruning is known as air pruning (Todd, 1981), and it is now used with a variety of other container styles.

2) Vic Pots or Native Tubes. These containers are deep square shaped pots with an open base. They are also designed to be elevated above ground level so that the open base creates an air pruning effect. The square shape inhibits circling of roots inside the container and encourages downward growth of the roots. Air pruning occurs as a result of the air space at the base of the container.

3) Jiffy Pots and Jiffy Strips. These types of propagation containers are made from compressed peat or other organic constituents, which allow the roots of young newly propagated plants to grow out through the walls of the container. This ensures that circling of roots inside the container is minimised. At the end of the propagation period the newly propagated plant is either planted out, or potted up with the container left intact on the young plant. It is important during the early stages of establishment of plants put into the field with these fibre containers, to ensure that the watering program keeps the containers uniformly moist. Prolonged drying out of these fibre containers after planting may lead to some root constriction problems.

4) Queensland Forestry Tubes. This is a deep circular-shaped propagation container with a series of raised vertical moulded ribs on the inside of the tube. These ribs prevent circling of roots and direct the roots vertically downwards and out through the base of the tube into open air for air pruning.

5) The Whitcomb Rootmaker Pot. This is probably the most complex design of propagation container for root control. It consists of an elaborate series of 24 air-pruning openings in the walls of the container, which are designed to air prune the root system so that secondary roots will be encouraged to develop as far back as the base of the stem (Whitcomb, 1989). Although this container may have the desired effect of preventing root circling, they are very expensive and their design complexity makes them very difficult for a pot manufacturer to produce.

There are many more individual styles of propagation containers which are designed to control root development, but the ones listed here will serve as sufficient examples to illustrate the techniques. There is no doubt that if these containers are used properly, they will result in a major improvement to the quality of the root systems of woody plants. The real problem is that most nursery producers are reluctant to use these types of containers. There are many reasons, including: “they are too expensive”, “they don’t fit our production systems”, “our customers don’t like them”, “our staff don’t like them”, or “ we can’t grow a good quality plant in them”. Whatever the reasons, most nurseries refuse to use these types of containers. This means that the customer is not getting the quality of root systems that they should be getting. It is also the reason why we are seeing this third option becoming a potentially viable one for the Australian nursery industry.

Use Chemical Compounds to Control the Young Developing Roots. Most early work on evaluating the effect of copper compounds was carried out in the U.S.A. and Canada, and was primarily concerned with coniferous forestry species such as pines and spruce (Beeson and Newton, 1992). Early problems focussed on how to apply the compounds to nursery containers. The most common method of application now in use is to incorporate the copper compound into a latex or acrylic paint, and to paint or spray the compound onto the inside wall of the nursery container.

Subsequently, a number of researchers have evaluated the technique with a wide variety of woody ornamental trees and shrubs. Furuta, et al. (1972), working in California, demonstrated that the technique could be used on many ornamental trees, including *Eucalyptus* species. Struve (1990), working at Ohio State University, incorporated copper treatment of containers into a wider tree production system called The Ohio Production System (OPS). This system enables nurseries to produce tree whips to a plantable size in containers in one year, compared to the three to five years normally required for conventional field production.

FORMULATIONS OF COPPER

A number of different formulations of copper have been assessed by different researchers. Copper carbonate was the formulation used by most early researchers, but many forms of copper will produce similar root inhibition. However, copper hydroxide now appears to be the most widely used compound. Copper hydroxide is the active constituent of the registered fungicide Kocide™. It is manufactured by the Griffin Chemical Company of Valdosta, Georgia, U.S.A. This company is currently marketing a product in the U.S.A. under the trade name of Spin Out™ which consists of 7.1% copper hydroxide in a latex paint solution.

Spin Out™ has received United States Environment Protection Agency registration for use as a root controlling compound. The Griffin Chemical Company, which markets the product in the U.S.A., is now selling Spin Out™-coated containers to the nursery industry. The product Spin Out™ has now been registered for nursery use in New Zealand, and it is expected that registration for Australia will be obtained by early 1995.

A similar product which originated in South Africa, is available with copper oxychloride as the root-control compound, and is marketed under the trade name Prune™. As far as I can ascertain, this product was initially developed as a coating for polystyrene speedling type trays, to prevent root growth in between the polystyrene beads of the trays. Root growth into the spaces between the beads of used trays makes seedling extraction very difficult, and dipping of the trays into a solution of this compound eliminates the problem.

Prune™ is presently not registered in Australia for root control in containers, but is being used by some forestry nurseries and seedling producers. The legal position regarding this manner of use is not clear.

For the last 3 years at Gatton College we have been experimenting with copper coating of native tubes for growing woody plants. Because of the unavailability, until recently, of any pre-mixed compound, we have been making our own preparation based on the recommendations of Struve at Ohio State University, which I visited in December, 1990. We use Kocide 101™ at the rate of 100 g per litre of white acrylic paint. This is then applied to the inside surface of the growing containers using a spray gun.

BENEFITS OF COPPER TREATMENT

Redistribution of Roots within Container. The primary effect of the copper treatment is the prevention of root circling within the container. At the point where the root tip comes in contact with the container wall, the root tip ceases growth. Secondary lateral root growth develops from further back and when these laterals reach the container wall they are also inhibited or "pruned" by the copper.

Overall root distribution within treated containers is quite different to untreated containers. In an untreated container, most of the roots will be located on the outside of the ball of media in the interface area between media and container wall. This type of root distribution is relatively inefficient, as most water and nutrients are located within the volume of media in the pot. With treated containers, the young feeder roots tend to be located within the container media volume rather than on the outside, and this leads to more effective utilisation of water and nutrients from the growing media. A number of researchers have reported a greater total amount of growth on plants in treated containers, and it is likely that this improved utilisation of water and nutrients is the principal reason.

Longer "Shelf Life" for Plants in Small Containers. Probably the main reason why we experience serious problems with woody plants grown in small nursery containers, is that frequently the seedlings remain in the containers for far too long before planting out or potting on. This may not be the fault of the nursery producer as factors such as availability of water for planting, weather conditions, and land preparation may contribute to this problem.

Plants grown in copper-treated containers will not experience the extensive root circling problems experienced in untreated containers. This means that the plants can be held in treated containers for much longer before planting out, without root distortion problems occurring.

Better Root Establishment after Planting in the Field. Burdett (1978), working with lodgepole pine in Canada, demonstrated that roots which were inhibited by copper treatment in the nursery container would resume growth once the plant was planted out in a field position. This means that the natural pattern of root development will occur after these treated plants are planted out. As the root system grows outwards and downwards in the natural pattern, the root system will provide greatly improved anchorage compared to untreated root systems with distortions present.

It also means that the root system is better able to forage for water and nutrients and that results in faster establishment after planting out. Many other researchers have confirmed that plants with roots grown in copper-treated systems have faster rates of establishment after planting out compared to plants with roots grown in untreated systems.

Increased Survival after Planting out. McDonald et. al. (1981) compared the survival rate of ponderosa pine (*Pinus ponderosa*) planted into a forest location from copper-treated containers, and from containers which had varying patterns of holes for air pruning to occur. Survival of plants which had been exposed to copper treatment was averaged at 93%, compared to average survival from air-pruning containers of 39%.

PRODUCT COMPARISON TRIALS

During 1994 a series of trials were undertaken to assess the performance of Spin Out™, Prune™, and the Kocide 101™ plus paint mix used experimentally at Gatton College. These products were evaluated using three species: *Jacaranda mimosifolia, Eucalyptus grandis,* and *Grevillea robusta.*

All three species were raised from seed sown in community trays, transplanted into 50-mm tubes, and some of each species subsequently grown on in 140-mm pots at the Gatton College Plant Nursery Unit during 1994. Due to time constraints I will only refer to results obtained with *E. grandis.*

The objectives of these trials were to:

1) Investigate the use of copper compounds to control root growth in general.
2) Evaluate the three copper products in relation to:
   - Their ability to reduce root system malformation in containers.
   - Their effect on shoot growth in treated containers.
   - Their effect on shoot growth and root regeneration once removed from treated containers.

Treatment Applications:

Control:	No treatment
Prune™:	This was mixed at the recommended rate of 1 kg of copper oxychloride to 1.8 kg of Plazdip (the paint carrier), and 7 litres of water. The initial preparation was thickened by the addition of extra Plazdip to provide better coverage on the containers.
Spin Out™:	This was supplied as a ready-to-use paint by Griffin Corporation.
Kocide™:	A mixture comprising 33 g of Kocide 101, 200 ml of white latex paint, and 50 ml of water was used. This is the standard experimental mix used at Gatton College.

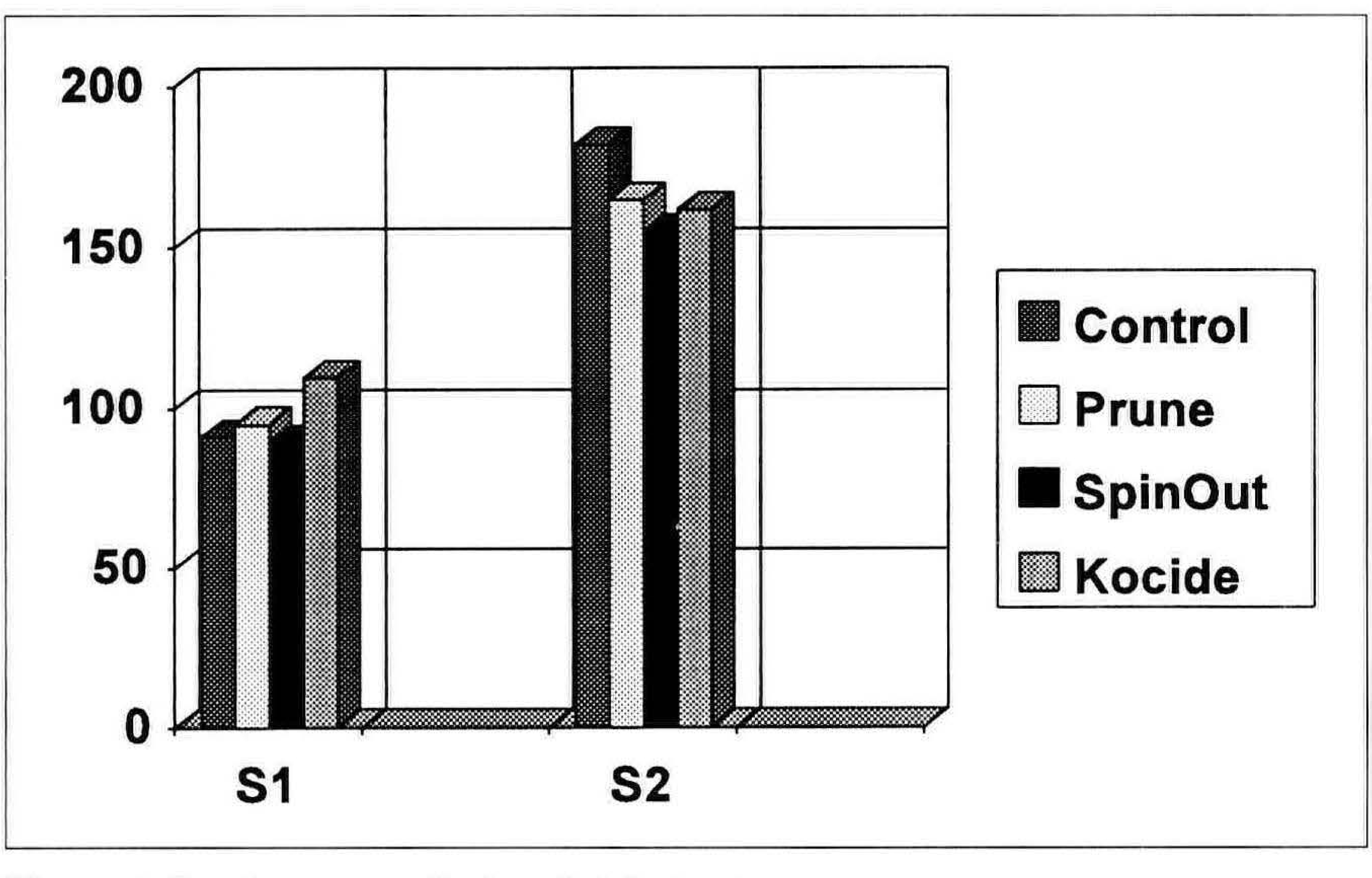

Figure 1. *Eucalyptus grandis* shoot height (mm).

RESULTS

Root System Malformation. All three products greatly reduced root system malformation in containers compared to the untreated controls with all three species. All products also altered root distribution in treated containers, with root growth within the container media rather than at the container wall-media interface.

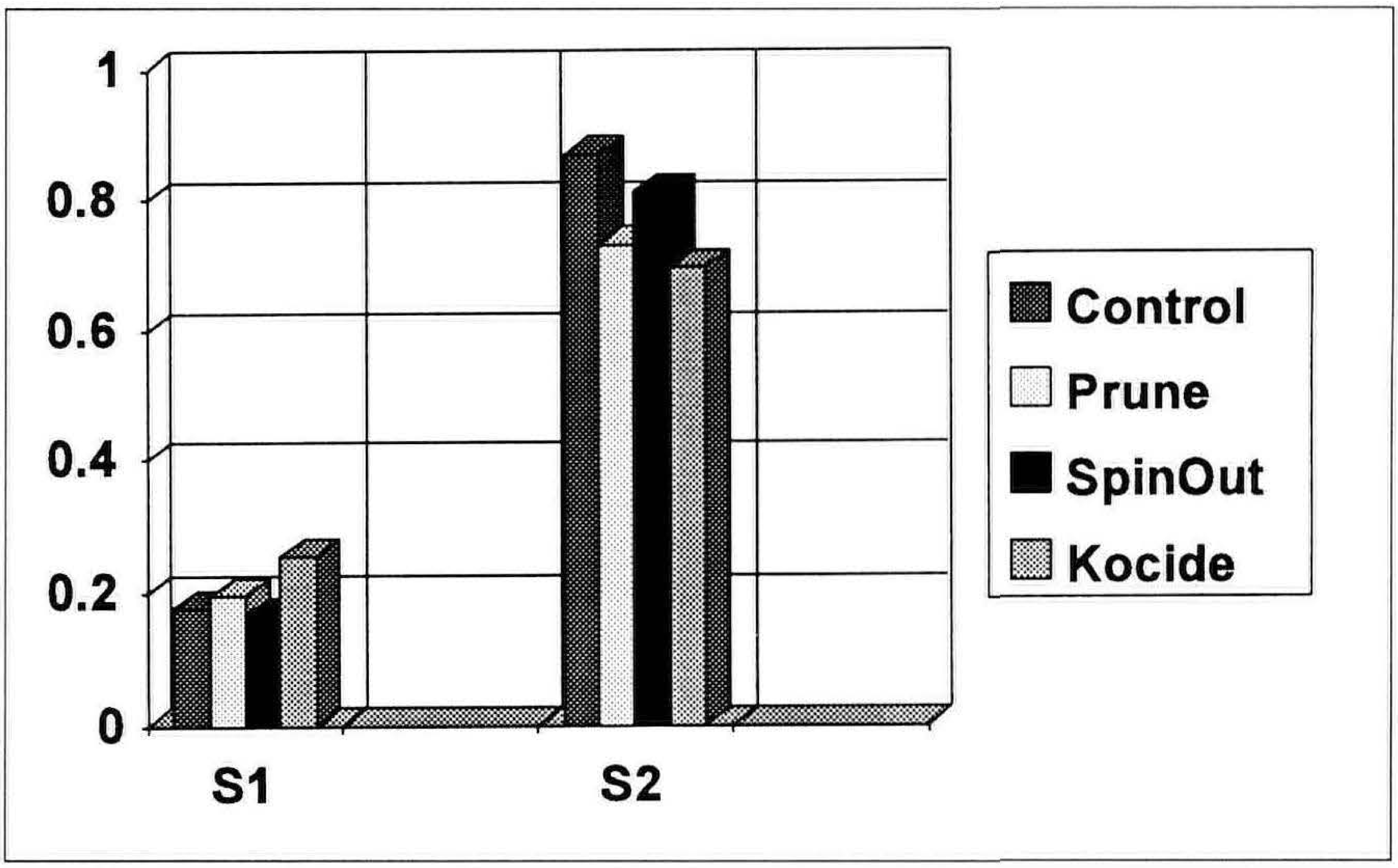

Figure 2. *Eucalyptus grandis* shoot dry weight (g).

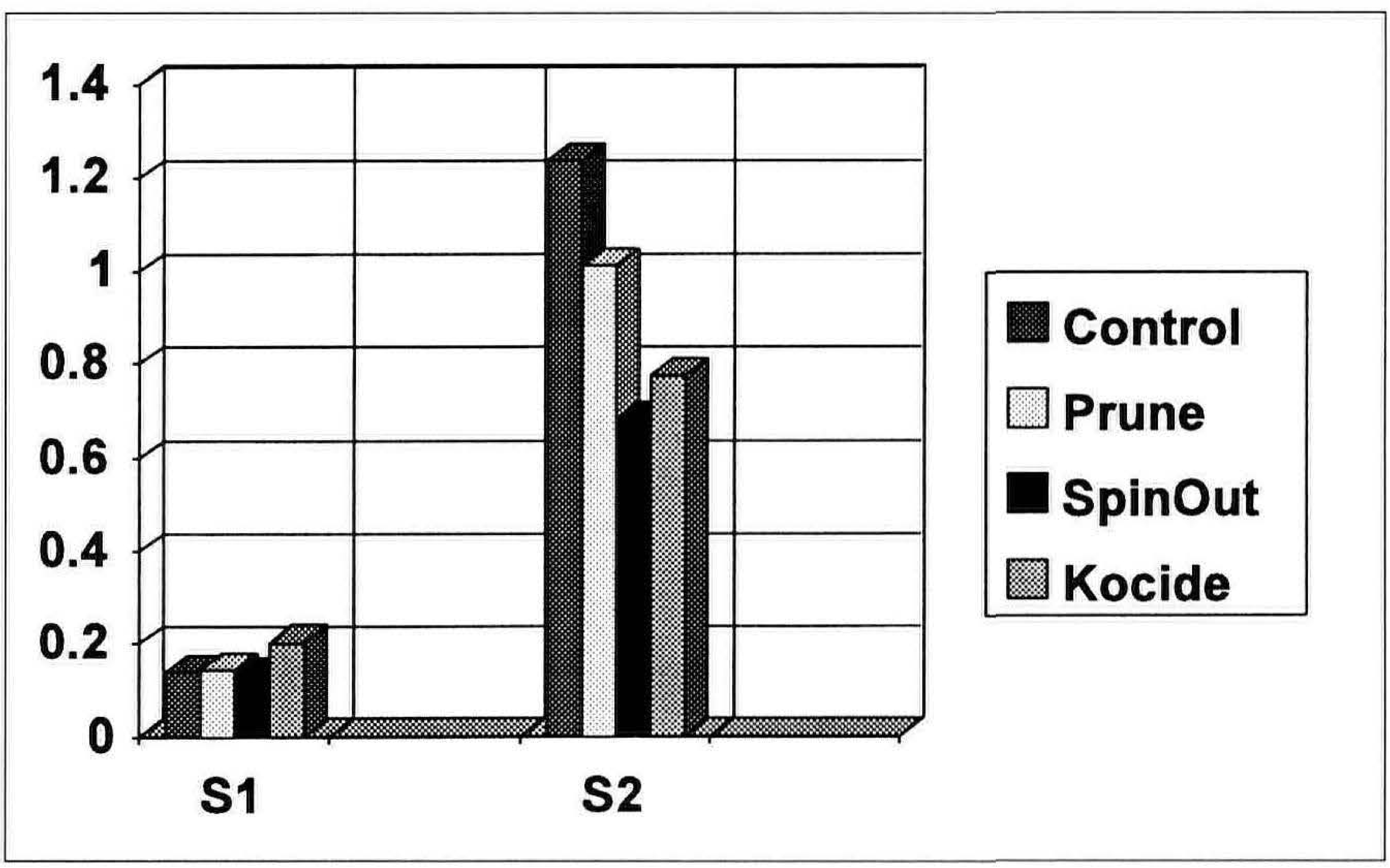

Figure 3. *Eucalyptus grandis* root dry weight (g). Note: Figure 3 root dry weight at S2 is root growth generated from the 50-mm tubes.

Shoot Growth. Fig. 1 illustrates that shoot growth of *E. grandis* in treated containers (S1) was not significantly suppressed with any of the copper treatments. Measurement of growth after further growing on in untreated containers (S2) was also not significantly suppressed.

Shoot dry weight (Fig. 2) was also not significantly different either at the end of growth in the treated containers (S1), or after further growth in untreated containers (S2).

Root Growth. Fig. 3 indicates that there was no significant difference at the end of the growing period in treated propagation containers (S1). However, after a period of further growth in untreated 140-mm containers (S2), root regeneration dry weight was significantly suppressed in those plants which had been grown in propagation containers treated with Spin Out™ and Kocide™ (at $P = 0.05$).

CONCLUSION

It is clear from the work of a number of researchers that the use of copper for woody root system control is an effective substitute for the various air-pruning systems outlined earlier in this paper. As more formulations of copper achieve registration in Australia, its popularity with nursery producers should increase.

The most significant current barrier to its use by nurseries is that it has to be applied to containers in the nursery. This constitutes another step in the plant production process and an additional cost to the producer, and many nursery producers will be reluctant to use the products for this reason. There is undoubtedly an opportunity here for the pot manufacturers to follow the lead of the Griffin Chemical company in the U.S.A. and supply pre-treated containers directly to the nursery producer. The additional convenience of purchasing pre-treated containers may make acceptance of this process by nursery producers more likely.

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Propagation and Production of *Ilex* species in the Southeastern United States

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Cultivars of *Ilex crenata, I. cornuta, I. vomitoria*, and *Ilex* hybrids comprise a very significant product group at Flowerwood Nursery Inc. of Mobile, Alabama, U.S.A. Flowerwood Nursery production facilities are located in Florida, Georgia, and Alabama. Consisting of 600 acres of field production and 600 acres of container production, Flowerwood Nursery serves independent garden centers, landscape contractors, and rewholesalers in the Southwest, Deep South, Southeast, and Mid-Atlantic areas of the United States. It is the largest wholesale nursery in the south. Evergreen rhododendrons and evergreen *Ilex* are the two predominant plant groups of that area. Our company produces 40 cultivars of hollies. The major three cultivars are *I. cornuta* 'Dwarf Burford', *I. crenata* 'Compacta' and *I. vomitoria* 'Nana', dwarf Yaupon holly. We will easily produce and sell 300,000 units of each primarily in 7-inch and 11-inch containers. Each cultivar is sold in smaller and larger sizes but in smaller quantities.

ILEX SPECIES

Ilex vomitoria. Commonly called Yaupon holly, *I. vomitoria* is native to our southern United States. Native Americans would drink the tea made from some portion of the plant, probably the leaves or seed and would vomit. I do not know the reason but that habit was common enough to have influenced the naming of the species.

The female has persistent bright red berries that are most ornamental and a few yellow-berried selections also are cultivated. The species is a small multi-trunked tree reaching 15 ft tall and 12 ft wide. However, the most popular forms of Yaupon holly are the dwarf Yaupon hollies, which can grow to be 6 ft tall, and have a mounding, very dense form, with gray-green small foliage, and no berries. Dwarf Yaupon is, as the species, widely adapted to soil pH, and is drought tolerant. In the landscape the shrub is mostly used for foundation plantings and maintained at approximately 3 ft tall. At least two cultivars, 'Schilling's Dwarf' and 'Stokes', are recognized as being widely cultivated, and there is considerable confusion as to which is which. Our cultivar is generally called 'Schilling's Dwarf'.

In 1994 'Bordeaux' dwarf Yaupon holly was introduced by our company. 'Bordeaux' is identical to dwarf Yaupon except the mature foliage is greener and the new foliage is burgundy, as is the winter color. We think we have dramatically improved a very good landscape plant with 'Bordeaux'. It is patented in the United States.

All other cultivars of *I. vomitoria* are typical of the species in form, with various horticultural features. Weeping Yaupon is the most unusual form. There may be more than one pendulous selection but the most recognized cultivar name is 'Folsom's Weeping' Yaupon. The leaves are small and the limbs dramatically sweep downward—a central leader is common. This selection is female. People either like it very much or find the form very unattractive.

'Pride of Houston' is the most widely known upright form. 'Pride of Houston' has a prolific, bright-red berry set and the leaves are bright shiny green and medium sized. 'Kathy Ann' has larger dark green leaves and a heavy berry set. The berries are dark red and large. 'Kathy Ann' is a new selection and our customers are anxious for any inventory that becomes available. 'Kathy Ann' has been well received. It is a selection of Mr. Dan Batson of Perkinston, Mississippi. 'Hightower' is a small grayish leaf cultivar with a strong upright branching habit. 'Hightower' is being grown as a small single-trunked tree. 'Shadow's Female' is a selection from Don Shadow of Winchester, Tennessee. The leaves are large, rounded, dark green, and flat. Cold hardiness is reportedly superior. The shrub appears to be very broad. 'Ocracoke' is a brand new selection from the North Carolina outer bank islands. Selected by Tim Gwaltney of Flowerwood Nursery, 'Ocracoke' appears to be fairly cold hardy and should be salt tolerant, being native to a coastal island. Winter foliage becomes shiny, almost metallic. The summer foliage is a pleasant green.

We have the best propagation success with Yaupon hollies after they have experienced some cold weather in October and November. Cuttings should be newly mature summer and fall growth about 2 to 3 inches long. It is important not to stick the cuttings more than 3/8 inches deep. Yaupon cuttings should be rooted in a very humid and enclosed environment. A high density of cuttings helps create this environment. If the cutting wood is soft, alcohol-based hormones can be harmful.

Ilex cornuta. Known as the Chinese holly, *I. cornuta* and its cultivars generally have lustrous dark green, spiny foliage. The leaves are leathery and can be 3 inches long and 2 inches wide. Some forms are shrubby while others are small trees. Most selections were made from a seed lot imported into the U.S.A. to Avery Island, Louisiana, from China in the early part of this century. Many of the original plants are alive on the plantation today. From less than 1000 seedlings many cultivars arose.

'Dwarf Burford' is the most significant. 'Dwarf Burford' is a dense shrub with a maximum height and width of 15 ft. Commonly, landscape plantings are sheared to 3 to 4 ft. Tolerant to a wide range of soil pH and conditions, 'Dwarf Burford' is a highly sought after shrub, valued for its foliage and form, not its fruit production. We strive to produce a dense bushy plant.

"Dwarf Chinese" or 'Rotunda' holly is another cultivar with a mounding habit. The leaves are bright green and very spiny. Once the most widely sold cultivar of this group, "Dwarf Chinese" in the last 15 years has been replaced by the sport 'Carissa'.

'Carissa' introduced by Wight Nursery of Cairo, Georgia, in the early 1970s is the second most popular Chinese holly. 'Carissa' has dark green foliage with a single spine at the end of a longer-than-wide leaf. The shrub is dense and wider than tall. A 10-year-old plant may be 4 ft tall and 6 ft wide.

'Burfordii' holly has large, 2¾ inches long and 2 inches wide, somewhat, spiny leaves. Mostly used as a multi-trunked, specimen tree, Burford holly has a heavy, profuse, red fruit set. The tree head is round. Other cultivars of note are 'Needlepoint', 'McIlhenny', and 'O'Spring', a beautifully variegated cultivar.

Ilex cornuta hollies should be propagated with newly matured or semi-mature wood. Overly matured and immature soft stems root poorly. Wood condition and nutritional level of stock plants are more critical than timing. Chinese hollies are heavy feeders and respond to high nitrogen levels. Scale insects can be a significant problem to old nursery plants or established plants that are stressed.

Ilex crenata. *Ilex crenata* known as a group as the Japanese hollies, is cold hardier than *I. vomitoria* and *I. cornuta*. Japanese hollies require acidic soil and will not tolerate extended periods of drought. Spider mites love Japanese hollies and can be an economic pest in production or be destructive to landscape plantings. Despite these limitations, the Japanese hollies are staples of gardens in many Southeastern states. The leaves are small, approximately 1/2 inch long and 3/8 inch wide. The shrubs are dense and dark green. Some cultivars can be trimmed to small specimens. The vast majority are mass planted as medium 4 to 5 ft hedges or 2 ft high foundation plants.

Ilex crenata 'Compacta' is the most popular cultivar. There seems to be two forms of cultivar in the trade, one of which has a larger flat leaf and slightly larger overall shrub size compared to the other which is smaller in general, with a slight cup to the leaf.

'Helleri' is the second most popular cultivar. The foliage is small, dark green, and leathery and the shrub will mature to 2 ft tall and is wider than it is tall. 'Helleri' is not tolerant of dry soil or very wet soils. Many nurserymen find 'Helleri' difficult to produce because of heat, therefore supplies are quite often short.

Other cultivars with different horticultural features are:

- 'Greenluster'—similar to 'Helleri' with more cold hardiness
- 'Soft Touch'—mounding, low growing and with soft foliage.
- 'Glory'—cold hardy and similar to 'Compacta'.
- 'Beehive'—very cold hardy, gray-green foliage, and somewhat upright.
- '151'—bright green and upright.
- 'Rocky Creek'—contorted branches.
- 'Hetzii'—cupped leaf and cold hardy.
- 'Chesapeake'—pyramidal, bright green, large with cupped leaves.
- 'Girard's Border Gem'—compact, dark green and very cold hardy.

Ilex latifolia. Luster leaf holly is maybe the largest-leaved evergreen holly. The trees are tall to 30 ft and pyramidal. Female selections are prolific fruit producers with many large clusters of fruit.

Ilex decidua. The possum holly, grows native in alkaline soils in the Southwest, Midwest, and southern United States. A large shrub, up to 20 ft, it grows wild in fence rows and along pasture edges. The fruit is prolifically produced and generally red but will occur as pinks and oranges. A fruited shrub adds beauty on a stark, drab winter day. The fruit is persistent until late winter and will disappear overnight when the birds determine that the fruits are ripe and delicious. Several selections have been made—but not enough. 'Warren's Red', 'Sundance', 'Pocahontas', 'Sentry', and 'Red Cascade' (syn.'Cascades') are a few cultivars. *Ilex verticillata*, the winterberry holly, is the common eastern U.S.A. deciduous holly. Occurring in acidic soil, this holly reaches heights of 12 ft. The horticultural characteristics are similar to *I. decidua*. This species has been hybridized and many selections for fruit size, color, and persistence and compact form are named. 'Bonfire' and 'Cardinal Red' are two cultivars.

Ilex cassine. The Dahoon holly with orange-red fruit is native to Florida and the Gulf of Mexico coastal area. It is a small tree to 15 ft tall. *Ilex cassine* var. *myrtifolia* is a smaller leaf form and somewhat hardier. Red-, orange-, and yellow-fruited forms are available. This native shrub can be sheared tightly and is attractive in a patio topiary form.

Ilex opaca. The American holly, is widely native to the U.S.A., with many selections. It is evergreen, and the female forms are the most desirable.

***Ilex ×aquiperni* 'Brilliant'.** This is a pyramidal and dense shrub. 'Brilliant' is very popular because it has very good cold hardiness, large red prolific fruits, and dark green foliage.

***Ilex glabra* 'Shamrock'**. 'Shamrock' is an inkberry holly cultivar. The species is native to the coastal plains from Texas to Maine. The species has a leggy, open form and is salt tolerant. 'Shamrock' is brighter green and compact. The fruit is black and the juice was once used for ink by early settlers. Other cultivars are 'Nordic' and 'Densafolia'.

Ilex integra. *Ilex integra* is a bushy, tall, upright shrub. It has large glossy leaves and thrives in coastal sandy soil, as well as, dry, alkaline tight soils.

ILEX HYBRIDS

Many evergreen holly hybrids are very beautiful and commercially produced. *Ilex* 'Nellie R. Stevens' is a hybrid of *I. aquifolium* × *I. cornuta*. This very widely used, large evergreen shrub can reach 15 to 25 ft in height. The large, dark green leaves are lustrous with 2 or 3 spines on each side. 'Nellie R. Stevens' is one of the best hollies for our area and has a vigorous growth habit.

Ilex ×*attenuata* is an interspecific hybrid between *I. cassine* and *I. opaca*. Many selections were made by E.E. Foster of Bessemer, Alabama. Only one, 'Foster's Number 2' is commercial. 'Fosterii' can be used as a foundation plant, hedge, or specimen. 'Fosterii' holly has dark green, glossy leaves, and pyramidal growth habit and fruits readily. 'Savannah' is another of that hybrid group. As a small tree, 'Savannah' is semi-deciduous and has bright red fruit. It can obtain heights of 30 ft. 'East Platka' is another discovered near East Platka, Florida. This cultivar is a female form with broad, flat, dark green leaves and few spines. It is popular when grown as a single trunk specimen or as a shrub.

Ilex 'Mary Nell' is a selection of Tom Dodd, Semmes, Alabama. 'Mary Nell' is a cross of *I. latifolia* × *(I. cornuta* × *I. pernyi)*. This tall, narrowly pyramidal, evergreen shrub is a female form with dark green, ribbed, spiny leaves. 'Mary Nell' was introduced only 15 years ago and is becoming very popular. Recently, Mr. Dodd released *I.* 'Lib's Favorite'. This cultivar has soft green, shiny foliage and is very vigorous. The fruit set is extremely heavy and the red berries are large.

Ilex×*meserveae,* Meserve holly, is an interspecific cross of*I. rugosa*×*I. aquifolium*. It is extremely cold hardy and does not like the southern heat. Several cultivars possess shiny, crinkled, dark glossy green foliage. The early releases, 'Blue Boy' and 'Blue Girl', are all but discarded. However, the later releases, 'Blue Prince', Blue Princess®, and Blue Angel®, are very successful in commerce. More recently, China Boy®, China Girl®, and 'Blue Maid' were introduced; 'China Girl' has proven to be more humidity and heat tolerant than other cultivars.

NEW *ILEX* HYBRID CULTIVARS

Many new hybrids are near release in the United States. Several open pollinated seedlings of 'Mary Nell' have been evaluated and named by Mitchell McGee of Poplarville, Mississippi. Three of these cultivars exhibit bright red foliage when the plants are actively growing. 'Little Red' is a shrubby selection which will be good for low hedges. 'Cardinal' and 'Robin' are larger in leaf size and growth habit. 'Oakleaf', with medium, dark green foliage shaped like an oak leaf, is an upright shrub. 'Festive' is a very compact small pyramidal shrub. The leaves are very spiny, dark green, and shiny.

Table 1. Liquid hormone rooting solutions for *Ilex* taxa.

IBA 1250	**KIBA 8000**	**IBA 1875**
I. crenata 'Beehive'	*I.* ×*meserveae* Blue Angel®	*I. vomitoria* 'Weeping Yaupon'
I. crenata 'Compacta'	*I.* ×*meserveae* 'Blue Prince'	*I. cassine* 'Myrtifolia'
I. crenata 'Border Gem'	*I.* ×*meserveae* Blue Princess®	*I. opaca* 'Carolina #2'
I. crenata 'Glory'		*I.* 'Hoogendorn'
I. crenata 'Greenluster'	**IBA 8750 + NAA 1500**	*I.* ×*attenuata* 'East Palatka'
I. crenata 'Soft Touch'	*I. opaca* 'Croonenburg'	*I.* 'Green Leaf'
		I. crenata '151'
IBA 6250 + NAA 750	**KIBA 10,000**	*I. glabra* 'Shamrock'
I. cornuta 'Burfordii'	*I.* ×*attenuata* 'Fosteri'	*I. crenata* 'Rocky Creek'
I. cornuta 'Dwarf Burford'		*I.* ×*attenuata* 'Savannah'
I. 'Fineline'	**IBA 10,000 + NAA 1500**	*I.* vomitoria 'Dwarf Yaupon'
I. integra	*I.* ×*aquiperni* 'Brilliant'	*I. vomitoria* 'Bordeaux'
I. cornuta 'Rotunda'	*I. latifolia*	*I.* 'De Worth'
I. cornuta 'O'Spring'	*I.* 'Martha Berry'	*I.* 'High Tower'
I. 'Wetumpka'		*I. vomitoria* 'Kathy Ann'
	IBA 8125 + NAA 750	*I. vomitoria* 'Pride of Houston'
KIBA 3000 + NAA 750	*I. cornuta* 'Carissa'	
I. decidua 'Warren's Red'	*I.* 'Mary Nell'	**IBA 8750 + NAA 1500**
I latifolia	*I. cornuta* 'Needlepoint'	*I.* 'Nellie R. Stevens'
KIBA 3000		
I. crenata 'Helleri'		

PROPAGATION

Ilex species and hybrids are generally easily propagated by cuttings of semi-mature wood. Cuttings are 2 to 3 inches long, and should be treated with a rooting hormone. Table 1 gives specified hormonal concentrations.

Micropropagation of *Luculia* Species

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A micropropagation method is described for selected forms of *Luculia grandifolia*, *L. gratissima* 'Rosea', and *L. pinceana*. Explants were taken in spring from new shoot growth. Continuous subcultures were necessary to reduce the leaf size, with the removal of the apical shoot to promote axillary branching. Murashige and Skoog medium with 3 to 10 mg litre^{-1} benzylaminopurine was used for shoot proliferation. Rooting was achieved using half strength MS with 1 mg litre^{-1} indolebutyric acid or 1 mg litre^{-1} naphthalacetic acid. Plants flowered in the second year after deflasking.

INTRODUCTION

Luculia grandifolia, *L. gratissima* 'Rosea', and *L. pinceana* are members of the Rubiaceae family. They are scented, frost-tender shrubs or small trees from the Himalayan regions of east Asia. Cutting-grown plants and seedlings are very susceptible to fungal infections and they are also sensitive to root disturbance, especially in the first year of growth and particularly over the winter months. Selected forms of each of these *Luculia* species were chosen for micropropagation. Economou and Spanoudaki (1985) used high levels of cytokinin for the micropropagation of *Gardenia augusta* (syn. *G. jasminoides*), another member of the Rubiaceae family. Trials began on the *Luculia* species following their published technique.

MATERIALS AND METHOD

Selected cutting-grown plants of each species were held in an acclimatisation area and sprayed with a general purpose fungicide. The explants were taken in spring from the new shoot growth.

Disinfestation was achieved after a dip in 95% ethanol, followed by soaking in a 0.6% sodium hypochlorite solution for 20 min. *Luculia grandifolia* required repeated dips in the sodium hypochlorite solution every 2 to 3 days until the plant material was clean.

The basic medium trialed for shoot multiplication, contained full strength Murashige and Skoog (MS) minerals (Murashige and Skoog, 1962) with Linsmaier and Skoog (LS) vitamins, 30 g litre^{-1} sucrose, 7 g litre^{-1} Davis food agar, with the pH adjusted to 5.6. The range of cytokinins included benzylaminopurine (BAP), furfurylaminopurine (kinetin), and dimethylallylamino purine (2iP) at strengths from 0 to 20 mg litre^{-1}. Plant pieces were subcultured at monthly intervals and held in a culture room at a temperature of 25C, photoperiod of 16 h, and light intensity of 2000 lux.

The media trialed for root formation contained half-strength MS minerals, LS vitamins, 20 g litre^{-1} sucrose, 7 g litre^{-1} agar, and a range of auxins [indole butyric acid (IBA), naphthalene acetic acid (NAA), and indole acetic acid (IAA)] at strengths from 0 to 10 mg litre^{-1}.

Rooted plantlets were deflasked into a 1 peat : 1 pumice sand (v/v) medium and held in a plastic humidity tent moistened by a fog system.

RESULTS

The explants required continuous subcultures to adapt to the environment. The higher cytokinin levels reduced leaf size, except with *L. grandifolia* which proved obstinate to these treatments and as a result fewer plants could be contained in the standard size container. It was necessary to remove the apical shoot to promote axillary budding at the base and then to lower the cytokinin level to allow branching and promote rooting.

The most favourable medium for shoot multiplication was MS with 10 mg $litre^{-1}$ BAP reduced to 3 mg $litre^{-1}$ BAP prior to root initiation. Rooting was achieved with 1 mg $litre^{-1}$ IBA and more particularly for *L. grandifolia* 1 mg $litre^{-1}$ NAA.

Flowering occurred in the second year after deflasking.

DISCUSSION

The vigour of these micropropagated plants overcame the susceptibility of cutting-grown plants and seedlings to fungal infection and root disturbance. In addition, this technique allowed for the selected forms to be multiplied quickly for release to the retail market.

LITERATURE CITED

Economou, A.S. and **M.J. Spanoudaki.** 1985. The in vitro propagation of gardenia. HortScience 20(2):213.

Murashige, T. and **P. Skoog.** 1962. Revised media for rapid growth and bio assays with tobacco tissue culture. Physiologia Pl. 15:473-97.

Propagation of *Corynocarpus laevigatus* and Cultivars

Jim Rumbal

Duncan & Davies Ltd., P. O. Box 340, New Plymouth

INTRODUCTION

The family Corynocarpaceae is a small genus of a few species native to New Zealand, the New Hebrides, and the New Caledonia region of the south-west Pacific.

Corynocarpus laevigatus, the New Zealand species, is a medium-sized tree, maturing at 10 to 15 m tall. It grows in lowland and coastal forests throughout the North Island and in coastal forests as far south as Jacksons Bay on the South Island's west coast, Banks Peninsula in the east, and the Chatham and Kermadec Islands.

Corynocarpus laevigatus, known as karaka by the Maori people and called the New Zealand laurel by early European settlers, has handsome obovate to oblong, rich-green glossy foliage, with entire margins. Small five-parted greenish-white flowers, arranged in terminal panicles, develop into 3- to 4-cm fleshy drupes, bright orange when ripe, with a nut-like seed. This was an important food source for the Maori people, who planted the karaka near their habitations. The fruits are extremely toxic and a great deal of preparation was required to prepare the kernels for eating. First they were baked in an earthen oven for several hours, then soaked

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The handsome karaka is under-rated as an ornamental plant. Although it is somewhat frost tender and must be regarded as only half-hardy, it will thrive in places as far south as Christchurch, as long as some shelter is given when young. In favoured mild climates, like those of the coastal North Island, karaka cultivars are useful in a wide range of outdoor garden situations. It is useful for coastal hedges, being tolerant of salt winds and light sandy soils. The cultivars as specimen plants are excellent in large pots or tubs for courtyard, terrace, or patio, where lush glossy leaves are desirable in the landscape.

Being largely a coastal species, the karaka has developed characteristics enabling the foliage to tolerate wind, salty air, and relatively harsh conditions. These attributes can be most useful in indoor horticultural situations. The glossy, leathery foliage tolerates drier, lower light conditions, and the fleshy fibrous roots withstand a wide range of soil conditions, as long as drainage is adequate and parching is avoided. This makes *C. laevigatus* a versatile, small, shrubby tree, useful for container growing for amenity horticulture, for city buildings, indoor shopping malls, covered atriums, foyers of hotels, and the like, where lush, glossy foliage conveys a cool clean atmosphere. The Auckland International Airport Authority have recently featured the karaka in its concourse gardens, the glistening foliage enlightening these indoor gardens superbly.

The species is propagated from fresh seed, which germinates readily in moist light humus containing compost at temperatures from 12C to 17C. As the juvenile seedling has a vigorous tap root, a deep liner tube or root trainer should be used so as not to restrict early root development. Airy, lightly shaded conditions and temperatures between 12C and 25C, will ensure the seedlings thrive. A potting compost with 4 to 5 kg/m^3 of controlled-release fertiliser, such as Osmocote 15-4.8-10.8, will promote good sturdy growth.

CULTIVARS THAT DUNCAN AND DAVIES HAVE RAISED

Cultivars that Duncan and Davies have raised over the years include the following:

***Corynocarpus laevigatus* 'Variegatus'.** Rich green foliage, broadly marginated with golden-yellow; compact and slower growing than the species, eventually 2 to 3 m tall and excellent as a tub plant.

***Corynocarpus laevigatus* 'Alba Variegatus'.** Dark glossy-green foliage, narrowly margined with crisp, white, slightly irregular variegation; vigorous strong upright bushy habit, 5 to 6 m tall.

***Corynocarpus laevigatus* 'Picturata'.** This cultivar is a bud sport of 'Variegatus', with reverse variegation—central golden and yellow marbled variegation, with green margins; vigorous bushy habit, 4 to 5 m tall.

***Corynocarpus laevigatus* 'Moonlight'.** This cultivar is similar to 'Picturata', but with pale lemon-yellow to cream-marbled, central leaf colour, with green edges—not as flamboyant, and with a tendency to revert to plain green; 3 to 4 m tall.

***Corynocarpus laevigatus* 'Brightly'.** A new cultivar, which arose as a seedling from 'Picturata', with clean golden-yellow margined young foliage, which fades to a clear cream margin with maturity. It combines the best of 'Variegatus' characteristics with those of 'Picturata' to produce a clean banded appearance and a vigorous, bushy, upright habit, to approximately 4 m.

Table 1. Rooting trials with *Corynocarpus laevigatus* cultivars.

Cultivar	Hormone	Rooting (%)	Month N.Z.	Weeks to root
Variegatus	IBA 1.0%	70	May	14
	IBA 0.8% + NAA 0.4%	70	June	12
	IBA 1.0% + NAA 0.6%	50	August	5
Alba Variegata	IBA 0.8%	95	June	8
	IBA 1.0%	80	May	15
	IBA 0.8% + NAA 0.4%	90	July	12
	IBA 0.8% + NAA 0.4%	96	May	8
	IBA 0.8%	50	May	8
Picturatus	IBA 0.8%	60	July	10
	IBA 0.8% + NAA 0 4%	40	July	10

+ = Combination Hormone IBA + NAA

PROPAGATION

The cultivars are all easily propagated during late summer to early winter from semi-hardwood cuttings with moderate intermittent misting or poly tent methods. Providing humidity is not maintained at a high level, gentle bottom heat of 18C to 22C is useful for rapid callusing. Wide wounding—a sliver of bark 1.5 to 2 cm long removed to expose cambium to hormone stimulation—will assist in more rapid and better rooting. Table 1. shows rooting trial results for *C. laevigatus* cultivars.

Because *Corynocarpus* cultivars produced from cuttings often lack the vigour and vitality that young seedlings have, grafting onto seedling understock is used to produce stronger young plants.

The oblique side graft is used with the incision made at ground level in the seedling rootstock in the manner of *Cedrus* grafting. An oblique whip cut is made at the base of a 10-cm scion, with a short cut made at the back of the whip tail and the cambiums are matched closely and tied together. The union area is buried in a light, airy, moist—but not wet—propagating medium, held at 18C to 22C to facilitate rapid callus formation. Foliage of the scion may be trimmed in half to reduce transpiration. The grafts are held in a moderately humid tent, or with light intermittent misting to maintain moderate humidity. After 5 to 6 weeks, the understock can be headed back and the graft potted up. Young plants produced in this way exhibit the juvenile vigour of the seedling rootstock and grow at twice the rate of cutting-grown plants of the same cultivar. Although grafting may be initially more costly, a quicker crop turnaround can prove more cost effective.

Perennials with Potential

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Acanthus. A genus of great shade-loving plants that have been used extensively for landscaping. Newer forms, such as the golden-foliaged 'Hollards Gold', and some of the smaller species, such as *A. hungaricus*, offer many opportunities for more widespread growing and greater garden planting.

Alstroemeria. Long known and grown as a long-lasting cut-flower, the development of more compact and dwarfer forms offer the opportunities for much wider garden and pot use. The success in tissue culture of selected cloning, and the recognition of the potential of alstroemerias as pot or garden plants by the cutflower breeders, will see a great increase in their popularity. The first of these new cultivars are starting to appear from both overseas and local sources now, and are likely to appear in a steady stream over the next few years. The introduction of some of the more hardy species into breeding programmes will also see the range of garden uses of *Alstroemeria* increase.

Aquilegia. Charming plants with beauty in both foliage and flowers available in such a range of sizes, colours, and forms. New easily grown, seed-raised miniature forms are now available by colour, and present gardeners and nurserymen with many opportunities for these small, spring flowering beauties. Variation in flower colours and flower form of some taller growing types, also offer lots of promise with new, very dark, almost black cultivars appearing. Golden and speckled foliage types are not new but offer a different perspective and accentuate the wonderful foliage of aquilegias.

Arisaema. Fascinating and easily grown curiosities, whose very striking and different flower forms deserve more exposure and use as novelty garden or pot plants. The species *A. candidissimum, A. jacquemontii,* and *A. sikokianum* are fascinating and quite unforgettable, with attractive foliage and are much prized by florists if ever they can obtain them.

Argyranthemum. The bush daisy or marguerite daisy have been accepted as extremely easy and free-flowering plants in this country for years, but little effort apart from selecting different coloured forms has gone into their improvement. Recent breeding programmes in Australia, in particular, have started to produce dwarfer more compact forms, better for pot and patio culture and for sale as potted colour. This, I believe, is the tip of the iceberg with many more developments in flower colour and form likely to appear in the next few years.

Agapanthus. These are much maligned plants in this country but one of the best landscape plants available. Agapanthus are extremely tough and adaptable to dry and difficult soils, and hardy in most coastal parts of the country, although deciduous in colder areas. Tissue culture has seen, and will continue to see, the development of improved clones in a range of sizes and colours. Longer and more prolific flowering will extend possibilities for both landscape and pot plant sales. Cut-flower use also offers other possibilities.

Blandfordia. These are an Australian genera of bulbous plants whose long-lasting flowers are very beautiful and robust. The species *B. punicea* has proved amazingly hardy, and whilst slow to get started makes a wonderful pot, garden, or cutflower plant.

Canna. These are usually grown for their prolific summer flowering, but new dwarf and interesting foliage forms offer many possibilities as indoor and outdoor foliage plants.

Clivia. Another indoor or outdoor plant, clivia is very tolerant of dry and shady conditions, whose development away from the strong orange colours into the yellows and creams offer many exciting possibilities. Although slow to tissue culture and expensive from seed, new technology will see their much greater utilization in the future.

Corydalis. A long neglected group of plants which have been revitalized by the introduction of an easily grown, blue-flowered Chinese species *C. flexuosa.* Many other species, such as *C. cheilanthifolia, Pseudofumaria lutea* (syn. *C. lutea*), *Pseudofumaria alba* (syn. *C. ochroleuca*), and *C. wilsonii* also have great appeal both for their long flowering and most attractive foliage. These are easily grown plants, wonderful in shade with beautifully textured foliage, which I believe have the potential for much greater use.

Dahlia. The recent interest and rediscovery of simple species and species-hybrid types of dahlias opens up an entire new world of this most popular group. Of extremely simple form with superb flower colours, the species types offer a very different free, but later-flowering option. Great for garden and landscape use, and with the selection of smaller forms, prospects for pot culture are also on offer. Species such as *D. scapigera* var. *australis* (syn. *D. australis*), and *D. merckii* are two of great promise, and the most beautiful ferny foliage of *D. dissecta* coupled with a neat habit and long show of white flowers, makes this a stunning introduction with loads of potential.

Other areas of dahlia breeding, such as selection of the taller tree species in a range of flower colours and the introduction of genuine dwarfs for pot culture, are also exciting. Foliage colour and more self-supporting garden forms are other areas of attention brought about by the current very high interest in the old cultivar 'Bishop of Llandaff', bred in 1927.

Dianthus. Many different types and coloured forms of *Dianthus* exist, but the current work by Dr. Hammett, who is crossing *Dianthus* with border carnations, has the prospect of introducing an incredible variety of colour and flower markings. The prospects of obtaining more compact and self-supporting plants in colours including yellow, mauve, and apricot, is very real.

Digitalis. Perhaps more than any, the foxgloves typify the current trend and interest in cottage gardening. Other species such as the small growing *D. trojana* and possible other hybrids with it, offer the gardener and pot grower a very different range of types.

Geranium. The beautiful, blue flowered true geraniums, such as the long-known 'Johnson's Blue' (*G. himalayense* × *G. pratense*), have shown themselves to be wonderful garden plants. The use of tissue culture to propagate the more free-flowering, sterile forms, has also opened the way for more plants of this same cross and others like it, to be produced and grown more widely. The new Australian cultivar 'Chris Canning', is one such cultivar.

Hemerocallis. Hugely popular overseas, particularly in the U.S.A., but slow to take off here. Further work, particularly in the area of longer flowering, will improve this situation.

Cultivars, such as 'Stella d'Oro', 'Black Eyed Stella', and others, with good habit and a long well-displayed flower show, have to have great potential. The more miniature types are starting to be used as flowering pot plants, and their landscape use, particularly of the evergreen types, is enormous. The introductions of the almost white culitvars, such as 'Sunday Gloves' is an interesting development.

Heuchera. New forms of these easy free-flowering plants, have started to accentuate their considerable beauty as foliage plants, in addition to their prolific production of flowers. Many with either *H. micrantha* or *H. americana* parentage are now displaying an incredible variety in foliage patterns and colours, and some of the *H. sanguinea* hybrids have magnificently coloured flowers.

Hosta. Hostas have long been grown and worked on overseas, but many of the newer forms have only recently made it to New Zealand. Magnificent foliage plants offering many pot and landscape uses in a stunning array of foliage colours and forms. Recent developments in flower colours, fragrances, and greater pest resistance, has seen the advancement of many exciting new types.

Kniphofia. Another group of easily grown plants available in both large and small culitvars. The colour range of oranges, creams, and apricots has the potential to be expanded with the glowing scarlet and maroon colours that exist on the west coast of the U.S.A.

Lavandula. These are not perennials but shrubs closely associated with the popular cottage style of gardening. Plants cultivated since antiquity with selections made over the centuries, lavenders are now the subject of more intense selection and breeding here in N.Z., Australia, and most likely in other areas as well. Strengthening of colours, particularly into the reds and pinks, and the production of compact pot forms with long flowering periods are the current areas of emphasis.

Oxalis. A genus of bulbous plants that, while it strikes fear into the heart of many New Zealand gardeners, also provides a delicious edible vegetable—the yam and the national Irish symbol—the shamrock. Many of the smaller growing species are not weedy and are the most easy and rewarding winter flowering pot plants with lengthy displays of orange, pink, white, and dusky red flowers. Species such as *O. massoniana, O. obtusa, O.versicolor, O. bowiei* (syn. *O. purpurata* 'Bowiei'), and *O. purpurea* 'Alba' must have a great future as novel container plants.

Petunia. The introduction of the so called "Perennial Petunias" has taken the world by storm in the last few years. I see the development by Dr. Keith Hammett of the smaller flowered forms from *Petunia integrifolia* var. *integrifolia* in an exciting range of colours and with good hardiness and rain resistance, as a most exciting development.

Rhodohypoxis. South African plants hailing from the Drakenberg ranges in Natal, these small, starry-flowered, bulbous plants have become internationally popular. The development of double forms, has the potential to open up a completely new and exciting series to maintain their interest for many years to come.

Tiarella. A pretty group of white-flowering, shade-loving, little plants whose recent development of glossy and beautifully marked foliage forms has given them a new lift. These new forms hold their own as foliage plants and the addition of masses of sweetly-scented flowers is a bonus.

Thalictrum. Stately perennials of great charm, but the beautiful dwarf forms, such as *T. kiusianum*, have been completely overlooked but offer great promise as garden and pot plants.

Tricyrtis. The toadlilies have a strange fascination, but have never been considered here to have the beauty or flower power to elevate them in to the ranks of the more popular perennials. The recent discovery of some beautiful, large-flowered forms and yellow-foliaged types, may well change their current perception.

Viola. Many different violas are grown for their flowers and fragrance, but few are aware of the beauty of the fantastic foliage of some species. *Viola grypoceras* var. *exilis* (syn. *V. koreana*) and *V. hirta* (syn. *V. hirsuta*) are two wonderful species worthy of growing for their foliage alone.

Increased Rooting in Difficult-To-Root Hibiscus Cuttings by Heat Shock

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Treating the bases of cuttings with hot water (40C = 104F) for 15 to 60 min dramatically increased the rooting of difficult-to-root hibiscus cuttings.

INTRODUCTION

In the basal part of a cutting, all cells are differentiated structurally as well as biochemically. Therefore, potential sites for root formation have to dedifferentiate, i.e., lose their previously developed characteristics, if they are to become root initials. Adventitious roots are normally initiated close to preexisting vascular systems (Lovell and White, 1986). Several factors are known to influence the ability of cuttings to root. Successful rooting starts with having stockplants growing under optimal conditions (Andersen and Moe, 1986). Factors, such as light intensity, temperature, and nutrients, are not only affecting the growth of stockplants, but also the ease by which their cuttings root. These factors have been well studied and, while they may give better and faster rooting in easy-to-root cuttings, the effect is less in more difficult-to-root plants. Growth hormones have also been shown to have a major role in the rooting process. They have been used in propagation since their discovery in 1934, but they have not been able to significantly increase rooting in difficult-to-root cuttings (Wilson, 1994). At the I.P.P.S. meeting in Cleveland in 1990, a now retired plant propagator—John Wilde—told me about how propagators in the "old days" used hot-water treatments on difficult-to-root cuttings. Today, many effects of heat shock (i.e., from hot water) have been elucidated. However, these affects are at the molecular level where it has been shown, that heat shock turns on some of those genes that are controlling cell division. In Copenhagen, we have been working with some difficult-to-root cultivars of hibiscus. I, therefore, decided to reinvestigate the effect of heat shock on difficult-to-root hibiscus cuttings.

MATERIAL AND METHODS

Three cultivars of *Hibiscus rosa-sinensis* were used: Holiday (easy-to-root), "a red-flowered form" (intermediate rooting ability), and Casablanca (difficult-to-root). The stockplants were 1 year old and grown in a greenhouse at a minimum temperature of 20C. For additional information on growing conditions see Bertram (1991). Apical cuttings were taken from non-floral shoots, and excised just above the node of the second fully developed leaf. The base of the cutting was stuck through a small hole in a styrofoam plate (30 cm × 40 cm). The styrofoam plate was placed in a water bath at 20C or 40C for up to 2 h. Each treatment consisted of 20 cuttings and was repeated three times. After the heat treatment, the cuttings were rooted hydroponically as described by Bertram (1990).

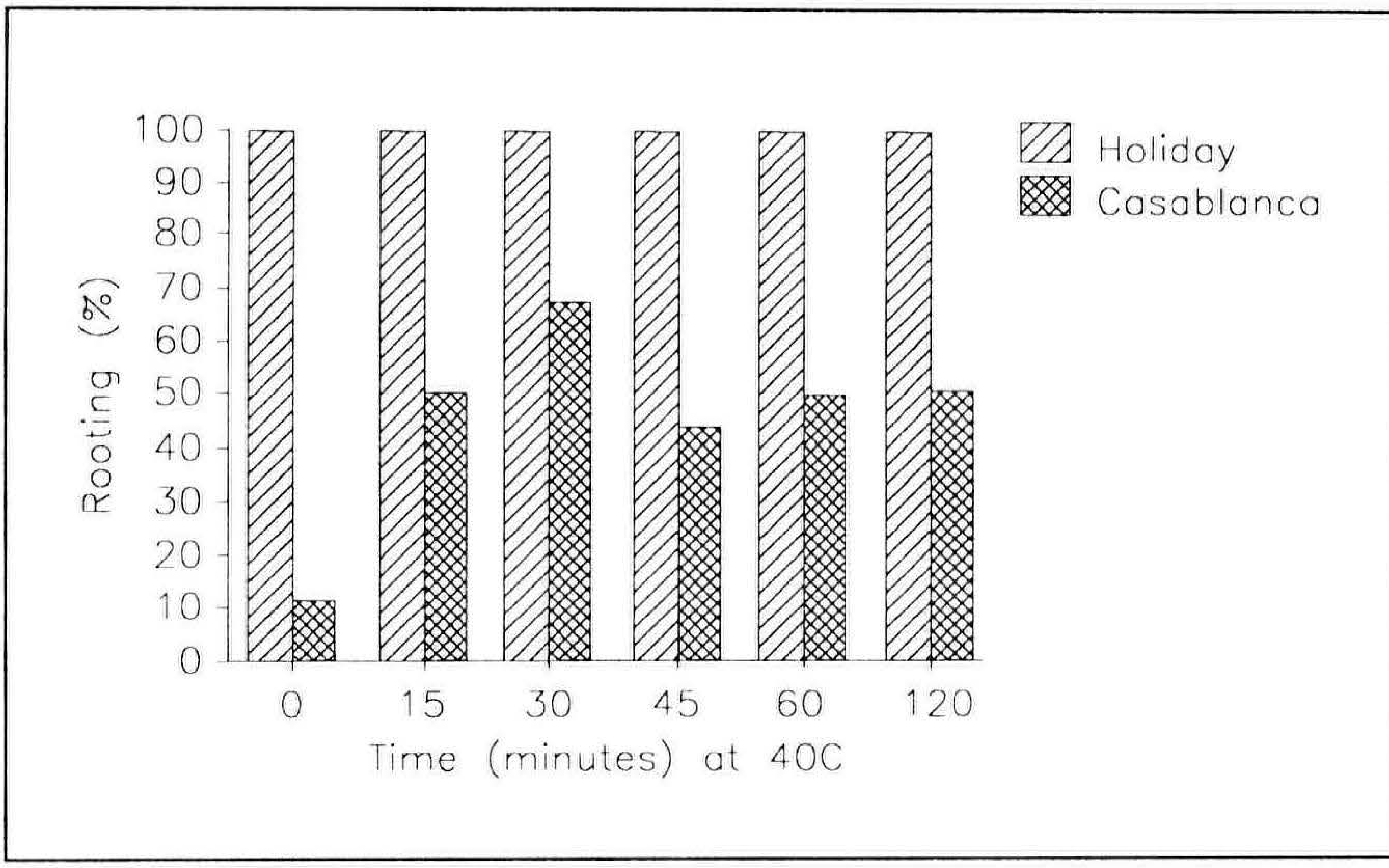

Figure 1. The effect of duration of a heat treatment on rooting of two cultivars of *Hibiscus rosa-sinensis*. The base of the cuttings were heated in hot water for the times indicated, whereafter the cuttings were transferred to room temperature. All cuttings were rooted hydroponically. Rooting percentage was determined after 26 days of rooting.

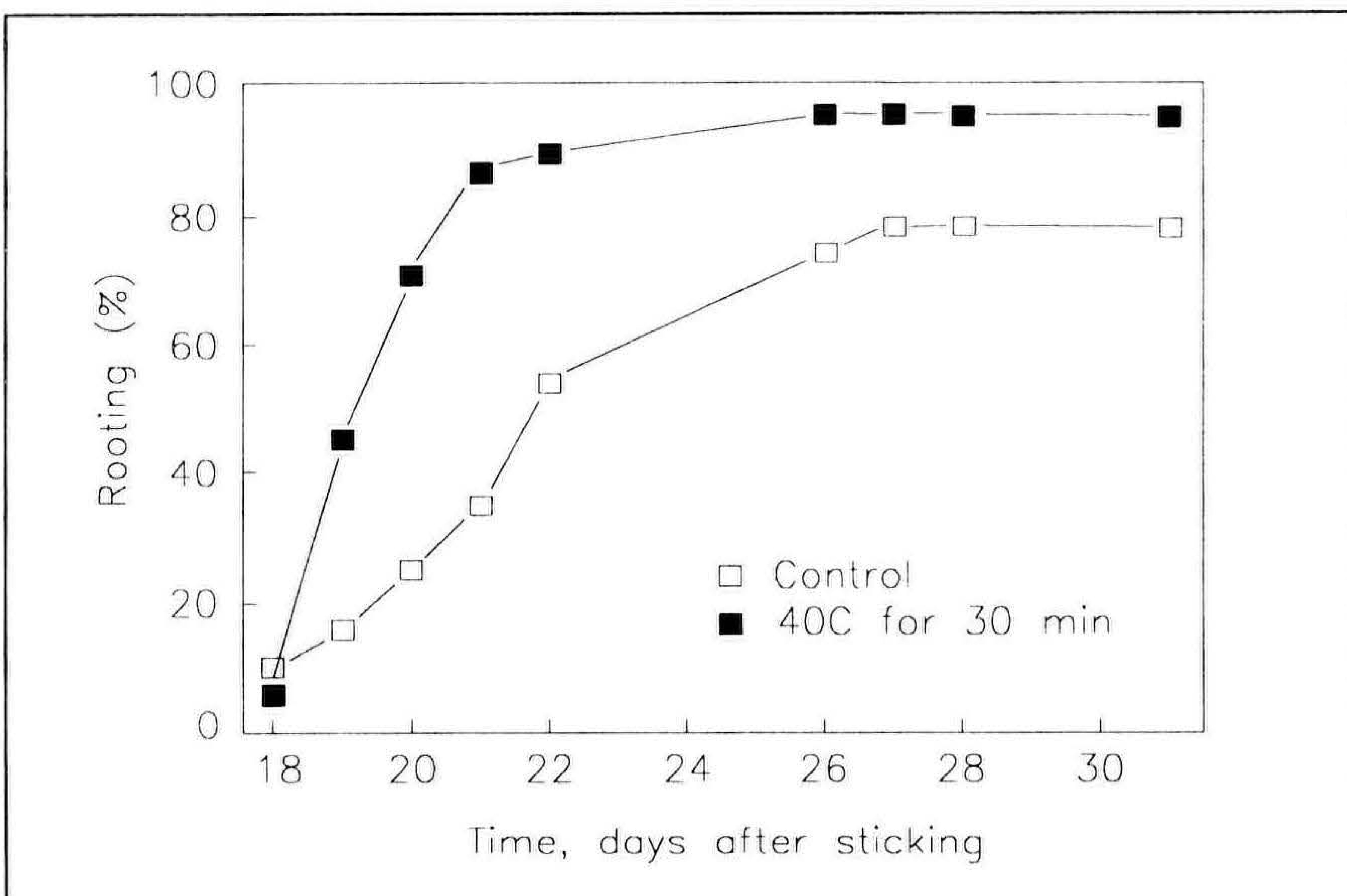

Figure 2. The effect of a 30-min heat treatment (40C) on rooting percentage of an intermediate-rooting cultivar of hibiscus (*Hibiscus rosa-sinensis* L., "a red-flowered form"). The bases of the cuttings were heated in hot water for the times indicated, whereafter, the cuttings were transferred to room temperature. All cuttings were rooted hydroponically. Rooting percent was determined during 30 days of rooting.

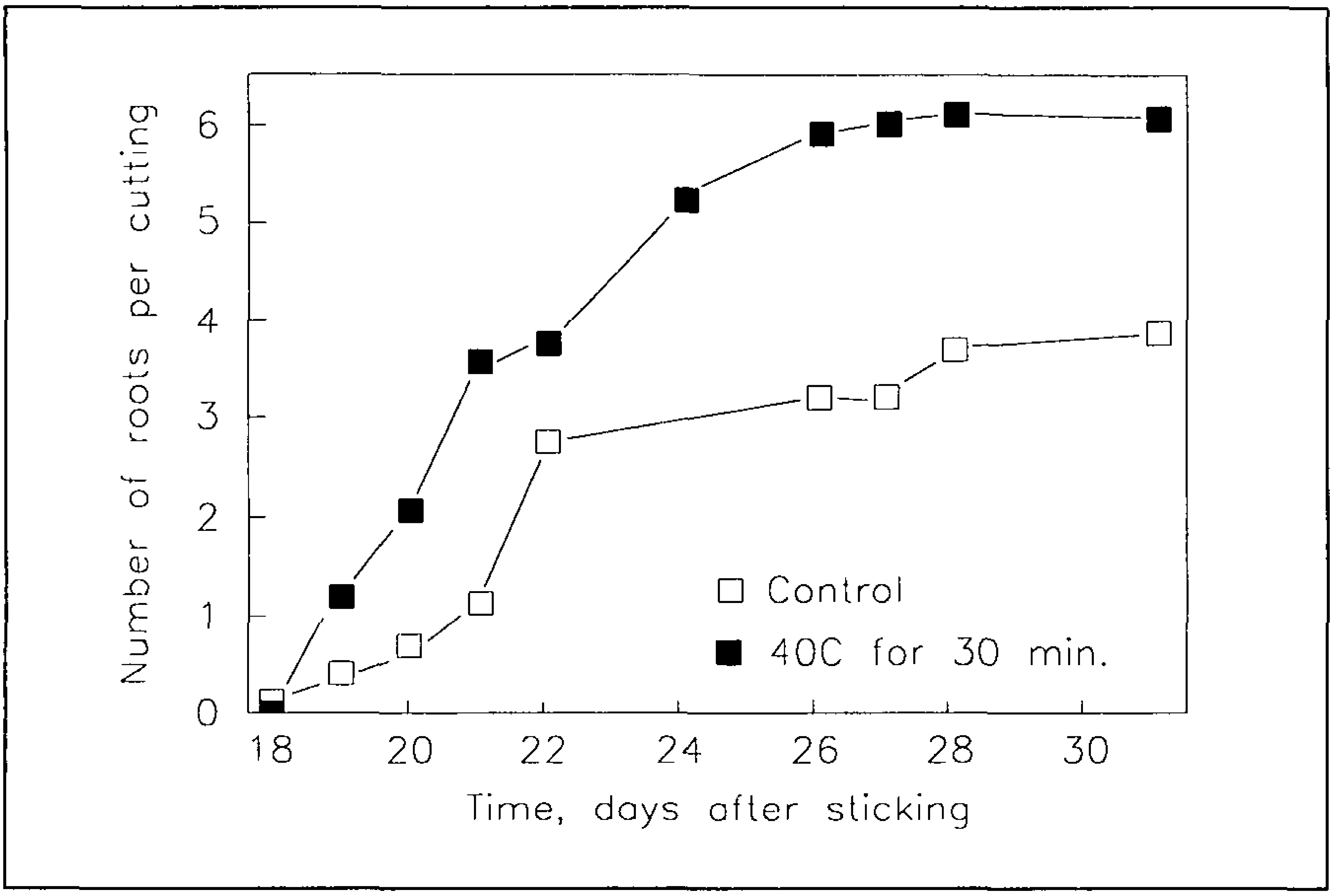

Figure 3. The effect of a 30-min heat treatment (40C) on the number of roots formed per rooted cutting from an intermediate-rooting cultivar of hibiscus (*Hibiscus rosa-sininsis* L., "a red-flowered form") The base of the cuttings was heated in hot water for the times indicated, whereafter, the cuttings were transferred to room temperature. All cuttings were rooted hydroponically. Root number was determined during 30 days of rooting.

RESULTS

The rooting of the difficult-to-root 'Casablanca' increased from 11% to 69% after a heat shock treatment of 40C for 30 min (Fig. 1), whereas the rooting of the easy-to root 'Holiday' did not respond to the heat treatment. Increasing the heat treatment time did not increase rooting of 'Casablanca'. The same effect was observed for the intermediate-rooting red-flowered form. A time course study on this cultivar showed both an increase in the rooting percentage and a decrease in rooting time from 26 to 21 days (Fig. 2). Concurrently with an increase in number of cuttings rooted, the number of roots per rooted cutting increased from 3.8 to 6.2 (Fig. 3).

DISCUSSION

Rooting temperature has been known to affect the rooting of cuttings since the beginning of this century, with optimal rooting most often found at temperatures from 18C to 25C. However, as far back as 1918, Curtis (1918) observed increased rooting in cuttings treated with 40C or 45C hot water. Although the effect of hot water treatment was well documented during the next decades, the practical use of this treatment ceased when rooting hormones and mist propagation became widely practiced. In recent years, I have not been able to find the documented use of hot-water treatments. Previous work on the propagation of hibiscus cuttings showed the importance of stock-plant condition (Bertram, 1991). However, even under optimized conditions, it was not possible to get satisfactory rooting in the difficult-to-root cultivar Casablanca. When the bases of these cuttings were treated with hot water, rooting was stimulated (Fig. 1). As little as 15 min was enough to stimulate rooting over control. The molecular changes that occur in plants from heat shock are now well documented (Howarth, 1991). A new set of genes are activated, while most of the previously active genes are turned off. These changes have been observed after a heat shock of as short as 10 min. (Lin et al., 1984). It is interesting to note, that some of the genes turned on by heat shock are key genes for the very early changes within the cell which must occur before the cell can start to divide. Because there was no effect of heat shock on the easy-to-root cultivar, heat shock may be that missing link in difficult-to-root plants that Wilson (1994) is calling the rooting morphogen. That heat shock stimulates early events in the rooting process may also be deducted by the fact that it accelerates the speed of rooting (Fig. 2). This happens because dedifferentiation of target cells occurred faster. It was also evident that more cells had become susceptible to division followed by differentiation into root meristems, because the heat shock treatment also increased the number of roots per rooted cutting (Fig. 3).

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Growing Heaths and Heathers in Europe

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INTRODUCTION

Through the ages heaths (Erica) and heathers (Calluna) have long been associated with humans from the thatching of dwelling houses, the making of ropes and pegs, the construction of roads, and dyeing of cloth to the recognised observation that some of the finest brands of whisky obtain their most delicate piquancy from heather in Scotland. However, heaths and heathers also have immense ornamental value: flowering year-round in a range of colours; having attractive spring foliage with red, white, or cream tips; and having golden, silver-grey, or dark and soft green foliage which, in the autumn, gives rise to fiery red hues. Garden cultivars have arisen through collection from the wild which in turn have given rise to sports and some cultivars have also arisen from breeding. Breeding and introduction of new cultivars have given rise to over 700 different types being grown and catalogued in Europe.

In the last 20 years, the professional growing of heaths and heathers has resulted in many specialist nurseries producing over 20 million plants each year.

NOMENCLATURE CLONAL STOCK

With a wide range of types and cultivars handed down through time and distributed, it was recognised by 22 members of the British Heather Growers Association that there was confusion and misnaming along with poor clonal material. In 1988, each member submitted one plant of each of their nurseries top 50 heaths and heathers.

These were propagated at HRI, Efford and in 1990 assessed for: trueness to type, vigour, form, density of growth, resistance to sun scorch, foliage colour, flower density, length of flower spike, and flower colour.

Five clones of each cultivar were short listed for growing on. In 1992 the final selection of the best clones was made. In 1993 the members received propagated plug trays of the selected clonal material which were then grown on for stock plants. In 1994 the new clonal material was available through members for sale to the garden centre trade.

STOCK PLANTS

With this new clonal material and other new cultivars, specialist nurseries select their mother stock very carefully each year. Many growers prefer to grow the mother plants in 3-litre pots which are then stood on sand-capillary and irrigated beds to ensure that the plants are adequately watered in summer and well drained in winter. In high rainfall areas stock plants prefer to have winter protection and are grown under glass or polythene structures.

An alternative method of growing stock plants is by growing on 90-mm pot stock plants into suitably prepared soil of the right pH and free of calcium carbonate. The stock plants are planted through a polypropylene mulch which eliminates weeds and helps to prevent soil-borne diseases from contaminating the foliage of the mother plants.

PROPAGATION

In mid summer heaths are the first to be propagated by cuttings. Cuttings are prepared 20 mm in length from fresh collected wood and inserted into 273-plug trays. Some prefer to strip the lower foliage in order to insert the cutting more efficiently, others prefer not to. After insertion, the cuttings are drenched with a fungicide solution of prochloraz and furalaxyl.

The trays are placed on sand beds and can either receive intermittent mist, fog, or be enclosed in shaded polythene tunnels. If mist is employed, water of the correct pH and calcium carbonate level must be used to obtain quality plants.

FUNGICIDE PROGRAMME

Heaths and heathers can suffer from many diseases when grown intensively especially so under protection and a fungicide spray programme is needed (Table 1).

Table 1. Diseases and fungicides used to control them.

Disease	Fungicide
Botrytis	Dichlofluanid
"	Iprodione
"	Chlorothalonil
"	Prochloraz
"	Thiram
Pythium	Furalaxyl
Rhizoctonia	Tolclofos-Methyl
Phytophthora	Furalaxyl
Cylindrocarpon	Benomyl
Pestalotiopsis	Prochloraz
	Carbendazim + Maneb

GROWING ON

Rooted cuttings are potted into 90-mm pots using an in-line, linear potting system, an ADAS potting bench, or potting machine. Increasingly, sand-capillary-irrigated beds are being used for growing heaths and heathers outdoors. These beds reduce losses, use the minimum amount of water, and avoid water application to the foliage. This in turn significantly reduces foliage diseases. Well drained beds through the winter ensure excellent survival of the root system, heighten the normal foliage colour, and ensure hardiness.

GROWING MEDIA

Propagation. No controlled-release fertilizer is added. Propagation media include 1 graded sphagnum peat : 1 graded pine bark (v/v) or 1 graded sphagnum peat : 1 medium grade perlite (v/v).

Growing on. Controlled-release fertilizer (2.0 kg m^{-3} 12-14 month) adjusted for type of irrigation and plant is added. Growing on media include: graded sphagnum peat or 3 graded sphagnum peat : 1 graded pine bark (v/v).

PESTS

Vine weevil, *Otiorhynchus sulcatus*. This pest can be damaging to the root system, causing death. The latest control measure is incorporating micro-encapsulated chlorpyrifos granules (trade name Suscon Green) into the potting compost. Alternatively, no control measures are incorporated into the compost, and good hygiene and monitoring for the pest are carried out.

Tortrix moth caterpillars. These are an occasional pest and are controlled by a routine programme using diflubenzuron, or when seen, by spraying with cypermethrin.

Aphids. These pests can cause considerable damage before being seen, and regular monitoring or occasional sprays are recommended usually Pirimicarb is used.

HEATHS AND HEATHERS

Heaths and heathers (*E. arborea*, tree heath; *E. carnea*, winter heath; *E. ciliaris*, Dorset heath; *E. cinerea*, bell heather; *E. erigena*, Irish heath; *E. tetralix*, cross-leaved heath; *E. vagans*, Cornish heath; *E.* ×*darleyensis*, Darley Dale heath; *E. praegeri*, Praegers heath; *Calluna vulgaris*, ling, heather, Scotch heather) enhance a garden with attractive flower and foliage for 12 months of the year, are hardy, and can remain attractive in the landscape, lasting 7 to 10 years providing they are well trimmed after flowering each year.

Technical Sessions

MONDAY MORNING, NOVEMBER 7, 1994

The Nineteenth Meeting of the Southern Region of the International Plant Propagators' Society convened at 7:45 AM at the Georgia Center for Continuing Education at the University of Georgia, Athens, Georgia, with President Dick Marshall presiding.

PRESIDENT MARSHALL: Good morning ladies and gentlemen. It is with great pleasure that I welcome you to the 19th Annual Meeting of the I.P.P.S. Southern Region in this wonderful facility, the Georgia Center for Continuing Education, on this beautiful campus of the University of Georgia in Athens.

I would like to congratulate the local site committee, under the direction of Dr. Mike Dirr, for the excellent accommodations, meeting rooms, tours, and all the special touches they have arranged for us. Yesterday's pre-conference schedule and the reception last evening at the State Botanical Garden of Georgia were indicative of the treat we are in for during the next 3 days as a result of the Site Committee's efforts.

Your program chairman for this meeting is regional First Vice-President Mike Miller and I want to thank him for assembling a fine technical sessions program for us. The fact that we have over 300 people registered for this meeting tells me that Mike has assembled a program tuned to our members interests.

At this time I would like to recognize members from other I.P.P.S. Regions who are present. From the Eastern Region are: Mark Cole, Pa.; Dale Depp, Michigan; Alan Jones, New Jersey; Jeff Lynch, Pennsylvania; Ron Simple, Pennsylvania; Randy Johnson, Washington, D.C.; Blaine Bunting, Maryland.; Bill Barnes, Delaware.; and Richard Bir, North Carolina. From the Western Region are: Wilbur Bluhm, Oregon, who is Secretary-Treasurer of the Western Region; Don Ekstrom, Oregon; and Ralph Pinkus, Texas.

Also, I would like to welcome any Southern Region members who are attending their first meeting. Would you please stand and give your name so we may all have the chance to make ourselves known to you over the next 3 days.

Welcome to all of our guests who are not members of the Society. We hope you will enjoy this meeting and want to become more involved in the I.P.P.S. If you would please stand and give your name we would like to meet you and make you feel welcome during the course of this annual meeting.

On behalf of the Southern Region, I would like to take this opportunity to thank Dr. Vivian Munday, our long-time Editor for the many years of service that she gave the Southern Region.

I would like to thank the people on the Editor Search Committee for the excellent job they did. They are Jim Gilbert, Mike Miller, and Don Covan, who chaired the committee.

Taking over the Editor's position, we have someone who really needs no introduction. He is a long-time member of the Southern Region-I.P.P.S., and has done just about every job imaginable up to and including the Presidency and serving as a Delegate to the International Board. The Board of Directors unanimously selected Dr. Fred Davies as your Editor and I know all of us welcome him aboard as Editor and look forward to working with him for many years to come.

Now I would like to introduce you to our host, Site-Committee Chairman Mike Dirr, and have him make some comments about the meeting.

At this time I would like to welcome to the podium Mike Miller, our Program Chairman, who will be in charge of the technical sessions during the next three mornings.

The first part of the morning session was moderated by Paul Tapia.

Incentive Pay In Propagation

Buddy Motley
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BACKGROUND

Most Nursery Jobs are on Incentive Pay. At our nursery, most jobs in propagation from taking cuttings to filling flats are on incentive pay or piecework. The incentive rates we pay vary from one job to the next. The rates are determined by using a study for distance and time. Each job has a job code number and a job code rate which it pays.

Incentive pay can increase your production as much as 300%. This must also be closely supervised for quality and consistency. On average, our crews usually consist of 10 workers.

Over 250 Job Descriptions In Plant Propagation. We have over 250 job descriptions just in propagation. For taking cuttings, each plant cultivar may have a different incentive pay scale. There are three different rates in taking cuttings: low, average, and high. This is determined by the availability of cuttings on each plant group.

Computer Software Systems. Our general operating software is maintained in-house. Software for inventory, production planning, piecework, and order processing were written at Flowerwood. We have modified other basic accounting functions (payroll, payables, etc.) to suit our requirements. The software was developed using a database management system and a specialized form of BASIC programming language. All of this runs on an operating system called Super DOS, which allows a standard PC to run multiple terminals. We run several of these systems. Flowerwood's main operation in Mobile and Baldwin counties uses a 486 PC to run about 40 terminals in four offices with various types of telecommunications equipment. We also have similar smaller systems in our facilities in Georgia, Florida, and northern Alabama, as well as the system which serves Flowerwood Liners. These systems can be linked for file transfer, on-line processing, and software maintenance.

BASIC USE OF PRODUCTION PIECE-WORK: HOW TO DETERMINE PAY RATES FOR PIECEWORK JOBS

Develop a Job Description. It is important to develop a job description, which includes exactly what must be done and what the finished product should be. After that, a job number is assigned.

Study Workers Performing the Job. Carefully study a group of workers doing the job that you have described. Chart the time of each worker and exactly how many production units or pieces each worker completes in the allocated time period. It is important to include **all** the time that the worker spends to accomplish the job. Typically, designated break times are subtracted from the job time. Trips to the rest room and other related work stoppages are included in the job time. This gives employees an incentive to stay on the job. A job study usually lasts anywhere from 2 weeks to 2 months depending on the frequency of the job, and theconsistency of the time data collected during the study.

Establishing a Pay Rate. Once you are comfortable with the data you have accumulated from the study, you are ready to set a pay rate. Take the amount of production units or pieces your average worker does in a 1-h period and divide that number into $4.25 (minimum wage). This will give you a minimum number of production units which a worker must complete in an hour (or any given time) to meet a satisfactory level of production for employment.

***Example* 1.** $4.25 (hourly wage) ÷ 212 (average number of production units completed in 1 h for a given job) = $0.02 (determined pay rate per unit or piece). Hence, the number of production units that an employee produces that is greater than the average 212 units (based on $4.25) is the *piecework incentive earnings.*

***Example*2.** If 400 units of production are produced per hour, than $0.02 (determined pay rate per unit) x 400 (amount completed in one hour) = $8.00 (money earned)—$4.25 is the hourly wage for this hour and $3.75 is the*piecework incentive earnings.*

Once a pay rate per production unit is set and an employee's hourly wage increases, they must complete more pieces an hour to meet the minimum production standard, which is the employee's hourly wage. If an employee produces less than the minimum amount for satisfactory production in a given time, then the employer's cost per piece increases because the employer must pay the minimum wage (or agreed upon hourly wage) regardless of the fact that the employee's production earnings fell below the hourly wage agreed to.

Establishing a Pay Rate for a Job Done by a Group. To use the piecework system for a job done by a group (i.e., filling and potting at the potting machine or loading a truck), take the total amount of production units completed by the group in a given time period and divide this number by the total worker hours used to complete the job. This will give you the number of units done per worker hour used.

Example 1. 20,000 units ÷ 48 h (6 workers @ 8 h/worker) = 417 units completed per worker hour. Credit each worker with 417 units for each hour they spent on the job and use this average as the basic piecework formula to figure incentive pay. A pay rate per unit of production for group jobs can also be established by using the same method as previously mentioned in the section on establishing a pay rate for an individual worker.

Recording and Analysis of Employee Time and Production Units. The employees time and production units completed for each job are recorded by a designated person, who is typically a crew leader/supervisor, and turned in at the end of the day. The numbers are entered into a computer program or processed to determine the employee's earnings for that job. The numbers and averages are posted in a designated area where all the employeescan see it. A report is generated at the end of the week which has all of the jobs an individual employee completed that week and their total piecework incentive pay for the week on one sheet (See Tables 1 and 2).

If a computer program is not available to calculate these figures and generate these reports, they can be done fairly easy and quickly by hand with a calculator.

Table 1. Some examples of how piecework works. Employee name, unit rate, total number of units produced, and employee total pay, which included the hourly wage + incentive wage.

Employee	Unit rate ($)	Units produced	Total pay	Hourly wage	Incentive wage ($)
Jose	.015	500	$7.50	$4.25	$3.25
Mike	.015	300	$4.50	$4.25	$0.25
Alice[1]	.015	200	$3.00	$4.25	-$1.25

[1] Note that with the third employee, Alice, the employer's cost per piece rises to $.021 because the company must pay the $4.25 even though the employee only produced $3.00 worth of units. This employee is working below the minimum standard of production for employment.

A Valuable Tool for Gauging Employee Productivity and Labor Costs. The piecework method is an excellent way to gauge employee production and track the labor cost involved in bringing a product to market.

Record Keeping by Crew Leaders. No matter what the task, a crew leader must record the following information:

- The name of the individual who did the work.
- Description of the work that was done.
- How many units were produced.
- The time it took to complete the job.

Crew leaders will use one the following methods to keep track of the work performed:

A) A pre-printed card 22 cm x 14 cm (8.5 inches x 5.5 inches)—best used for individual or very small groups and will tolerate exposure to inclement weather.

B) Standard 22 cm x 28 cm (8.5 inches x 11 inches) pre-printed paper sheets—best used for larger groups where various start and stop times and various task performed will need to be recorded. Samples of the forms used are found at the end of this article.

Stream-lining Record Keeping. To ease computation and record keeping for the crew leader, time is rounded to the nearest 5 minutes and converted into 100s, as indicated below.

Minutes	Hundreds
5	.08
10	.17
15	.25
20	.33
25	.42
30	.50
35	.58
40	.67
45	.75
50	.83
55	.92
60	1.00

To reduce the amount of writing required of the crew leaders, every task (or job) has been assigned a code number. Propagation has an additional set of code numbers for each type of plant cut and propagated. This second set of numbers for propagation helps in keeping track of additions to the inventory.

A sample of the daily production incentive earnings analysis at Flowerwood Liners, Inc. is shown in Table 2. Also included is the date, liner identification number, employee number and name, description of the job performed, plant name, percentage of pay rate, total hours, and the incentive pay earned.

Table 2. Daily production incentive earnings analysis at Flowerwood Liners, Inc. Included is the date, liner identification number, employee number and name, description of the job performed, plant name, percentage of pay rate, total hours, and the incentive pay earned.

Date 10/31/094 04:32 PM

Liner # done	Emp #	Employee name	Units	Description	Plant name	Pay rate(%)	Actual min.	Total hours	Incentive earned
For 10/28/94									
Liners									
011299	01133	Danita L. Hall	2074	Cuttings stuck	Azalea 'Gumpo Pink'	189	105	1.75	$11.17
011300	00133	Danita L. Hall	6480	Cuttings stuck	Azalea 'Hinode-giri'	229	250	4.17	$38.32
011301	00151	Katherine E. Winston	2098	Cuttings stuck	Azalea 'Gumpo Pink'	191	105	1.75	$11.44
011302	00151	Katherine E. Winston	6310	Cuttings stuck	Azalea 'Hinode-giri'	227	244	4.08	$37.18
011303	00409	Gabrielle Atkins Over	1836	Cuttings stuck	Azalea 'Gumpo Pink'	169	109	1.83	$8.58
011304	00409	Gabrielle Atkins Over	5094	Cuttings stuck	Azalea 'Hinode-giri'	194	244	4.08	$25.95
	GRAND TOTALS						1057	17.66	$132.64

Propagation of Camellias by Cuttings

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INTRODUCTION

Camellias are relatively easy to root. Our biggest problem is obtaining enough cutting wood. This is especially true with the *Camellia japonica* cultivars. At Hines Nurseries, Houston facility, we grow camellia cultivars of *C. japonica*, *C. sasanqua*, and *C. hiemalis*, and selected hybrids.

ROOTING CAMELLIAS

Collecting Propagation Wood. All propagation wood is collected from container-grown material. Normally, this occurs in July. We like to cut as early as possible to allow the stock plants more growing time before fall sales. Most of the cuttings are taken from plants that are 2 to 4 years old. In the first year of container growing, no cuttings are removed from the 1-gal container plants. This allows us to prune more frequently, which increases the branching of the young plants. When making cuttings, we only use tips that are about 15 cm (6 in.) long and firm. The color of the wood is green or light brown. The shoots are stored in a 10C (50F) walk-in cooler for 24 h or less before use.

Preparation of Cuttings. Preparation of cuttings take place indoors. During preparation the lower leaves are removed. Usually 3 to 5 leaves are retained per cutting, depending on the leaf size. We do not reduce the size of the leaves and the terminal bud is pinched off. The cutting is wounded by dragging the clipper along the side of the base. The wound is 2.5 to 5 cm (1 to 2 inches) in length. The length of the final cutting is 10 to 13 cm (4 to 5 inches). It is not precise, because we hold our cuttings in bundles and cut the bottoms off as a group. After the bottoms are cut, the bundles are held together with a rubber band.

Treatment with Rooting Compounds. The cuttings, still in bundles, are dipped for 2 to 3 sec in the liquid rooting compound, Dip & Grow®. We use a mixture of 5000 ppm of IBA and 2500 ppm of NAA. After dipping, the cuttings are immediately stuck into 8-cm (2.5-inch) rose pots at two cuttings per pot. Sticking depth is about 2.5 to 4 cm (1 to 1.5 inches). We are careful not to stick cuttings too deep.

Propagation Medium. The medium we use is 2 fine pine bark : 1 peat moss : 1 sand (by volume). To that we add 3.3 kg m^{-3} (5.6 lb yd^{-3}) of 18N-6P-12K (8-9 month formulation) Osmocote® and 0.6 kg m^{-3} (1 lb yd^{-3}) of Micromax ®.

Placing Cuttings in the Mist Bed. The cuttings are rooted under intermittent mist in a quonset house with 40% to 50% shading. The misting is done using brass spinners spaced 3.5 m x 4.6 m (12 ft x 15 ft). The duration of the mist is 6 to 8 sec. The misting frequency depends on weather conditions. Usually we will start the cutting crop off at a higher frequency for about 2 to 3 weeks, then reduce it to a medium frequency. Typically when it is hot the mist will come on every 6 min. The mist is turned on about 3 to 4 h after sunrise and is turned off 2 h before sunset.

Sanitation. Sanitation is important in camellia rooting. We disinfect our clippers with Consan® both when collecting and preparing the cuttings. By not cutting any leaves we reduce potential wounds where pathogens enter. To reduce disease problems in the mist area, foliage is provided ample time to dry before sunset—normally about 2 h. But in our humid environment, fungicides are still required. Cuttings are sprayed twice a week with a rotation of Daconil®, Clearys 3336®, Kocide®, or Bayleton® at the recommended rates. Application takes place after the mist is turned off at the end of the day. Once the cuttings are rooted, we make sure the quonset house is well aerated and that no watering is done late in the day.

Table 1. Rooting percentages of selected *Camellia* cultivars in 1992 and 1993 at Hines Nursery, Houston, Texas.

Cultivar	Rooting (%) 1993	Rooting (%) 1992
***Camellia* hybrids**		
Tom Knudsen (*C. reticulata* × *C. japonica*)	75	100
Yuletide (*C.* ×*vernalis*)	99	100
Camellia japonica		
Ave Maria	70	100
Colonel Fiery	85	95
Debutante	72	94
Grace Albritton	100	-
Julia Drayton	71	100
Mabel Bryan	99	100
Margie	75	99
Mathotiana Supreme	12	84
Charles Cobb	91	100
Nuccio's Gem	82	95
Pearl Maxwell	59	43
Pince Eugène Napoléon (syn. Pope Pius IX)	88	100
Professor Sargent	96	-
Rosea Plena	98	-
Scentsation	74	100
Kramer's Supreme	80	100
Nuccio's Pearl	97	98
C. sasanqua		
Bonanza	100	94
Cleopatra	98	100
Hana-jiman	100	100
Kanjiro	100	100
Setsugekka	100	95
Shishi Gashira	100	99
White Dove	97	-
C. hiemalis		
Shôwa-no-sakae	94	100

Rooting Period. Camellia cultivars differ in rooting time, but typically most are rooted within 3 to 5 months. We do not separate the cultivars as to rooting speed. All are stuck at basically the same time and all are removed from the mist at the same time. We like rooting camellias in quonsets because the rooted plants are then overwintered in the same area, saving labor to move the rooted liners to another area.

Liquid Fertilization of Rooted Liners. Liquid fertilization starts when the plants are in the latter stages of rooting, typically Oct. Those rates are 50 ppm of nitrogen and 20 ppm of potassium. Also, the plants are top dressed using 17N-6P-12K (3-4 month) Sierra® blend with micros in Jan. and April.

Rooting Success. Typical rooting percentages are in the 70% to 100% range. Table 1 shows actual rooting percentage for 1992 and 1993. These results are based on the number of pots that had quality plants rooted in them. There could be one or two rooted cuttings in the pot, but the key is that at least one rooted cutting must be a quality plant.

Cuttings that are stuck in July are mostly rooted by Oct. or Nov. After being overwintered in the same quonset, these plants are shifted into 1-gal containers in April or May. In the field, plants are pruned as needed until July, about 15 months later. It is after this pruning period that we start to take cuttings off of them.

Biggest Concern in Propagating. As stated earlier, our biggest concern in propagating camellias is obtaining enough cutting wood. Once that is accomplished there are few problems, as long as you follow basic propagation and growing procedures.

Perennial Propagation And Production On The Texas Gulf Coast

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INTRODUCTION

Customer demand for herbaceous perennial color has steadily increased over the past few years, and will continue to increase as customers become educated in the landscape attributes perennials have to offer. Methods of propagating, producing, and marketing herbaceous perennials are as diverse as the number of species and cultivars available. It is the intent of this paper to present methods of propagation, production, and marketing of herbaceous perennials in the Gulf Coast region of Texas.

REGIONAL CLIMATIC INFLUENCES

Treesearch Farms Inc. is located in Houston, Texas. Houston has a humid, subtropical climate and is located in Zones 8 and 9 on the USDA Hardiness Zone Map. Temperatures in Houston can exceed 38C (100F) in July, Aug., and Sept., and sometimes drop to -9C (15F) in Jan. The average growing season in Houston is 300 days, with the average first frost occurring around Dec. 1st and the last frost occurring around Feb. 22nd. Winter temperatures are often very mild and temperature fluctuations are a common occurrence, creating production problems for nurserymen.

During winter, temperatures may be 21 to 27+ C (70 to 80+ F) in the afternoon only to drop to below freezing during the night. Precipitation is greatly influenced by the Gulf of Mexico and usually occurs from thundershowers which move in from the southeast. The average annual rainfall in Houston is around 127 cm (50 inches), with March the driest month, and May and Sept. the wettest months. Frozen precipitation rarely occurs in Houston and when it does it usually takes the form of sleet. The most feared weather phenomenon are tornadoes and tropical storms, such as hurricanes, which can destroy nursery buildings, greenhouses, and plant material.

SEXUAL PROPAGATION (SEED)

Only 5% of the perennial propagation at Treesearch Farms is done by seed with plants that are either too difficult to root or can be produced more efficiently and economically through seed. Examples include: *Gaillardia, Penstemon, Coreopsis, Echinacea, Asclepias, Liatrus,* and selected ornamental grasses. The 10 to 12 perennials which are seed propagated are hand sown from Jan. to March. Seed is sown 2 to 3 per cell into 121 Plug Trays® filled with 1 Fisons #5 plug mix : 2 perlite : 2 fine pine bark (by volume) and lightly covered with the same medium. The seeded flats are placed inside a greenhouse and manually misted twice daily with an overhead mist bench system. Upon emergence, the young seedlings are drenched weekly with Subdue® to prevent damping-off pathogens.

ASEXUAL PROPAGATION (CUTTINGS & DIVISION)

Ninety-five percent of herbaceous perennials at Treesearch Farms are propagated asexually, with cutting propagation as the most common method. Two distinct advantages of cutting over seed propagation of perennials are: 1) better uniformity and 2) faster turnover. Soft, vigorous stems from newly potted 1-gal stock provides the best rootable cutting material, with rooting exceeding 95%. This process also provides well-branched, full stock.

All perennial cuttings are processed in early morning. Plug trays are filled the previous day with the seed propagation medium. Before the cuttings are stuck, they are submerged in a bleach solution containing 2 tablespoons of bleach and 5 gal of water to eliminate pathogens. Since some species may be chlorine sensitive, cuttings are resubmerged into fresh water just prior to sticking. In general, most cuttings are processed so that they are approximately 8 to 10 cm (3 to 4 inches) in length with leaves stripped at the basal end and leaves left intact on the tip of the stem. Cuttings basal ends are dipped into a rooting solution of 1 Dip-n-Grow® : 10 water (v/v), and stuck at a 1-cm (0.5-inch) depth into the moist rooting medium. The cuttings are rooted under mist inside a polyhouse equipped with fans and vents to provide good ventilation and stable temperatures. The mist bench is sterilized before the cuttings are placed inside using a bleach and water solution. The bench is covered with polyethylene sheeting to maintain high humidity and prevent scorching.

Mist duration and frequency varies with season and weather patterns. Mist duration is set at 4 to 6 sec during cooler months and 8 to 16 sec during warmer months. Mist frequency varies from every 15 to 30 min in the summer months to every 45 to 60 min in the spring and fall. During cloudy and rainy days, the cuttings are monitored and mist frequency and duration is cut back to prevent waterlogging and rotting. During winter months, bottom heat is used to enhance soil media temperatures and decrease the time to root cuttings.

Most perennial species are rooted and ready for removal after 14 days. Newly rooted cuttings are then placed in a hardening-off or acclimation area and monitored closely. During summer months, the rooted cuttings are hand-misted once every 2 to 3 h to prevent stress during the acclimation process. The young plants are fertilized through a Dosatron® Injector using a 300 to 400 ppm continuous feed of 20N-18P-18K Technigro-plus®. After 10 to 14 days, the young plants are actively growing and ready to be potted up.

DIVISION

Division of plants such as daylilies, rain lilies (*Zephyranthes*), and grasses, which do not come true from seed, is a quick, uniform method to increase production numbers. The time of the season is often critical for successful divisions. "Bulbous" plants such as lilies, society garlic, ligularia, and iris are more successfully divided during the dormant period, whereas grasses and sedge are more successful in the late spring and summer. "Bulbous" plants are gently divided by hand. The medium around the bulbs is carefully removed from the roots, damaged roots are trimmed back, and the bulbs are placed in slatted baskets and kept moist and out of direct sunlight until potting can begin. Bulbs are triangulated with 3 per pot and covered with 4 to 5 cm (1.5 to 2 inches) of pine bark medium. The triangle method produces a fuller, 1-gal plant in less time.

Ornamental grasses and sedges are divided using folding pruning saws or, for larger clumps, carpenters saws are sometimes used. The clumps are quartered and the leaf area is trimmed to prevent stress and facilitate handling. Damaged roots are trimmed off, and the divisions are kept moist and out of direct sun until potting can begin. With some grasses, the divisions are often too small to place directly into a 1-gal pot. In these cases, 4-inch pots with a peat based medium are used.

For larger divisions, plants are potted directly into 1-gal containers. The fresh divisions are placed in a 25% shaded greenhouse until active growth resumes and they can be placed in full sun.

PRODUCTION AND CULTURE OF PERENNIAL PLUGS

After acclimation and when the perennial plugs have begun to actively grow, they are brought to the potting table for transplanting. Generally, 2 to 3 plugs are planted per 1-gal pot in a medium consisting of 3 remilled pine bark : 1 Hadite® (v/v), with 3.6 kg m^{-3} (6 lb yd^{-3}) of nitrogen (Nutralene® + Nitroform®). During potting, the roots are gently reoriented to prevent circling and to help establish the root system more rapidly. The newly potted plants are placed on a nursery trailer and watered in with a solution of Superthrive® and Subdue®. The plants are placed inside polyhouses equipped with floor bottom heat, fans, and louver vents. The plants are watered by hand and are fertilized at each irrigation (fertigated) with 500 ppm soluble fertilizer using a Dosatron® fertilizer injector. The well water at Treesearch Farms has a pH of 8.4 and phosphoric acid is added to fertigation tanks to lower the pH to 6.5.

After approximately 6 to 8 weeks, the plants are well rooted in the containers and can be sold directly from the greenhouse, moved outside to the container yard for further growth, and/or used as stock plants for future cutting material. If the plants are moved outside, they are top-dressed with 21N-7P-11K Slocote® slow-release fertilizer and Ronstar® preemergence herbicide.

PESTS AND DISEASES

Constant monitoring of crops has proven very successful in early detection of disease and insect problems. The greenhouses at Treesearch Farms are scouted daily to check for insects and diseases, and the whole farm is walked twice a week. Most disease and insect problems are observed inside the greenhouses and coldframes where high humidity, low air circulation, and plant crowding help insects and disease get a foothold. Outdoors in the container production area where plants are under full sun, well spaced, and have good air circulation, very few problems are found.

White fly and spider mites are the main, persistent pests, and can cause unsalable plant material. An IPM approach is used to monitor the pest population with crops being flagged and subsequently sprayed as needed. Rotation spraying of Avid®, Enstar®, horticultural oils, insecticidal soaps, and synthetic pyrethroids, using two-cycle Solo® jet-pak sprayers has been very successful at keeping insect populations at non-damaging levels. In mid-summer, with high temperatures and relative humidity, root rot pathogens become very prolific. To combat root pathogens in perennial crops, top dressing with Banrot® or Subdue® granules has proved very successful. The biggest key in eliminating these types of problems has been the constant monitoring of plants by a well-trained staff.

PRODUCTION SCHEDULING AND SALES

One of the biggest challenges in growing perennials is knowing how many to grow, what species to grow during what time of year, and in what pot sizes. To solve this dilemma, we have added an option to our computer and inventory system. The option allows us to look at what species sold, during what times of the year, and in what pot size. With this monthly and biannual information, we can better plan production and have crops ready in a timely manner. This option has helped in eliminating some of the guesswork in perennial production planning.

One of the biggest problems facing perennial growers is selling plants when their growth has peak ornamental characteristics. This avoids the need for added inputs to keep the crop marketable. While the computer system has eliminated crop number guesswork, another piece of electronic equipment that has become a necessity is the fax machine. Each Friday, a weekly availability list is compiled with the following information: 1) species available, 2) size of plants, 3) price, and 4) a short commentary on the plant product. The fax is sent via computer modem each Monday at 8:00 AM and reaches 30+ retail nurseries and 30 to 40 landscape contractors and landscape architects. The fax program has been one of the best additions to our sales system, and has helped our customers immensely by eliminating travel time and plant locating. The Fax is also used to help us move crops that have been discounted so that no further maintenance and production inputs are put into the crop.

CONCLUSION

The demand for herbaceous perennial color has increased as customers have become educated in the landscape attributes perennials have to offer. Perennials are easily asexually propagated by cuttings and division. Constant monitoring of perennial crops for diseases and insects allows a more environmentally safe approach, if problems are recognized early and the proper control is implemented. Tracking of sales records by species, size, and numbers sold through computer records eliminates much of the guesswork involved with production scheduling. The weekly faxing of available plant materials to customers has been very helpful in selling perennial crops which are in prime condition. The fax machine can also be used effectively to move discounted crops so that further production inputs are not necessary. The lack of customer education is one of the biggest problems facing perennial growers. However, this problem can be minimized by informing customers and potential clients about the attributes of perennials! Good luck in your perennial production program!

Enhanced Propagation of Viviparous Water Lilies

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INTRODUCTION

The market for water garden plants has recently become one of the fastest growing facets of environmental horticulture. The most popular flowering water garden plants include species and hybrids of both tropical and temperate (hardy) water lilies (*Nymphaea*). Reliance on inefficient vegetative propagation techniques, requirements for large production space, and extended time periods to produce a salable plant limit the producers' ability to rapidly adjust to changes in market demand. Consequently, demand for specific water lily cultivars, particularly new introductions, can exceed growers' production capacity. Unlike other horticultural crops, information on the specific cultural requirements for efficient nursery production of water garden plants is lacking (Kelley and Frett, 1986; Brumback, 1990).

Clearly, more efficient propagation techniques for water garden plant production, including use of micropropagation techniques, are needed to enable aquatic plant nurseries to remain competitive. To date, very limited progress has been

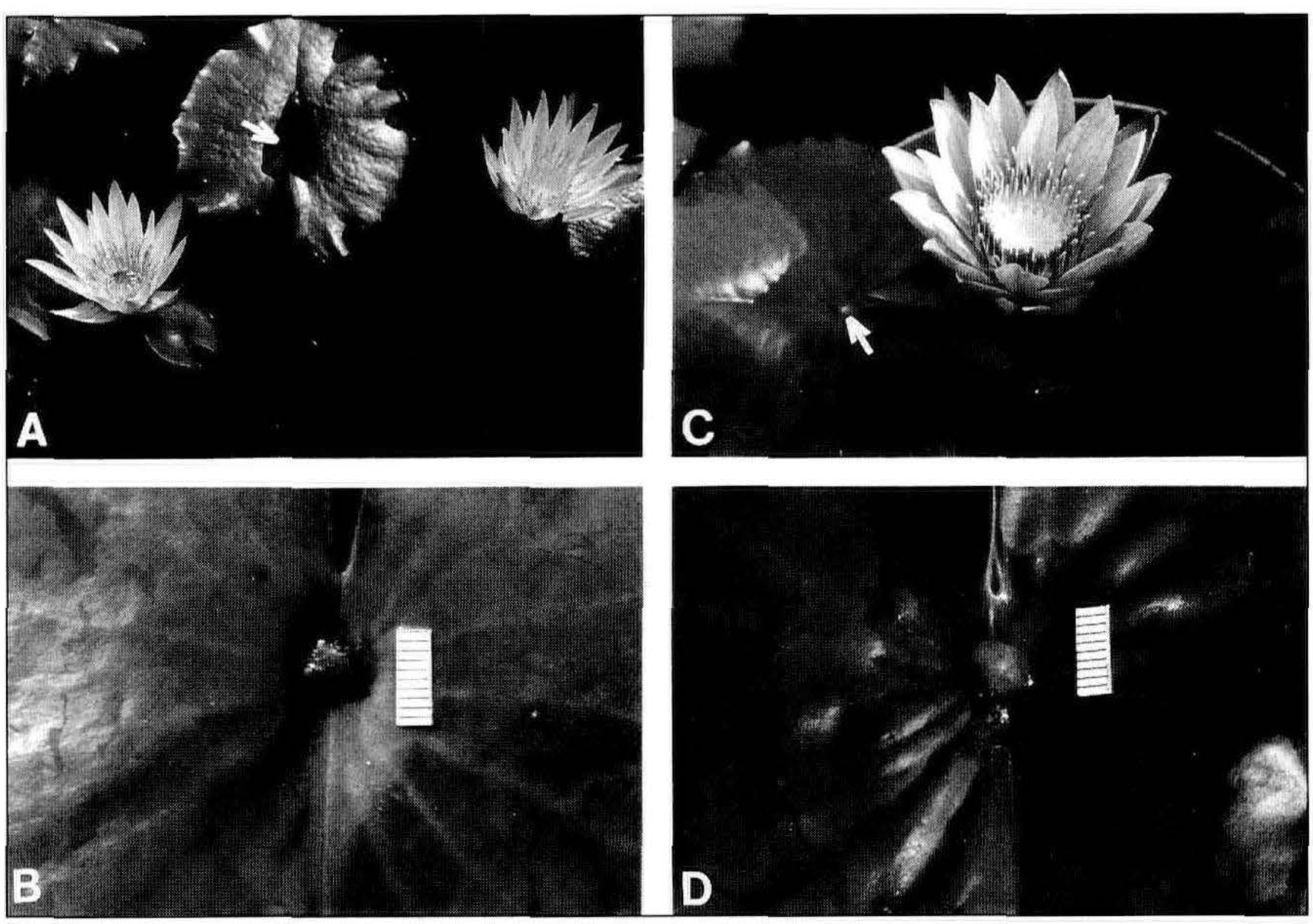

Figure 1. A. Flower and growth habit of *Nymphaea* ×*daubenyana*. Note presence of epiphyllous plantlet on floating leaf (arrow). **B**. Immature epiphyllous plantlet on floating leaf of *Nymphaea* ×*daubenyana*. Scale bar = 10 mm. **C**. Flower and growth habit of *N*. 'Shirley Bryne'. Note presence of epiphyllous plantlet on floating leaf (arrow). **D**. Immature epiphyllous plantlet on floating leaf of *N*. 'Shirley Bryne'. Scale bar = 10 mm.

made in developing commercially viable micropropagation protocols for water lilies (Jenks et al. 1990; Swindells, 1990; Lakshmanan, 1994). Consequently, other efficient production practices need to be evaluated which can be directly used by growers at minimal expense.

One alternative technique is possibly the use of plant growth regulators to enhance growth and branching. Growth regulators are widely used in the production of other ornamental crops. The use of plant growth regulator applications to enhance water lily propagation efficiency by forcing rhizome bud break has been proposed (Defeo, 1987). However, the efficacy of growth regulator applications on water lily propagation is untested. Certain tropical water lily cultivars are asexually propagated via the formation of epiphyllous ("viviparous") plantlets or offsets. These epiphyllous plantlets form at the junction of the petiole and the blade (Fig. 1). This method of propagation can be inefficient in some cultivars because of incomplete or slow plantlet development.

In a preliminary study, we examined the influence of the plant growth regulator Promalin® on epiphyllous plantlet growth in the viviparous tropical water lily hybrids *Nymphaea* ×*daubenyana* (highly viviparous) and *N.* 'Shirley Bryne' (moderately viviparous).

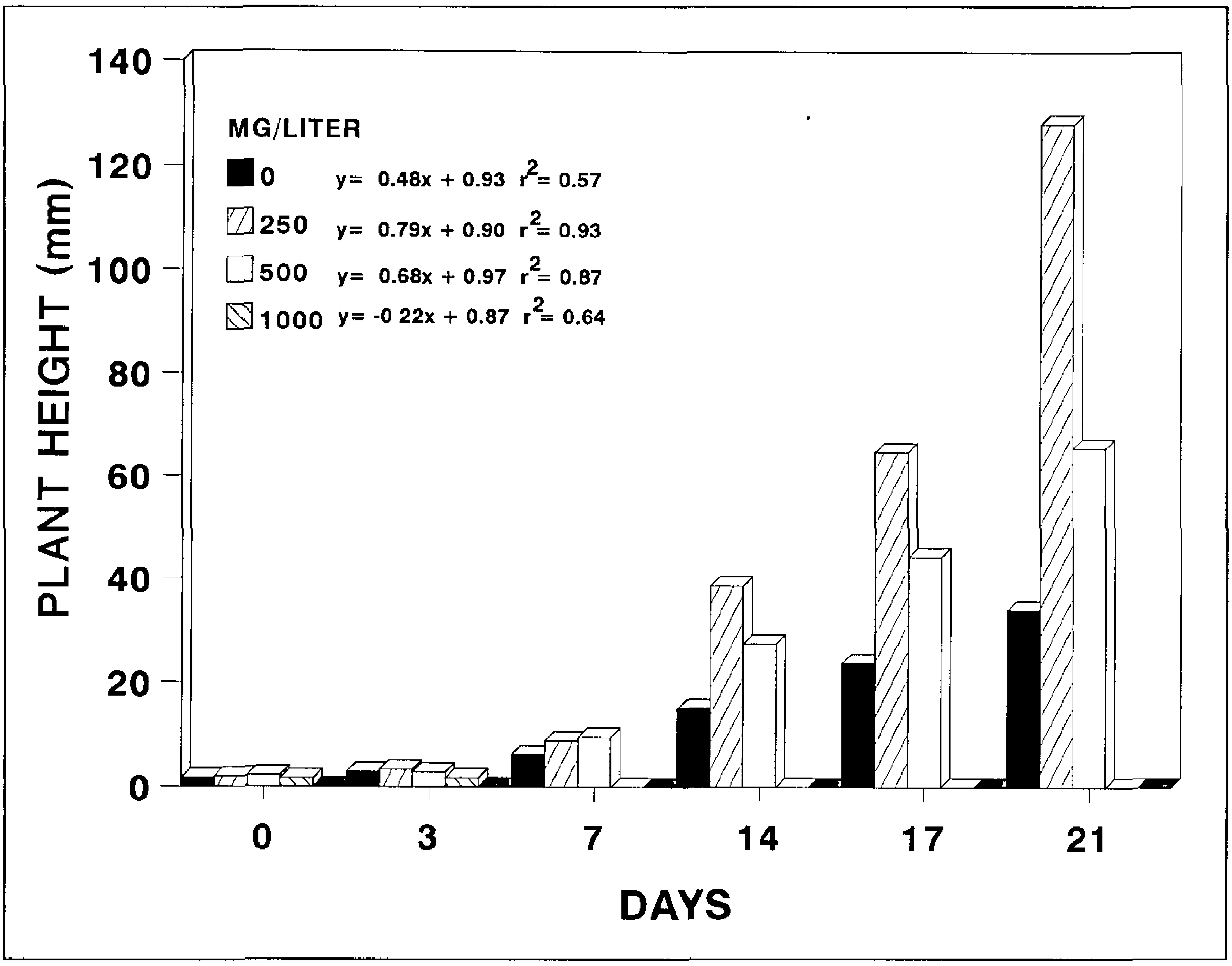

Figure 2. Effect of Promalin® on epiphyllous plantlet height in *Nymphaea* ×*daubenyana*. Each value represents the mean response of six replicate plantlets. Regression analysis was performed on logarithmically transformed data.

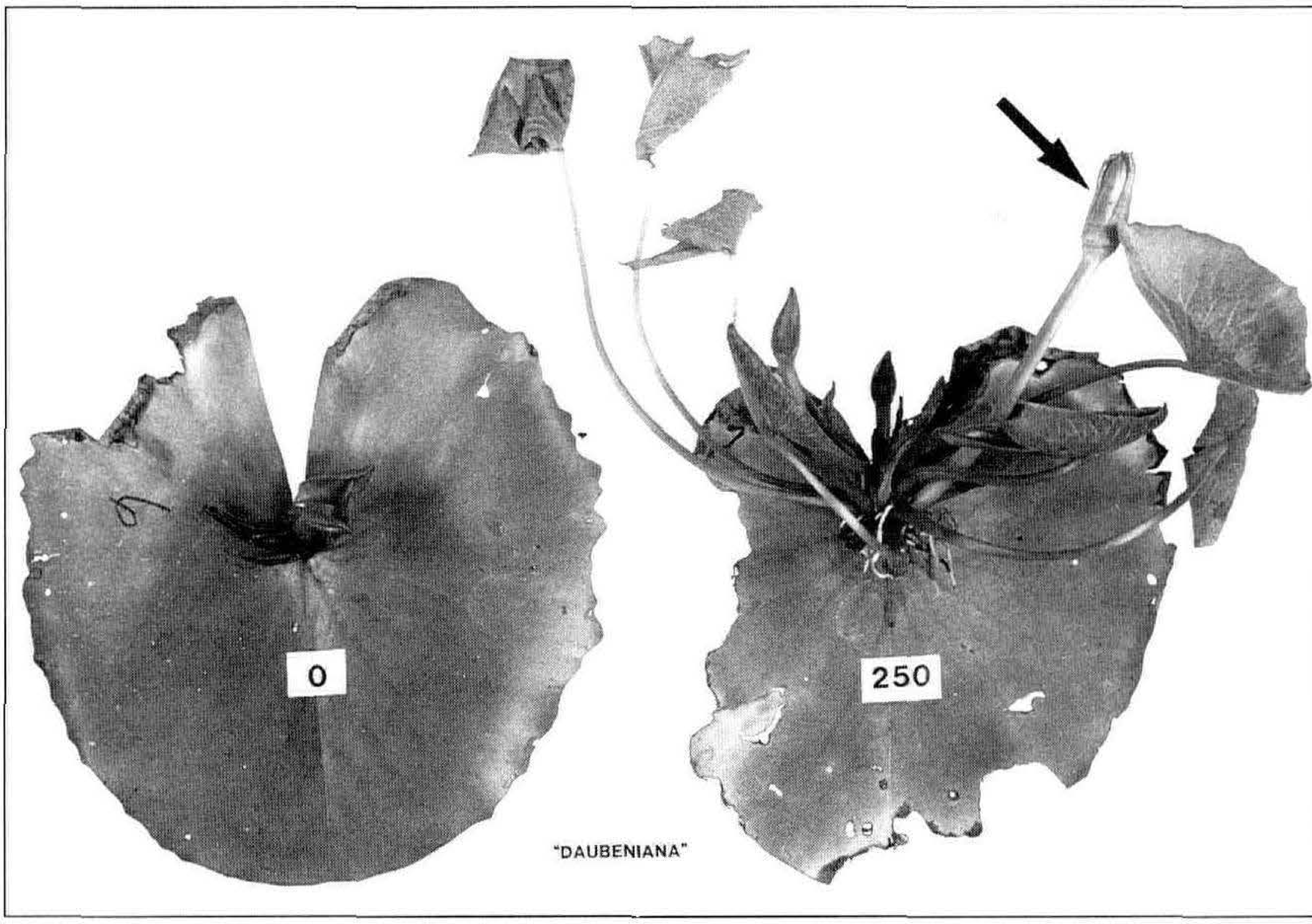

Figure 3. Effect of Promalin® at 0 and 250 mg Liter^{-1} on epiphyllous plantlet development in *Nymphaea ×daubenyana* after 21 days. Note presence of flower buds (arrow) on Promalin® treated plantlet. Scale bar = 10 mm.

MATERIALS AND METHODS

Stock plants of *Nymphaea ×daubenyana* and *N.* 'Shirley Bryne' were grown individually in 19-liter (5-gal) plastic pots containing Metro-mix 500® soilless potting medium (W. R. Grace, Fogelsville, Penn.) overlaid with a 2-cm (1-inch) layer of quartz sand. Each plant was fertilized monthly with three Sierra® 16.8N-7.4P-13.9K controlled-release fertilizer tablets. Water lilies were cultured under full sun in outdoor tanks constructed of landscape timbers lined with Permalon® PLY X-210 polyolefin film (Reef Industries, Houston, Texas). Promalin® is a proprietary formulation of 1.8% (w/v) N^6-benzyladenine (BA) and gibberellin$_{4+7}$ (GA_{4+7}) from Abbott Laboratories, North Chicago, Illinois. The concentrated stock solution was diluted with deionized water to prepare stock solutions containing either 0, 250, 500, or 1000 mg liter^{-1} (ppm) of BA and GA_{4+7}. Several drops of the wetting agent, Tween-20®, were added to each solution. Each treatment consisted of a specific Promalin® dilution applied as a single 50 microliter (µl) drop with a Pipetman adjustable pipette (Rainin Instrument, Woburn, Massachusetts). Treatments were applied directly to immature (1.0 to 3.0 mm long) epiphyllous plantlets on floating leaves. A 5 cm × 4 cm × 1.5 cm styrofoam collar was attached to the petiole of each floating leaf to prevent submergence of the plantlet. Treatment applications were made on day 0, 3, 7, 14, and 17 with six replicate plantlets per treatment. Measurements of epiphyllous plantlet height and basal diameter were made prior to each application. Final treatment effects on growth were determined on Day 21.

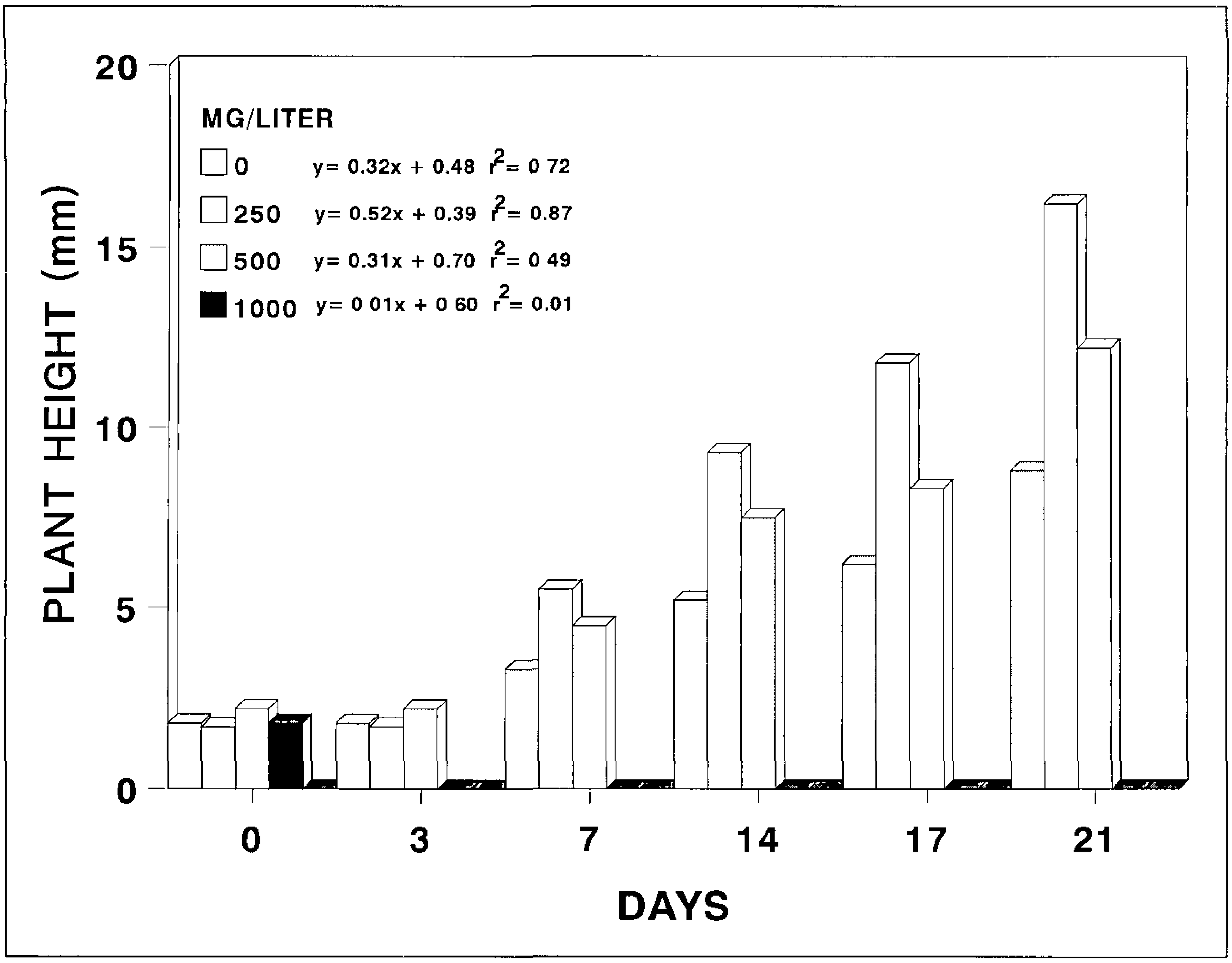

Figure 4. Effect of Promalin® epiphyllous plantlet height in *Nymphaea* 'Shirley Bryne'. Each value represents the mean response of six replicate plantlets. Regression analysis was performed on logarithmically transformed data.

RESULTS AND DISCUSSION

Nymphaea x*daubenyana* is a popular water lily which produces light blue narrow petaled flowers (Fig. 1A) and is considered highly viviparous (Masters, 1974). Promalin® treatments significantly promoted epiphyllous plantlet development in this cultivar. Treatment with either 250 or 500 mg liter^{-1} Promalin® significantly enhanced plantlet basal diameter (data not shown) over the control. However, maximum plantlet height (276% increase over untreated plantlets) was achieved following application of 250 mg liter^{-1}Promalin® (Fig. 2). By Day 21, plantlets treated with five applications of 250 mg liter^{-1} Promalin® were unbranched and highly rooted (mean: 11.3 roots per plantlet) and consisted of multiple leaves with elongated petioles and flower buds (mean: 2.8 flower buds/plantlet) (Fig. 3). Treatment with 1000 mg liter^{-1} Promalin® severely burned the epiphyllous plantlets following the second application.

Nymphaea 'Shirley Bryne' is considered a moderately viviparous water lily in which many of the epiphyllous plantlets produced do not develop to a propagatable size (D. Bryne, pers. comm.). Promalin® application also significantly promoted epiphyllous plantlet basal diameter and height in *N.* 'Shirley Bryne' (Fig. 4) but to a lesser degree than *N.* x*daubenyana*. Regardless of treatment, neither flower buds nor root development was observed on any *N.* 'Shirley Bryne' plantlets by Day 21.

Exogenously applied cytokinins promote both bud growth and branching in many plants (Wang, 1987). Cytokinin induced branching has also been shown to be enhanced with concomitant application of GA_{4+7} (Popenoe and Barritt, 1988). Although Promalin® application promoted epiphyllous plantlet growth, no branching was observed in the water lilies tested. These preliminary results, however, indicate that applications of cytokinin (BA) and gibberellins enhance epiphyllous plantlet development in viviparous water lilies and that treatment efficacy is cultivar dependent. Additional studies are required to determine the effects of: 1) other cytokinins alone and in combination with gibberellins and 2) plant growth regulator concentration and frequency of application on epiphyllous plantlet development. Any long-term effects of plant growth regulator treatment on the subsequent growth and development of the plantlets once they attain a propagatable size should be determined for each cultivar tested. However, the use of plant growth regulators for enhanced propagation of water lilies looks promising!

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The World of Hosta Breeding

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INTRODUCTION

Of the 1050 *Hosta* cultivars registered by the American Hosta Society through 1994, nearly half were hybridized by bees, yet the introducers of these cultivars dared to call themselves hybridizers. To date, there are only 12 serious hosta breeders in the U.S.A.

While controlled crosses are the norm with iris and daylilies, such is not the case with hostas—yet! Surely, with controlled breeding efforts, we could far surpass the random efforts of our winged friends.

BREEDING HOSTAS

The Breeding Program at Plant Delights Nursery. We began our breeding program in 1984 to do just that—to make controlled crosses. After researching earlier breeding efforts, we found that most of the breeding had been done using only two species,*H. sieboldiana* and*H. tokudama* (now elevated to specoid status). The reason that many hostas looked like large blue-green clumps was due to the lack of new genetic material in the breeding lines.We began our breeding program, designed to produce distinctive-looking hostas, using as many species as possible in our breeding lines. The following hosta specoid have been used in our breeding program to date: *H. capitata, H. clausa, H. fortunei, H. hypoleuca, H. kikutii, H. longipes, H. longissima, H. montana, H. nakaiana, H. nigrescens, H. plantaginea, H. pycnophylla, H. rupifraga, H. sieboldiana, H. sieboldii, H. tardiflora, H. tibae, H. tokudama, H. tsushimensis., H. ventricosa, H. venusta,* and *H. yingeri*

Breeding Hostas in Containers. While some of our breeding takes place on plants in the field, most crosses are done with plants in containers. Bee pollination, which can introduce unwanted pollen, is a problem when crossing in the field, so we have developed "hosta condoms" which are placed over the bloom stalk to be used as the pod parent. In the morning when the blooms are receptive, we remove the condom and make the cross, replacing it after we are finished.

When breeding hostas in containers, we take the containers into a cooled greenhouse, where there is no danger of stray insect pollination. The daily crossing is done between the hours of 8 AM and noon, depending on the ripening schedule of the pollen to be used.

Our Goals in Breeding Hostas. Our goal, since 1989, has been to make at least 200 different crosses each season. Each cross is repeated from 5 to 20 times, so that we are assured of good seed set and a representative set of offspring. When making interspecific and other wide crosses, there is a high percentage of failure of pollinated plants to set seed. In a given year, nearly 30% to 40% of our crosses fail to set seed due to this phenomenon.

Procedures for Breeding Hostas. Each cross is tagged on the bloom scapes which contains information on both the cross and the date of the cross. We leave the seed pods on the plants until they turn yellow, although the seed are actually mature within 30 days of the cross.

As the pods begin to yellow, the seeds are harvested and removed from the pods. The seeds are planted in a heated green house, with seeds from each cross sown in a community pot. A commercially prepared potting soil is used, and the seeds are covered lightly with the potting soil in the pot. The seed will typically germinate in 30 days or less. We will normally have to sort through about 20,000 seedlings each year.

By Dec., we have transplanted all of the desired seedlings into cell packs, usually culling down to 500 plants at this point. These seedlings remain in the heated greenhouse under 24 h of fluorescent lights, which speeds the growth of the seedlings. The young seedlings are fertilized weekly with a water soluble fertilizer. Hosta seedlings can be pushed without any dormancy requirement when they are at this age.

In May, these cells are transplanted into 1-gal containers, where the pots will fill with flowering plants during the summer months. By the end of their first summer, we hope to have reduced the number of plants remaining from the year's breeding efforts to 200 plants.

CONCLUSION

The goal of our breeding program is to produce attractive-looking, fast-growing, distinctive, fragrant hostas with good-looking flowers. Another goal of ours and many of the current hosta breeding programs are developing hostas with red leaves and flowers. While each hosta may not meet all of the criteria, it must fit our **10-ft rule**, which means that it must be distinctively recognizable from 10 ft away from any other current cultivar on the market.

To commercially bring a new hosta into the market will typically take about 7 to 10 years, varying of course with the use of tissue culture, or the size of market that one wants to reach.

Propagation of Wetland Species

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INTRODUCTION

Getting Started with Wetland Species. Three years ago I started researching constructed wetlands. Today, Flowerwood Liners is producing over 50 species and more than 200 cultivars of aquatic plants. From water lilies to native grasses, we are developing our own aquatic program to go along with our standard woody ornamental and liner production materials. Most of these plants are easily produced but there are few written resources on how to propagate these plants. Mike Kane (see the *Comb. Proc. Intl. Plant Prop. Soc.*, Vol. 44) reported on the progress being made in tissue culture production of aquatics. In this paper, I will present a general overview of the uses and propagation techniques of some of the other wetland species.

The Three Distinct Markets for Aquatic Plants. There are many uses for both native and exotic aquatic plants. There are three distinct markets for aquatics: mitigation or restoration, constructed wetlands, and ornamental water gardens. Each market has its own specific needs.

Mitigation. Mitigation is the reconstruction or enhancement of a natural native habitat because of construction or destruction by natural or unnatural causes. In the past this has been a very unpredictable market due to a lack of standardized regulations and enforcement by federal agencies. This unpredictability is a problem because of rapid growth of aquatic plants and, therefore, the short sales period before these plants become overgrown and pot bound and lose their marketability.

Constructed Wetlands. These are wetlands constructed not to recreate an environment but to clean up waste water.This area of aquatic nursery production, in my opinion, has the greatest growth potential. These systems are usually installed not as a primary, or solitary treatment for waste waters, but as the final stage treatment for many different types of waste water. Constructed wetlands are used in the treatment of municipal and rural sewage; agriculture—including swine, poultry, and dairy facilities; acid mine drainage, and landfill leachate. These are only a few examples of constructed wetland uses. Almost any type of waste water can be treated with a constructed wetland system.

Ornamental Water Gardens. These are as small as cut-off whiskey barrels and as large as 2 acres, and are being created specifically for the aesthetic beauty of the plants and animals that they possess. Water gardens are probably the hottest trend in the nursery industry. You can't open a trade journal without finding an article on how to build one or how to sell related products. Plants, such as water lilies with blue and purple blooms and night-blooming tropicals that only bloom after 8 PM, are some of the most beautiful works of art that God created. Of all the aquatic plants, water garden plants are more satisfying to grow, and give the grower a better appreciation of nature.

In the production of aquatic plants, there are generally three types: trees, shrubs, and herbaceous species. Flowerwood Liners has focused on the herbaceous species, mainly because of their ability to be used in all three markets: mitigation, constructed wetlands, and water gardens.

Propagation Techniques. In describing propagation techniques, it is important to have an understanding of the plant's growth characteristics and use. The propagation of some representative aquatic species is reported below.

***Sagittaria lancifolia* (arrowhead)** is a common native wetland species in the southeast U.S.A. It is prolific in fresh water marshes and shallow bays. This plant has an arrow or lance shaped leaf, is herbaceous in nature and can grow in 31 to 46 cm (12 to 18 inches) of water. Arrowhead is a hardy perennial that blooms all summer with attractive white petals and golden-yellow stamens. Propagation is fairly easy with the species. They can be propagated by seed or by division. To mass produce them from seed, collect the seed when the head is just about to shatter. Don't place them in cold storage, but keep them dry and out of the sun. In Dec., I place flats on old camellia rooting tables. The flats are filled with a bark mix that has the highest water holding capacity that I can find. The seeds are spread evenly over the trays and a thin layer of peat moss is sprinkled on top to keep them from drying out. I keep the soil saturated by irrigating at least 1 h per day. Within a couple of months seedlings come up. All *Sagittaria* species look the same at this stage, so it is important to label your trays so that there are no mix ups when transplanting.

***Sagittaria latifolia* (duck potato)** is named for its tuber. Ducks love to dig through the soft mud at the bottom of ponds and swamps to eat the tubers of this plant. It can be propagated with the same method described for arrowhead. Duck potato may be easier to propagate from their tubers than by seed, but we have found that seeds give us a more uniform crop.

***Schoenoplectus validus* (syn. *Scirpus validus*) (soft-stem), *Scirpus americanus*, (three square), *Scirpus acutus* (hard-stem), and *Scirpus californicus* (giant bulrush)** are all*Scirpus* species that can be easily propagated by division. Divisions should be kept wet and cannot be allowed to dry during any stage of the division process as this could be fatal. They are fresh water species that usually persist in coastal marshes and in some cases, fresh water swamps in upland regions. Soft-stem and three square are found in the southeastern U.S.A. in water up to 0.6 m (2 ft) deep. The hard-stem is a more northern USA species, has much the same growth habit and is indistinguishable from soft-stem, except for the bloom structure. Giant bulrush is well named—a very large species that can grow to the height of 3.7 m (12 ft), with stems up to 8 cm (3 in.) in diameter. *Scirpus californicus* is commonly used in agriculturally constructed wetlands, where high ammonia levels would normally kill most other wetland species. Division for all species is virtually the same. Each crown or rootstock can be divided into numerous divisions, with a minimum of one growing point per division.

***Pontederia cordata* (pickerel weed**), in my opinion, was unfairly named. It is a herbaceous perennial that grows in much the same environment as the*Sagittaria* species but unlike most native aquatics, it has a purple flower spike that persists all summer. Propagation is done either by division or by seed. Seed is normally not the chosen method because germination tends to be sporadic. Division can be done, as with Louisiana iris. The rhizome should be cut into sections that include at least one leaf stem. Carefully placed cuts can create many plants from only a few stock plants. They should be placed in water so that the rhizome does not dry out and until roots are established.

***Juncus effusus* (soft rush)** is similar, yet very different from the *Scirpus* species. Each plant has the same upright habit with tubular stems, but where soft-stem tends to spread in a downward and linear direction from the base, the soft rush has a clumping characteristic. All of the propagation that we have done has been by division with generally 100% survivability. We have collected seed and plan to study seed production over the next year. Soft rush grows in fresh water swamps and along streams throughout the southeastern U.S.A. They are very tolerant and have been found to even withstand grazing by cattle. Division is done by separating the rhizomes that grow in perpendicular sections with 6 to 8 stems per section. Do not divide these sections into pieces with less than five stems, because smaller sections are not viable. Plant in a saturated soil and fertilize monthly. Growth is slow at first but will become rapid after 2 months.

***Cyperus involucratus* (syn. *C. alternifolius*) (umbrella palm)** is native to the southeastern U.S.A., and grows in roadside ditches and shallow depressions. It can be seen in low-land areas on trips to Houston or Florida. Propagation is quite simple. The leaf structure is much like an umbrella with a central leader and blades radiating out like spokes from a hub. The head should be cut with about ½-inch of the main leader attached. This is pressed into saturated soil so that all of the central leader is buried. You can place the head upside down on the soil with overhead mist, but with this method you are at the mercy of the wind. Any slight wind can blow the cuttings off of the soil and destroy your propagation attempts. Umbrella palm will root within 1 month. The only care needed is constant watering.

***Spartina alterniflora* (smooth cordgrass)** is the most commonly used plant of all wetland species and grows in salt to brackish water environments. No plant comes more highly recommended than smooth cordgrass, which is the primary species used in Louisiana for shoreline erosion control planting. The Coastal Restoration Division favors it because it does not spread from the break water area. It also retains soil, protecting fresh water marshes from salt water intrusion during high water periods. Propagation has been primarily by seed. Other than our own collections, the only source that we have found is a northern supplier. We have started stock beds of *S. alterniflora* 'Vermillian', which is a Louisiana selection that was found to be superior during field trials when compared to other selections from the East Coast. Propagation by division has not been as successful, but there are a few tips I can give. Make sure not to break the brittle root stock. Plant the root stock as soon as the division is finished. Don't plant them too deep to avoid rotting at the stem. The root system, like the soft-stem bulrush tends to grow down into the soil. *Spartina* differs from other species that we grow because it sends a spike directly below its root system. This spike then grows into another plant or offset, and pushes deeper into the soil than the parent. Hence the plant is less susceptible to washing out and is excellent for erosion control.

***Spartina patens* (saltmeadow cordgrass)** is widely used, more in the regions of Virginia and Maryland than in Alabama, Georgia, or Florida. This is a very hardy plant, which grows well and is easily propagated by division. The stems are very small, and straw like. They are deceiving because even the smallest will be a viable bib if not split during division. The rootstock is separated at the base into single bibs and placed into a fine bark mix that has been thoroughly moistened. In 1 to 2 months a well rooted plant with new growth is produced. This species is tolerant of salt to brackish water, and grows right along the coast. It usually grows in tussocks that are submerged, although they have been seen growing on berms that were hard, packed, and dry.

***Juncus roemerianus* (black needle rush)** is another salt-tolerant species. When planted on brackish mud flats, black needle rush will spread, cover, and outcompete both smooth and salt-meadow cordgrass. The rhizome is linear and tends to spread in one direction at first. Propagation has not been a simple process, since this plant is not easily divided into small rhizome sections. Cooperative research is currently going on with Charles Gilliam and Gary Keever at Auburn University, studying hormone and growth regulator treatments that will promote root growth and establish smaller rooted cuttings for liner production. Black needle is needed in large quantities for mitigation work, but the larger plants required to maintain viability make availability limited.

***Orontium aquaticum* (golden club)** is a strap-leafed fresh water aquatic plant that can grow totally submerged or with only moist soil. Propagation from seed is effective. The best time to collect seed is during late April to early June. The seeds are round, bean-like capsules that when floated in water will readily sprout. What works best is to separate out the viable seed by allowing them to float and germinate in a bucket of water. The viable seedlings are then transplanted. Digging and collection of plant from its natural habitat is not recommended because of its deep root system. Even small plants can have a root system as deep as 30 cm (12 inches) in clay soils. Due to its gold bloom spike, it is mainly used as a water gardening plant. Because it is native, it can be used in both constructed wetlands and mitigation sites. When grown submerged, the leaves and stems have a reddish coloration.

***Equisetum hyemale* (horsetail, scouring rush, snake grass, and moses reed)** are just a few of the names that this plant has acquired over time. Horsetail grows in slow-moving streams all over the United States. It was used to clean dishes in the 1800s because of its vicinity to water and the cleaning ability of silicone filaments in its stems. The stems have an attractive segmented appearance. To obtain rooted divisions, lengths of the segmented foliage are cut and placed in a shallow pan of water. Within three weeks there will be small growing points at each node of the stem. It is best to let these rooted plantlets grow for a few weeks to get fully established before transplanting. Care should be taken during transplanting to prevent plantlets from drying out. Horsetail is very susceptible to desiccation and will die very quickly.

***Typha laxmannii* (dwarf cattail)** is a non-native species that is easily propagated by division. It is desirable because it develops a smaller form of the typical seed head of the cattail, and grows to a smaller mature height of only 1.2 m (4 ft).

***Nelumbo* (water lotus)** is one of the most interesting plants that I have had the opportunity to work with. It can be propagated either by vegetative division of the banana-like tubers, or by collection and sowing of the seed. There is a species native to the United States, *N. lutea,* that can be found in slow-moving streams and marshes. The native water lotus has a yellow bloom and can reach 1.8 to 3.1 m (6 to 10 ft) in height. Cultivars that we propagate are hybrids that have a range of colors from pink to yellow, and dwarf forms that only reach 1.2 m (4 ft). Propagation is done by division to keep true-to-type hybrids. To divide the rhizome, wash the loose soil away, carefully lift, and cut the rhizome leaving two nodes on each section. The most important thing to remember is if the growing tip is broken the plant will die. A fungicide dip is recommended. Do not let them dry out during division or they will lose viability.

***Cyperus papyrus* 'Nanus' (syn. *C. haspan*) (dwarf papyrus)** is viviparous and easy to propagate, thus the same method for rooted cuttings can be followed as described for the umbrella palm. Papyrus may be grown from seed, but propagation by cuttings is effective and easy. It is an attractive plant for the water garden having stems that reach 0.6 to 0.9 m (2 to 3 ft) and tufts of foliage that add a fine texture to the garden. With the viviparous seed, the mature flower heads are cut off the plant (after the germinated seedlings have developed roots) and then pressed into moist soil. The seedlings develop quickly.

***Cyperus papyrus* (Egyptian papyrus)**. Currently, the only method of propagation that has been successful for us has been vegetative division of the root stock or crown. The flower head does not readily root when placed in moist bark like dwarf papyrus, but seed are prolifically produced during the season. We are working on seed production and hope to include this in our cultural techniques soon. Some sources advise that when floated upside down in water, the head will root, however, we have not been successful with this method.

***Thalia dealbata* (hardy thalia)** is an attractive specimen plant having an elliptic cup shaped leaf. Thalia or "praying hands" has a mature height of 2.1 to 3 m (7 to 10 ft). The bloom looks like a bird of paradise, but with a purple waxy color. Propagation may be done by collecting seed or division of the rootstock. Divide the rootstock or crown with the same method that is used to divide Egyptian papyrus. Tillers will develop along the original root stock and intensive division will provide steadily smaller and more uniform plantlets. Seed will sprout readily when placed in water.

***Colocasia esculenta* (elephant ear)** is one of the more common plants that we are dealing with and is very adaptable. It can be grown in most landscape situations including rich soils, as well as submerged in 8 cm (3 inches) of water. Propagation is best done by plantlets formed at the end of stolons. These stolons can be up to 3 m (10 ft) long and have as many as one or two nodes per 30 cm (1 ft). Stolons are prolific along the base of each plant. Taro can be produced by placing the stolon in a tray of water. After a few weeks, plantlets will sprout at each node along the stolon. There are a number of variegated and colored cultivars more popular than the nonvariegated green cultivars, though propagation seems to be slower with these cultivars.

CONCLUSION

Aquatic plants are a focal point for many aspects of our society, with their ability to enhance water quality, reestablish and maintain wetlands habitats, and add ornamental value to landscapes. Mitigation, constructed wetlands, and water gardens are becoming nursery trends. Hydro-Perfect Vegetation®, the aquatic division of Flowerwood Liners, will continue to develop the propagation procedures needed to produce the product that our market demands.

A selected list of aquatic plants for mitigation, constructed wetlands, and water gardens is included at the end of this article.

Selected aquatic plants for mitigation

Juncus effusus
J. roemerianus
Pontederia cordata
Sagittaria lancifolia
S. latifolia
Schoenoplectus validus (syn. *S. validus*)
Scirpus acutus
S. americanus
S. californicus
Spartina alterniflora
S. patens
Zizaniopsis miliacea (syn. *Zizania miliacea*)

Selected aquatic plants for constructed wetlands

Acorus gramineus 'Variegatus'
Canna flaccida
Colocasia esculenta
Cyperus involucratus (syn. *C. alternifolius*)
C. papyrus 'Nanus' (syn. *C. haspan*)
Equisetum hyemale
Juncus effusus
J. effusus
Pontederia cordata
Sagittaria lancifolia
S. latifolia
Scirpus californicus
Typha laxmannii
Zizaniopsis miliacea

Selected aquatic plants for water gardens

Acorus gramineus 'Variegatus'
Canna flaccida
Colocasia esculenta
Cyperus involucratus (syn. *C. alternifolius*)
C. papyrus
C. papyrus 'Nanus' (syn. *C. haspan*)
Equisetum hyemale
Juncus effusus
Orontium aquaticum
Pontederia cordata
Thalia dealbata
Typha laxmannii

Plant Growth Regulators: Potential Uses in the Nursery Industry

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INTRODUCTION

Plant growth regulators (PGRs) are chemical compounds which alter plant growth and development through hormonal action and are annually used on over 2.5 million acres worldwide on a diversity of crops (Thomas, 1982). Most applications of PGRs are to high-value horticultural crops to enhance crop quality or aid in more efficient crop management (Gianfagna, 1987). Specific uses of PGRs on floricultural crops include: promotion and retardation of growth, promotion of flower initiation and development, inhibition or promotion of flower and/or foliage abscission, and enhancement of lateral shoot development (Larson, 1985). While PGRs are used less extensively in the nursery industry (except for auxins, which increase root development in the propagation of cuttings), greater potential benefits may occur with their wider use. Possible uses in the nursery industry include: growth suppression to produce a plant form for a given market or to reduce the frequency of pruning, and enhanced branching to improve plant quality or propagation material. Potential exists for greater use of PGRs in the landscape to reduce growth rates and/or improve plant quality.

CAUTIONS

On numerous occasions growers have asked me to recommend PGRs for specific situations that were better addressed through sound cultural practices. PGRs are not a substitute for proper crop culture and accurate environmental control. On other occasions growers and I have experienced seemingly inconsistent results when using PGRs. It should be understood that any factor that affects the rate and quality of plant growth and development will potentially influence a plant's response to a PGR. McAvoy (1989) has written an excellent article discussing these factors which are summarized below:

I. Plant factors.
- Cultivar.
- Physiological stage of plant development.
- Plant status (physical condition of plant).
- Plant size.

II. Environmental factors.
- Light and temperature.
- Growing medium.
- Water quality.
- Crop nutrition.

III. Physical and chemical factors.
- Residual chemical effect.
- Spray droplet size.
- Crop coverage.

Over the past 9 years I have conducted extensive research with PGRs. Some of this work is summarized below. Due to space constraints, generalizations occasionally are made; however, a more detailed discussion is given in the referenced articles.

GROWTH INHIBITION

Bonzi (paclobutrazol) was tested on several container-grown nursery crops in a 72-week study. The magnitude of growth inhibition was directly correlated with application rate. Spray application appears to have more potential uses in the nursery due to less chemical persistence compared to drenches. The values which follow the species listed below are: rates that suppressed shoot growth and minimum time period of growth suppression. Species include: *Euonymus japonicus* 'Microphyllus' (Japanese euonymus)—1000 to 2000 ppm, 17 weeks; *Ilex cornuta* 'Dwarf Burford' (dwarf Burford holly)—250 to 1000 ppm, 72 weeks; *I. crenata* 'Compacta' (compacta Japanese holly)—500 to 2000 ppm, 72 weeks; *Juniperus conferta* 'Blue Pacific' (shore juniper)—1000 to 2000 ppm, 17 weeks; *Photinia ×fraseri* (photinia)—250 to 2000 ppm, 72 weeks; *Rhododendron* 'Hino-crimson' (Hino Crimson azalea)—50 to 2000 ppm, 72 weeks; *R.* 'Formosa' (Formosa azalea) and *Ligustrum japonicum* 'Aureo-marginatum' (Japanese privet)—250 to 2000 ppm, 72 weeks (Keever et al., 1990).

Sumagic (uniconazole) on container-grown *Camellia sasanqua* 'Shishi Gashira' (sasanqua camellia): shoot growth was either unaffected or was inhibited by single foliar sprays, while flower number was increased. A 5 ppm spray increased flower number 53% without affecting plant size, while a 20 ppm spray increased flower number 113% but reduced plant size by 21% (Keever and McGuire, 1991).

Sumagic on *Elaeagnus pungens* 'Fruitlandii' (thorny eleagnus): 500 to 1500 ppm foliar sprays were ineffective on established, field-grown plants; 15 to 45 mg a.i.per plant drenches suppressed growth for at least two seasons. Reduced pruning was needed to remove rank shoots (Keever and West, 1992).

Sumagic on ×*Cupressocyparis leylandii* (leyland cypress): 200 to 500 ppm foliar sprays or 5 to 15 mg a.i. per pot drenches provided short-term growth retardation in containerized plants. Neither sprays (500 to 1500 ppm) nor drenches (15 to 45 mg a.i. per plant) inhibited growth of established, field-grown plants (Keever and West, 1992).

Sumagic on *Trachelospermum asiaticum* (Asiatic jasmine): a single 75 to 200 ppm spray provided less than 6 weeks of shoot suppression; a 300 to 900 ppm spray provided season-long control.

Sumagic on *Gelsemium sempervirens* (Carolina jessamine): 150 to 900 ppm foliar spray suppressed shoot growth during the season of application; drenches of 1 to 20 mg a.i. per pot provided control for at least a year.

Sumagic on *Mandevilla ×amoena* 'Alice du Pont' (mandevilla): single 5 to 20 ppm spray applications controlled shoot elongation for 3 to 4 weeks; multiple 5-20 ppm sprays provided long-term control. Single 30-120 ppm sprays distorted foliage (Deneke et al., 1992).

Cutless (flurprimidol) on *Buddleja davidii* 'Royal Red' (butterfly-bush): a 62.5 ppm spray controlled shoot elongation for less than 120 days, while 125 to 250 ppm sprays provided longer control without affecting flowering. Sprays of 500 ppm or greater caused excessive shoot suppression and reduced inflorescence number and size (Keever and Gilliam, 1994).

Cutless on *Ilex* China Girl® (China Girl holly): 500 ppm controlled growth during the season of application; 1000 ppm or greater inhibited growth for at least 2 growing seasons (Keever et al., 1994).

BRANCHING

Branching of the species listed below was increased by the foliar spray treatments of selected PGRs:

Ilex crenata 'Helleri' (Heller holly): 125 to 1000 ppm BA (Keever and Foster, 1990a).

Ilex vomitoria 'Stoke's Dwarf' (dwarf yaupon): 1000 ppm BA (Keever and Foster, 1990a).

Photinia ×fraseri (photinia): 1500 to 2500 ppm BA, 2000 to 5000 ppm Promalin (Keever and Foster, 1990a).

Nandina domestica 'Harbor Dwarf' (dwarf nandina): 1000 to 2500 ppm BA, 5000 ppm Promalin (Keever and Foster, 1990a); 50 to 200 ppm ASC-66952 (Keever, 1993).

Vinca minor (lesser periwinkle): 1000 ppm Promalin (Foley and Keever, 1993).

Pyrus calleryana 'Bradford' (Bradford pear): increased branching and wider crotch angles with 300 to 450 ppm BA or 600 to 900 ppm Promalin (Keever et al., 1993).

Hosta sieboldiana (blue hosta): enhanced offset formation with 2000 to 3000 ppm BA (Keever, 1994).

SPROUT CONTROL

Basal sprouts (basal shoot formation) of *Lagerstroemia* 'Natchez' and *L. indica* 'Country Red' (crapemyrtle) were controlled with 0.75 to 1.0% NAA (Tre-Hold). Minor height and shoot dry weight suppression occurred (Keever and Foster, 1990b).

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Handling Bareroot Tree Whips at Greenleaf Nursery

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INTRODUCTION

High quality, vigorous-growing bareroot tree whips {1.2 to 1.8 m (4 to 6 ft) tall ornamental tree liners} are the ultimate goal of the Hidden Lake Division of Greenleaf Nursery.

All of the time and effort of producing such a plant can quickly turn into a total loss if the tree whips are not properly cared for during the digging and storing process. What may seem like a small, minor procedure can quickly become vitally important to the quality and survival of the plant—particularly since the exposed root system of a dug, bareroot whip is very vulnerable to the environment.

The Digging Process. The initial steps in preparing for the actual digging process include:

1) Removing any suckers.
2) Grading the tree tops for size and quality.
3) Marking the base of the trunk with paint for later identification.

Any tree that does not have a satisfactory top is simply broken off and destroyed, so it cannot be sold. Also at this time, any trees that are to be sold are tagged with a cultivar label.

Our digging season for bareroot whips starts in mid-Dec. when the flowering pears drop their leaves. Since it is approximately 50 km (30 mi) from the Hidden Lake Division to the cold storage building at the main nursery, we must constantly monitor the moisture and temperature of the plants.

A track digger does the actual undercutting and lifts the trees out of the soil. Then a series of crews follow closely to shake any remaining soil off the roots and to load the plants on a flat bed trailer. Each crew picks up only one certain size of a cultivar. For example, the first crew will only pick up 5- to 6-ft whips while the second crew just picks up 4- to 5-ft whips. Each crew throws out any culls as they go through. In this way, only trees of the same size reach the grading barn together plus they will have been graded several times before reaching the grading barn. A final crew goes through to collect culled and damaged plants and discards them. This leaves the field clean of nursery stock and ready to be worked and planted with cover crops in preparation for future production of new tree-whip generations.

Every tractor and trailer being used in the digging process is equipped with a sprayer so that the tree roots can be kept moist while they are still in the field. If the soil is too wet to shake off easily, the trailer is driven under a large overhead water pipe to wash the extra soil off and clean the bare roots.

Processing in the Grading Barn. As the trailers are driven through the grading barn, the trees are quickly unloaded so the trailer can return to the field for another load. The trees are once again graded, counted into groups of five, and loaded into racks. The number of trees put in each rack is recorded. Then the rack number, cultivar, size of the trees, number of trees, and whether they are to be planted at Greenleaf Nursery or sold are recorded.

From this time until planting, the trees are handled only by fork lift. The tree racks are loaded into a temperature-controlled semi-trailer which takes them to the cold storage building at the main nursery. The trailer temperature is maintained at 10 C (50F).

Cold Storage Facilities. When the trailer reaches the cold storage building the tree racks are off-loaded by fork lift. They are separated by cultivar and also separated for sale or for transplanting and internal use at the nursery. The tree racks are stacked in bays, and the bay number is recorded on the same sheet that has the cultivar, size, and other information already on it. A copy of this sheet goes to inventory control and two more copies go into notebooks for future reference.

The cold storage building is maintained at a constant 1C (34F). An intermittent fog system keeps the humidity at 95%. When whips are sold, it is a simple matter to check the records to find where selected cultivars at given sizes are stored. The required tree rack, which contains the requested cultivar and tree size, is brought into a grading room. The liners are then regraded and tied into bundles for shipment.

Planting Whips into Containers. Planting is also a fairly simple ordeal. For instance, if we want to plant 1.2- to 1.5-m (4- to 5- ft) Bradford pears, they are located by using the written records and whole racks of whips are moved to the tree planting machine by fork lift. Workers with pneumatic pruners trim the roots so the liner will fit into the desired container. Water hoses are in constant use to ensure the roots never dry out. The whip is placed in a container and an auger adds the soil mix. The newly containerized plants are loaded on to a wing-ding (converted flat-bed pick-up truck) and taken to the field. They are set off into beds, thoroughly watered, and grown under standard container-production practices for 1 year.

Keeping the Whips Alive. Perhaps the single most important factor in handling bareroot whips is to **never** let the roots dry out—not even momentarily. The liveability and overall vigor quickly drops if the plants are allowed to desiccate. An extremely well-formed whip can turn into a lost product to be discarded into the dump pile if adequate moisture of the bare roots is not maintained.

Quality Control Through Liner Improvement

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Evaluation of Programs to Improve Quality. In 1992, American Nursery Products, Inc. began work on several programs to make much needed improvements in the quality of the plants that the company produced at its Oklahoma and Alabama nurseries. In addition, the timing of maturity of some crops needed to be changed so that plants reached marketable size at the time when our customers wanted them. In many cases, plants needed a flush of growth in the spring to be of salable quality, which would not normally occur until after the spring shipping season was largely finished. Since quality starts with liner production, we began new programs on several fronts to improve liner quality and crop timing.

Production of 1-Gal Conifers. This paper deals with one particular aspect of our quality improvement program, the production of 1-gal conifers of various *Juniperus* and *Thuja* species. This program was initiated simultaneously at our nurseries in Cherokee County, Alabama, and in Cherokee County, Oklahoma. The Alabama and Oklahoma nurseries are located in the northeast corner of their respective states and are classified in plant hardiness Zones 7 and 6, respectively.

The previous production system was to plant bed-propagated, bareroot liners in Feb. with the goal of producing salable 1-gal conifers in 1 year and 2-gal conifers in 2 years. The 1-gal plants were not as well developed and the market was less accepting of the quality of these plants. As a result, approximately 50% of the plants had to be carried over to the following year and, even the best of the plants that were shipped the first year generated several complaints.

Devising a Plan to Produce 1-Gal Plants in One Year. Since we could not afford financially to avoid the market for 1-year, 1-gal plants, we had to devise a plan to produce a product in 1 year that would be ready to ship in the primary selling season from Oct. through April of the next year.

High Winter Losses. The Oklahoma nursery had previously tried planting the bareroot liners in the fall, but there were unacceptable losses during the winter. Since Ben Davis had successfully fall-planted, bareroot conifer liners in the field for many years, we decided to do another test planting of bareroot liners in 1-gal containers in the Fall of 1992. Two thousand liners of four different cultivars were planted in Sept. in beds of closely spaced (jammed) containers. The liners were well cared for and great precaution was taken to avoid having the roots dry out. All plants were thoroughly soaked with overhead irrigation as soon as planted. Nevertheless, winter losses were approximately 80%.

Sticking Cuttings Directly into Cell Trays. Next, we made the decision to stick all conifer cuttings directly into cell trays instead of sticking into ground beds inside our quonset propagating houses. To convert the quonset houses to cell-tray liner propagation, we leveled the media in the ground beds and covered them with the same type of Supack® mat that is used under asphalt paving. This mat acts as a weed barrier, and when the cell trays are placed on it, acts as a wick to draw excess moisture from the cells. To facilitate this, we selected a tray with a square top, a cone shaped bottom, and one large drain hole in the center of the bottom. Secondly, we replaced the mist lines so that nozzles were 0.9 m (3 ft) apart instead of 1.5 to 1.8 m (5 to 6 ft) apart. We also changed nozzles and increased water pressure to produce a finer mist with more even distribution.

Taking and Sticking Cuttings. The procedures for taking and sticking cuttings remained the same as for bareroot liner propagation. Cuttings were taken in late Dec. and in Jan. and were treated with a quick-dip rooting hormone solution. Hard-to-root cultivars were dipped into a solution containing 5000 ppm IBA and 2500 ppm NAA. Easier-to-root cultivars were dipped into a solution that contained 2500 ppm IBA and 1250 ppm NAA. Cuttings were then stuck directly into the cell trays after the trays were filled and set in the houses. The propagation mix in the trays was 6 fine pine bark : 2 horticultural perlite : 1 peat moss : 1 sand (by volume). To this was added: 2.9 kg m^{-3} (5 lb yd^{-3}) pelletized gypsum, 1.2 kg m^{-3} (2 lb yd^{-3}) magnesium oxide, 7.4 kg m^{-3} (12.5 lb yd^{-3}) Osmocote® 18-6-12, and 0.9 kg m^{-3} (1.5 lb yd^{-3}) of a pre-formulated micronutrient product. The unheated houses were covered with clear polyethylene film. The misting cycle was set to stay on for 12 sec, every 10 min to 3 h, depending on the weather conditions.

Cultural Practices for Rooted Liners. As rooting progressed, liners were gradually hardened off and the top parts of the houses were uncovered by cutting away the poly film, while leaving the poly in place on the sides up to about 1.8 m (6 ft). As the liners became thoroughly rooted in the cells, the trays were raised off of the ground to allow for air pruning of the roots. This was accomplished by using old plastic flats that we had in surplus. The flats were turned upside down on the floor of the house and the cell trays were set on top of them. The liners were then sheared and liquid fertilized throughout the spring and summer to assure bushy tops and heavy root systems. In Sept., we began pulling the liners from the cell trays, top pruning them to a height of about 4 inches, and packing the liners in poultry boxes for delivery to the planting machines. We found that it is better to have the liners pulled and processed by the Propagation Department staff so that we have better control on liner count, quality of liners planted, and care of the liners that are repotted. This also makes planting more efficient, since the planting crew does not have to be concerned with grading.

Procedures for Poorly Rooted Liners. Some of the liners were not rooted well enough to maintain an intact root ball when removed from the cell. These liners were immediately re-potted back into the cell trays and placed back in the propagation houses. They remained there until planted into 2-gal pots in the spring. Since our production program for 2-gal conifers is a 2-year program, spring planting is acceptable.

Liners can be planted from Sept. through Oct., but planting should be completed as early as possible to allow new roots to be established in the 1-gal container during the warm fall days. We prefer to start planting the day after Labor Day and complete 1-gal planting by Oct. 1st. The planting mix used is: 8 fine ground pine bark : 2 concrete sand (v/v). To this is added: 5.9 kg m^{-3} (10 lb yd^{-3})pelletized, dolomitic lime, 2.9 kg/m^{-3} (5 lb yd^{-3}) of custom blended, semi-slow release, 12-6-6 fertilizer, 5.9 kg m^{-3} (10 lb yd^{-3}) of 23N-6P-12K, 9-month encapsulated slow-release fertilizer, and 0.9 kg m^{-3} (1.5 lb yd^{-3}) of a pre-formulated micronutrient product. This mix provided nutrition to the liners until cold weather and by then release of fertilizer was greatly curtailed.

Overwintering of 1-gal Containers. The 1-gal containers were left can-tight over the winter and protected along the edges by a wind barrier of 18-inch tall felt roofing backed up by a layer of fluffed up wheat straw. In the spring, the felt roofing and straw were removed, but the plants remained can tight until late June or early July. During this period, the tops are mowed with a shearing machine and any long runners are cut back to the edge of the container. Beginning about the 1st of July, the plants are spaced to approximately 12-inch centers and are top dressed with fertilizer immediately after spacing. Top dressing was done with a 22N-4P-8K plus minor elements, encapsulated, slow-release fertilizer at 12 g per 1-gal container. At the same time, an additional side pruning is done, forcing plant growth back to the edge of the container. In the case of upright *Thuja* cultivars, the tops were sheared again with a shearing machine. In September, the plants are given another top dress of 12N-6P-6K semi-slow-release fertilizer at 12 g per container. This helps maintain an acceptable foliage color into the fall and winter.

CONCLUSION

The old production program, using bareroot liners planted in Feb., did not produce an acceptable 1-gal plant until 14 months later, when the prime selling season was mostly over. Thus, plants had to be carried over for another summer, taking up production space, requiring an extra season of care, and increasing production costs. The new production program, using cell-tray liners planted in Sept. or Oct., produced plants in 12 months that are equally as good as the 20-month-old plants produced with the old program. More importantly, they are ready to be sold when the market demands them.

Pushing Plants for Maximum Versus Optimum Growth: Beware of Imbalances

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Balanced Nutrition. "Balanced nutrition" is the key to good plant health and vigor. Growers and researchers have tried for years to quantify and identify exactly what it takes to maximize plant growth. Not everyone agrees on the proper quantity or source of plant nutrients that is best for maximizing plant growth, but everyone does seem to agree that a proper balance of all plant nutrients is essential.

When trying to maximize growth, especially with high N soluble fertilizers, K frequently becomes deficient. When "pushing" with N and K, Ca and/or Mg, and S deficiencies usually occur. It is extremely difficult to keep **all** nutrients in balance when trying to maximize growth.

Problems with Trying to Maximize Growth. Fortunately, plants can and do survive on less than perfectly balanced nutrition. My purpose today is to alert you to problems associated with trying to maximize growth and to suggest guidelines for optimum nutrition. Problems caused by imbalances/deficiencies are not worth the little extra growth the grower wished to get. Unfortunately, there are many hidden deficiencies/imbalances that are not easily recognized, but often become painfully obvious at times of stress. Less plant tolerance to stresses caused by moisture excesses, nutrient deficiencies, high and low temperatures, insects, and diseases are often related to nutrient imbalances. Guidelines for nutrient ranges based on the saturated media extract (SME) Method are given in Table 1. I have found that plant growth is better with balanced nutrition levels even at low fertility levels, than when N, K, Ca, and Mg are out of balance. Table 2 shows a desirable nutrient balance which I have found to be an excellent guide.

Table 1. Suggested nutrient ranges for organic media analyzed by the saturated media extract (SME) method.

Analysis	Category				
	Low	Acceptable	Optimum	High	Very high
pH	-5.0	5.0-5.5	5.5-5.9	5.9-6.4	6.4+
Sol-salts, mmhos	-0.5	0.5-1.5	1.5-2.5	2.5-3.5	3.5+
Nitrate-N ppm	-35	35-85	85-105	105-220	220+
Phosphorous ppm	-2	2-6	6-10	10-16	16+
Potassium ppm	-35	35-85	85-105	105-220	220+
Calcium ppm	-20	20-60	60-85	85+	-
Magnesium ppm	-15	15-40	40-60	60+	-

Guidelines for Optimum Nutrition. "Optimum growth" is difficult to define, but some of the features are good uniform color and vigor with no excessive succulence and a balance of shoot and root growth. Before using a new, untried growing medium, first test for available nutrients, pH, and soluble salts. Also, media samples should be taken regularly (at least monthly) to maintain a balance of nutrients at levels within accepted guidelines.

The SME method is ideal for testing media before and after planting, but for growers who do their own sampling and testing, the Virginia Tech Extraction Method (VTEM) is much simpler to use after planting. Guidelines for optimum levels using the VTEM must be established by each user. I have found comparisons between growers to be useless unless they use the same medium, the same fertilizer source and rate, the same water source, and they are in the same climatic region.

For all crops with good established root systems, adjust the nutrient levels to the optimum range (Table 1), prior to planting. Use the lower end of the range for salt sensitive crops.

Table 2. Desirable nutrient balance in saturated medium extract.

Nutrient	Percent of total soluble salt
Nitrate N	8-10
Ammonium N	less than 3
Potassium	8-10
Calcium	6-8
Magnesium	4-6
Sodium	less than 6
Chloride	less than 6

Testing Lime Requirements for pH Adjustment. A good way to test lime requirements for pH adjustment is to mix a small batch (0.1 yd^3) of medium using the lime rate you think is correct. Moisten the medium and place in a large plastic bag for 2 weeks, then check the pH. Be sure to use finely ground limestone with a minimum of 50% passing through a 100 mesh sieve. Avoid media with too high a pH as it is more difficult to lower pH than to raise it.

Conclusion. Briefly summarizing, potassium is the nutrient most often limiting in container fertility programs and in my experiences this has been caused by improper N-P-K rations (a 3-1-2 ratio is my preference) and excessive nitrogen applications used to maximize growth. Also, S, Ca, and Mg deficiencies often are associated with attempts to maximize growth. My suggestion is to find a good slow-release fertilizer source that will give you optimum nutrient levels for an entire growing season and avoid trying to maximize growth.

Water Analysis: Test Kits for Nurseries

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INTRODUCTION

Water is a primary consideration for growing any crop. Plants are 95% water by weight and it is considered to be the universal solvent. Water carries all the essential elements taken up by plants from the soil and is responsible for the transport of nutrients and metabolites throughout the plant. Often times we concern ourselves with water quantity and not as much on the quality of the water supply. The objectives of this paper are to compare some laboratory water analyses with an inexpensive test kit for on-site testing of water.

Water Quality. Many Colorado greenhouse and nursery growers use mountain water, which is nearly pure, and many growers out on the prairie use water from shallow wells, 10.7 to 15 m (35 to 50 ft), and that water is often alkaline. The water quality from these wells also varies considerably during the year depending upon aquifer depletion from irrigation as well as the use of anhydrous ammonia on area farms. Water used in irrigation of nursery plants should be tested at least two times annually.

When selecting a laboratory or a procedure for testing water, there are at least six items that are important for a grower to consider. These include: soluble salts, iron, sodium, calcium, magnesium, and alkalinity. Most laboratories test and analyze other elements, as well. Private laboratories charge from $20 to $90 depending on the total number of individual elements tested (Table 1).

Table 1. Selected private testing laboratories that perform water quality analyses or test kits.

A & L Laboratories	411 North Third Street Memphis, Tennessee 38105-2723	$40.00
Scotts Testing Laboratory	6656 Grant Way Allentown, Pennsylvania 18106	$20.00
Soil and Plant Laboratories	P.O. Box 153 Santa Clara, California 95052-0153	$90.00
SunGro Analytical Laboratory	177 Sanford Road Warwick, New York 10990	$24.00
TGI Technical Services	P.O. Box 173354 Denver, Colorado 80217	$28.00
HACH Company	P.O. Box 389 Loveland, Colorado 80539	$26.50

Testing for Soluble Salts. Soluble salts or the electrical conductivity of the water is probably the most important characteristic of any water source to be determined. The amount of soluble salts is the key to good plant growth. Soluble salts are expressed in units of electrical conductance, that is dS m^{-1} or mS cm^{-1}, which is equal to the more familiar mmhos cm^{-1}. A satisfactory electrical conductivity for irrigation water is between 0.25 to 0.75 mS cm^{-1}. This is measured with a soluble salts meter. Many models exist, including laboratory grade and portable, and there is a model available for every budget.

Iron Problems. Iron is often a problem in some irrigation water. Water that has passed over iron-bearing rock and soil often has a high level of ferrous bicarbonate dissolved in it. As this water is aerated in an irrigation system, overhead for example, it is changed to ferrous hydroxide and becomes a rusty precipitate collecting on cuttings, bench tops, and floors. The easiest means for eliminating iron from your water is by using an oxidizing system that sprays the water in the air and filtering out the iron precipitate or allowing the iron to settle in a pond.

Sodium Problems. High levels of sodium in irrigation water are detrimental to plant growth, especially lanceolate-leaved foliage species. The addition of soluble fertilizers to irrigation water high in sodium may also complicate plant growth. However, the relationship of the amount of sodium in the irrigation water to calcium and magnesium is more important than the amount of sodium alone. The sodium absorption ratio (SAR) is calculated by the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{\dfrac{Ca^{+2} + Mg^{+2}}{2}}}$$

Where sodium, calcium, and magnesium are in milliequivalents per liter (meq $liter^{-1}$). This value should be less than 10, but water with a SAR greater than 10 can be made more acceptable for irrigating plants by adding magnesium sulfate (epsom salts) or calcium sulfate (gypsum) to the media.

Understanding Alkalinity. Alkalinity is defined as the amount of carbonates and bicarbonates in the water. A water source that contains many carbonates and bicarbonates is usually considered to be very alkaline and often has a high pH. However, water that has a high pH does not always indicate high alkalinity. Water that has a high pH and low alkalinity often requires little modification. However, highly alkaline water, 100 ppm bicarbonates or greater, can raise the pH of soil media rendering many elements unavailable to plants. This is especially true with plants that require an acidic root environment. Alkalinity is traditionally determined by a laboratory, but there are inexpensive test kits available for on-site testing.

Understanding Water Analysis Results. A typical water analysis is expressed in ppm and/or in meq $liter^{-1}$. The water analyses in Table 2 is from a Colorado greenhouse grower who has two water supplies. One source is from a shallow well and the other from a municipal source. The municipal source originates from mountain reservoirs and is nearly pure compared to the well water, which contains many contaminates including a high level of bicarbonates. The well water requires some form of treatment to reduce the alkalinity and prevent any soil pH problems.

Water tests performed by commercial laboratories are important, but often the results do not come fast enough. Water quality test kits may be the answer to this dilemma. They are inexpensive and can be done in a timely manner. However, many consider their accuracy questionable and they are not as complete and thorough as standard laboratory testing. The HACH Company has a diverse collection of test kits suitable for on-site testing at reasonable prices (Table 1).

An Example of an Alkalinity Test Kit. The HACH Alkalinity Test Kit (Model AL-AP MG-L) retails for $26.50 for 100 tests. It is based on indicator colorimetry using two indicator dyes, phenolphthalein and bromcresol green-methyl red and they are titrated with 0.035 N sulfuric acid. To perform the test, a volume of irrigation water is measured and phenolphthalein indicator is added. If this turns the water pink, sulfuric acid is added one drop at a time until it becomes clear. This yields the alkalinity in ppm of calcium carbonate. Next the bromocresol green-methyl red indicator is added, which turns the solution green. To this solution sulfuric acid is added one drop at a time until the solution turns pink. The total number of drops to turn the phenolphthalein solution to clear and the number of drops to turn the bromocresol green-methyl red solution to pink multiplied by 20 yields the total alkalinity in ppm.

Table 2. Water analyses from two water sources in Colorado as tested by TGI Technical Services of Denver, Colorado.

	Well water		Municipal water	
Element	ppm	meq $liter^{-1}$	ppm	meq $liter^{-1}$
Ammonia	0.00	0.0	0.00	0.0
Bicarbonate	427.00	7.0	37.00	0.6
Calcium	40.00	2.0	15.00	0.7
Carbonate	0.00	0.0	0.0	0.0
Chloride	13.00	0.4	29.00	0.8
Copper	0.02	-	0.05	-
Iron	0.06	-	0.06	-
Magnesium	58.00	4.8	4.00	0.3
Nitrate	8.00	0.1	0.00	-
Phosphate	0.40	-	0.00	-
Potassium	20.00	0.5	0.00	-
Sodium	61.00	3.5	7.00	0.3
Sulfate	198.00	4.1	26.00	0.5
Zinc	0.07	-	0.04	-
Manganese	0.02	-	0.02	-

Table 3. Comparison of alkalinity values resulting from the HACH Alkalinity Test Kit and analysis from a private laboratory.

Laboratory/test kit	Well water (ppm)	Municipal water (ppm)
HACH Alkalinity Kit	400	40
TGI Technical Services	427	37

Comparing the reported alkalinity from a commercial laboratory and the results from the colorimetric test indicates that similar values can be achieved (Table 3). Using a series of sodium bicarbonate solutions in deionized water from 0 to 500 ppm indicates that results from the colorimetric kit may deviate as much as 5% at higher concentrations (Fig. 1). In most cases, this is still acceptable for determining acid ratios for the amelioration of alkaline water.

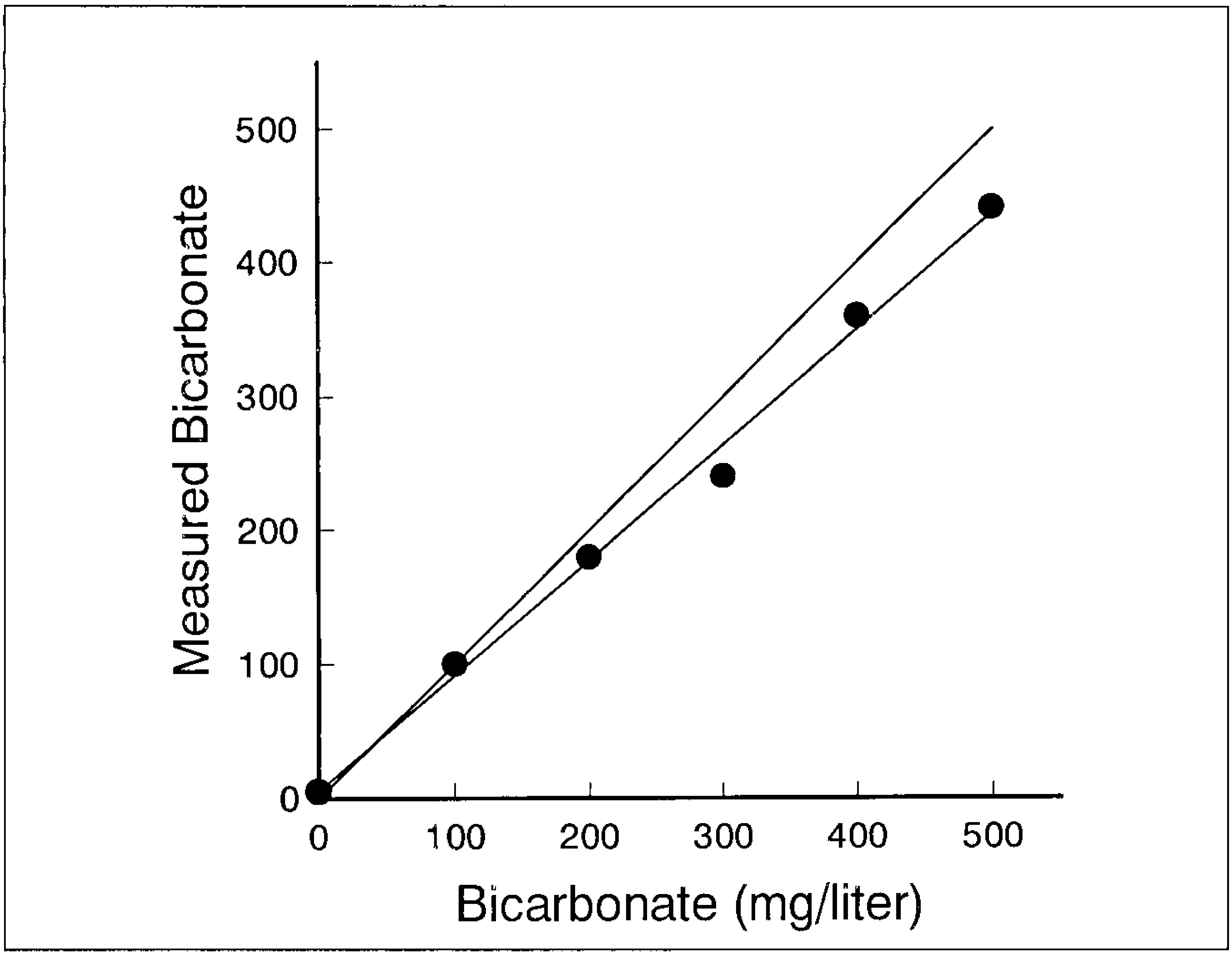

Figure 1. Results from a colorimetric kit for analyzing alkalinity may vary as much as 5% at higher concentrations. A series of sodium bicarbonate solutions in deionized water from 0 to 500 ppm was utilized.

CONCLUSION

Colorimetric test kits do not replace laboratory water analyses, but are inexpensive and appropriate for in-house testing. This can be done to monitor injection equipment and track changes during the interim between laboratory tests.

Herbicide-Coated Fertilizers and Weed Control in Container-grown Ornamentals

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Herbicide-coated and herbicide-blended fertilizers were evaluated for weed control and plant injury with container-grown *Gardenia augusta* 'August Beauty'(syn. *G. jasminoides* 'August Beauty'). Herbicide-coated and -blended fertilizers provided similar weed control, compared to standard broadcast or spray application of herbicides. In a second experiment, herbicide-coated Nursery Special 12-6-6, Osmocote 17-7-12, and Polyon 24-4-12 provided effective prostrate spurge and crabgrass control.

INTRODUCTION

Broadcasting herbicide over container-grown ornamentals is the standard herbicide application practice in container nurseries. Gilliam et al. (1992) studied granular Ronstar and nontarget herbicide loss. They reported that when empty containers were on 12-inch centers, 80% of the herbicide missed the container. Follow up research by Porter and Parish (1993) concluded that, depending on container spacing and plant growth habit, up to 86% of broadcast herbicide fell between containers. In a nursery situation these nontarget herbicide losses raise environmental questions concerning herbicide runoff and potential groundwater contamination. Keese et al. (1994) studied granular herbicide runoff from container nurseries and reported that the greatest herbicide concentrations were detected within 15 min after initial irrigation. Camper et al. (1994) researched containment ponds as a possible solution to polluted runoff water. They concluded that herbicides did not accumulate in the collected water, but detected trace levels of herbicides a year after application.

A possible solution to non-targeted herbicide loss is by using container-applied, herbicide-coated fertilizers to reduce the total amount of herbicide utilized.

In Experiment 1, the objective was to evaluate Nursery Special 12-6-6 fertilizer as a herbicide carrier in container-grown *Gardenia augusta* 'August Beauty' (syn.*G. jasminoides* 'August Beauty'). In Experiment 2, the objective was to incorporate results from Exp. 1 and compare two controlled-release fertilizers, Osmocote 17N-7P-12K and Polyon 24N-4P-12K, with Ronstar 50WP-coated Nursery Special 12N-6P-6K.

MATERIALS AND METHODS

Experiment 1. Ronstar and Pennant were evaluated for their potential to be blended or coated onto Nursery Special 12N-6P-6K fertilizer. The two granular formulations (Ronstar 2G or Pennant 5G) were layered with 25 lb (11.4 kg) of

Nursery Special using a Patterson-Kelley Twin Shell blender and mixed. The coated products (Ronstar 50WP and Pennant 7.8E) were prepared similarly except that the herbicide, mixed with 100 ml water, was poured into a funnel and sprayed through the horizontal rod in the blender as the shell was mixing. Herbicide rates were determined based on the container surface area of a trade-gallon container treated with 6.5 g of Nursery Special. Each herbicide formulation was prepared at 2, 4, 8, and 16 lb ai per acre .

Uniformed *G. augusta* 'August Beauty' liners were potted in trade-gallon containers in a growing medium of 6 pine bark : 1 sand (v/v) amended with 0.9 kg m^{-3} (1.5 lb yd^{-3}) Micromax and 2.9 kg m^{-3} (5 lb yd^{-3}) dolomitic limestone. Plants were treated on 3 May 1993 by applying 6.5 g of the herbicide-coated or -blended fertilizer evenly over the container surface. Herbicide-coated and -blended treatments were compared along with an untreated, broadcast, and spray-applied controls. The blended herbicide-fertilizer treatments received 0.2, 0.4, 0.8, or 1.4 g of Nursery Special 12N-6P-6K, based on the rate applied, to equalize the amounts of fertilizer applied to all treatments and controls. All containers were overseeded with approximately 20 seeds of prostrate spurge, *Euphorbia humistrata*, on 10 May 1993. Prostrate spurge was selected because it is a troublesome weed in southeastern-container nurseries. The experimental design was 10 single plant replicates in a completely randomized design (n=10). Prostrate-spurge weeds were counted every 30 days. At termination (90 days after treatment, DAT) weed number, fresh weight, and dry weight were recorded and *Gardenia* growth indices ((height + width-1 + width-2)/3) were taken.

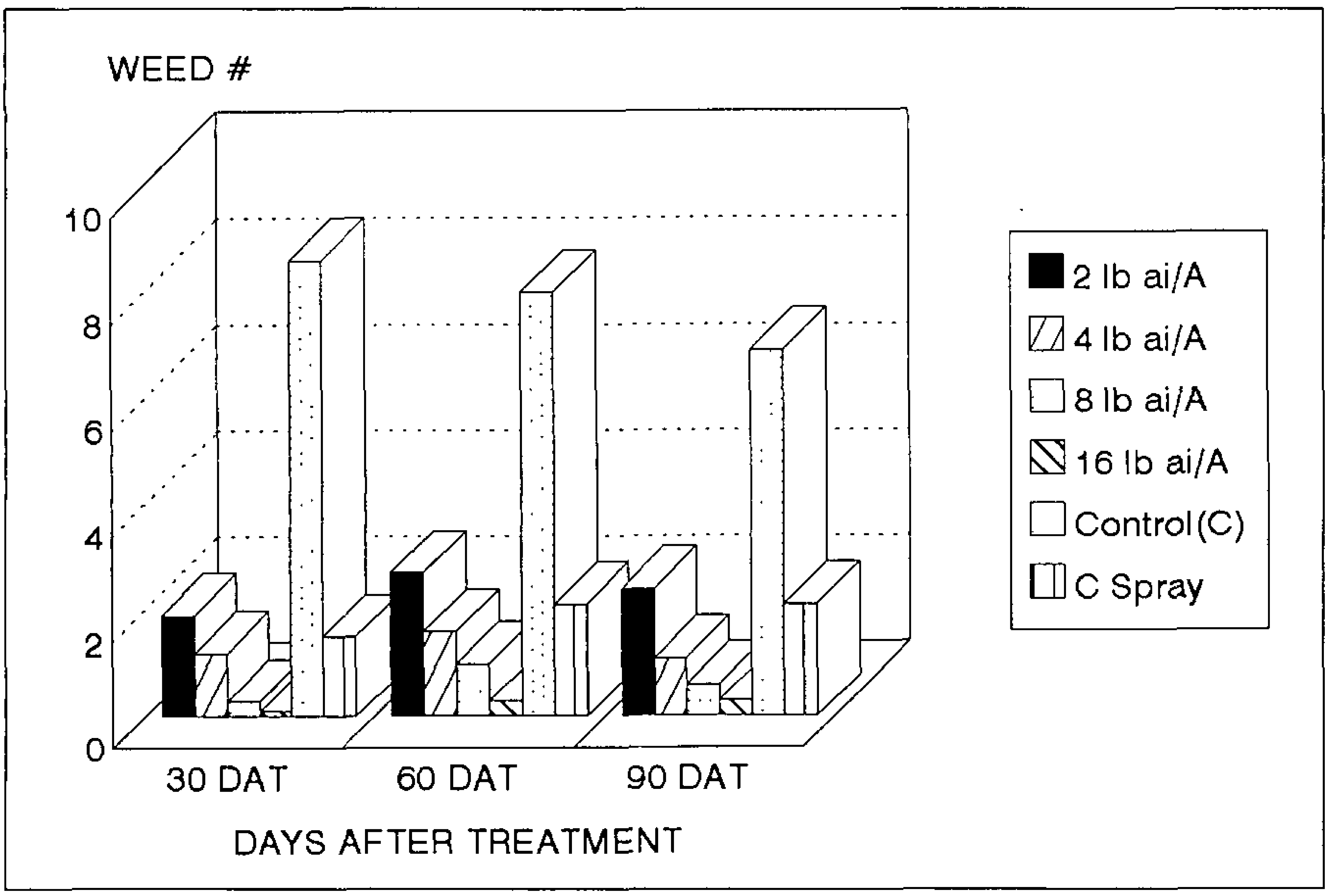

Figure 1. Spurge number per container with Ronstar 50WP, Experiment 1. Represented is 30 DAT LSD .05=3.0 linear, 60 DAT LSD .05=3.5 linear, and 90 DAT LSD .05=3.1 linear.

Experiment 2: Gallon containers were filled on 14 April 1994, with a medium similar to Exp. 1. Ronstar 50WP was coated on Nursery Special 12N-6P-6K, Osmocote 17N-7P-12K, and Polyon 24N-4P-12K at the 2, 4, 8, and 16 lb ai per acre rates. Herbicide-coated treatments were prepared similarly to Experiment 1. Containers were treated on 5 May 1994 with 6.5 g of Nursery Special and 20 g of Osmocote or Polyon. Containers were overseeded with 10 seeds each of prostrate spurge or crabgrass, *Digitaria sanguinalis*, 7 days after the treatments were applied. The experimental design was completely randomized consisting of 10 single-container replicates per weed species. Spurge and crabgrass emergence numbers were recorded every 30 days. At termination (60 DAT-crabgrass and 90 DAT-spurge) weed number, fresh, and dry weight were recorded.

RESULTS AND DISCUSSION

Experiment 1: Ronstar 50WP-coated fertilizer provided similar weed control at the 2, 4, and 8 lb ai per acre rates compared to standard spray application (Fig. 1). With a spray application the average spurge weeds per container was two, whereas with 16 lb ai per acre had less than one.

Ronstar 2G-blended fertilizer at the 4, 8, and 16 lb ai per acre rates provided similar weed control to standard broadcast applications (Fig. 2) with approximately one spurge per container.

A comparison of mean spurge numbers over all rates, 90 DAT, revealed that Ronstar 50WP and Ronstar 2G had the best spurge weed control. The untreated control had five times as many weeds per container. Fresh and dry weights followed a similar trend when analyzed.

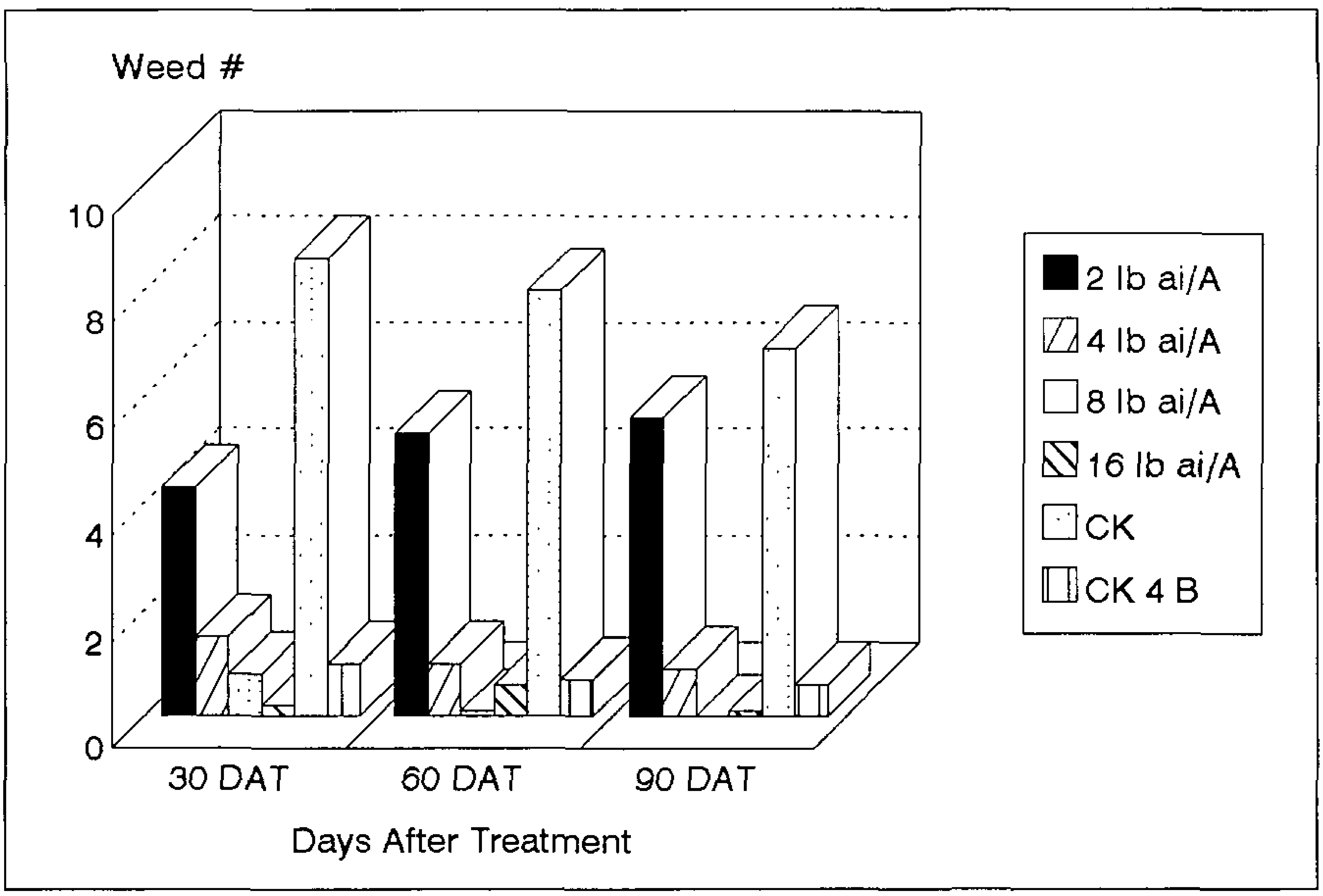

Figure 2. Spurge number per container with Ronstar 2G, Experiment 1. Represented is 30 DAT LSD .05=3.0 linear, 60 DAT LSD .05=3.5 linear, and 90 DAT LSD .05=3.1 linear.

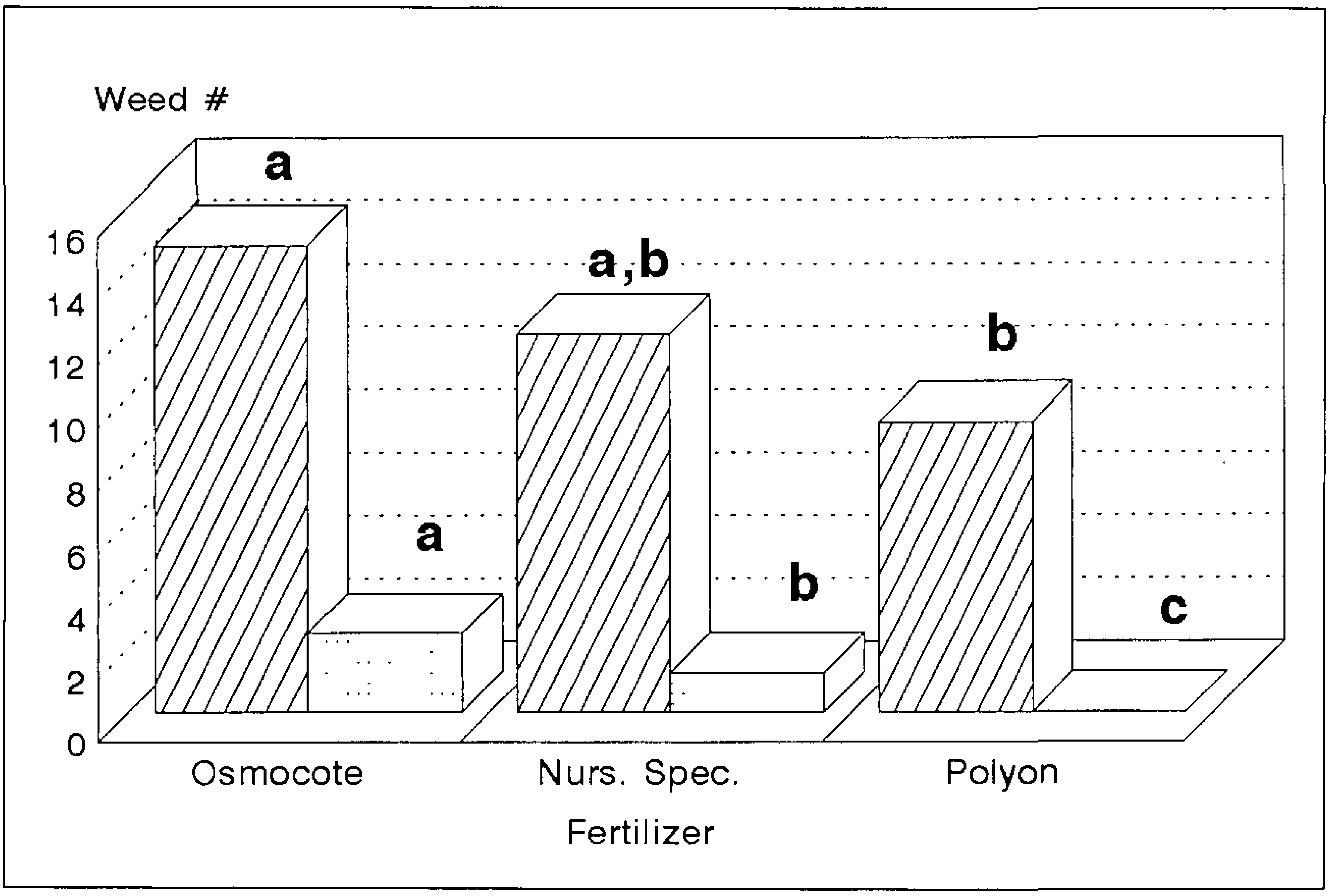

Figure 3. Spurge and crabgrass number per container, Experiment 2. Herbicide-coated Polyon and Nursery Special provided the most spurge control, 90 DAT, and herbicide-coated Polyon provide the crabgrass control at 60 DAT.

Ronstar provided more effective spurge control than Pennant (data not shown). As herbicide rate increased spurge control increased; this trend was linear and quadratic with Ronstar and linear with Pennant. Fresh and dry weights of spurge followed the same pattern.

Herbicide formulations were not statistically different (data not shown). With these results and the concern of herbicide-fertilizer separation in the blended products, work was continued only with Ronstar 50WP-coated products.

Gardenia growth indices were similar among all treatments. No differences were observed in *Gardenia* growth habit or size. Since these herbicide-coated or -blended fertilizers are applied directly to the container, there was no foliage burning or phytotoxicity.

In Experiment 2: Ronstar 50WP was used as the herbicide-coating on two controlled release fertilizers. At termination, herbicide-coated Osmocote at the 2 lb ai per acre rate did not provide adequate weed control of either crabgrass or spurge. Herbicide-coated Osmocote did provide effective (less than 1 weed per container) spurge control at 16 lb ai per acre and with crabgrass at 4, 8, and 16 lb ai per acre.

Herbicide-coated Polyon provided the most crabgrass control. Herbicide-coated Nursery Special and herbicide-coated Polyon provided similar spurge control at 90 DAT and herbicide-coated Polyon provide the most crabgrass control at 60 DAT (Fig. 3).

All herbicide-coated fertilizers at the 4, 8, and 16 lb ai per acre rates provided comparable results to the sprayed herbicide control application. Data based on weed fresh and dry weight followed a parallel trend as herbicide rate increased weed weight decreased.

CONCLUSIONS

Data collected indicated that herbicide-coated or blended fertilizers may provide effective weed control in nursery container production. These products reduce the amount of herbicide needed by 90% to provide effective weed control. They are environmentally friendly due to the elimination of nontarget herbicide losses. Even when these herbicide-coated fertilizers are directly applied to the container at higher than industry standard rates, no phytotoxicity or growth reduction occurred. Concern exists with herbicide blended fertilizer due to potential separation of the herbicide and fertilizer in handling and shipping; smaller particles may settle to the bottom.

Data indicated that herbicide-coated fertilizers should be considered as an alternative to either broadcast or sprayed application to diminish pesticide contamination in the environment.

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Field Evaluation of Two Cultivars of Red Maple From Tissue-Culture and Budded Origins

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The growth of tissue cultured and budded trees of 'Franksred' and 'October Glory' red maple (*Acer rubrum* L.) were compared in a field study. There were no differences between the two propagation methods for the two cultivars in annual mean height or increase in stem caliper, fall coloration, or gas exchange. No rapid screening technique for early detection of bud union failure was developed.

INTRODUCTION

Current methods of propagation for cultivars of red maple (*Acer rubrum* L.) include softwood cuttings (Moller, 1985; Schwab, 1979; Still and Lane, 1984), tissue culture (Bracken, 1988; Suttle, 1992), and budding onto seedling rootstocks (Santamour, 1992). Losses exceeding 50% in the first year and 10 to 20% in the second year as a result of bud union incompatibility have been reported in selected cultivars (Moller, 1985; Schwab, 1979). In a previous red maple evaluation conducted by the Alabama Agricultural Experiment Station (Fare et al., 1990), bud union failure was evident in eight of nine cultivars tested within 3 years after planting. All trees included in the study were budded onto seedling rootstocks. The only cultivar without visible compatibility problems was 'Franksred'. 'October Glory' was not included in previous evaluations.

The objective of this study was to evaluate the influence of tissue-culture and budding propagation systems on the growth of two field-grown cultivars of red maple. Specific characteristics evaluated included mortality, annual growth, morphological characteristics, and gas exchange capacities. Gas exchange measurements were conducted in an effort to develop a rapid screening technique for early detection of stress from bud union failure, prior to physical evidence of bud union failure.

MATERIALS AND METHODS

In March 1988, *A. rubrum* L 'Franksred' (Red Sunset^{TM}), and 'October Glory' tissue-culture-produced microplantlets and budded trees on seedling rootstocks were obtained from A.G. McGill & Son Nursery, Fairview, Oregon. Trees were containerized in 2.8-liter pots in an amended 6 pinebark : 1 sand medium (v/v) and grown in a double layer polyhouse for 3 months, then moved outdoors under overhead irrigation for the remainder of the growing season. In 1989, trees were transplanted to 9.5-liter containers for another 12 months. Trees ranged from 1.2 to 1.5 m (4.2 to 4.9 ft) in height when transplanted in March 1990, into a Cecil gravelly sandy loam soil at the Piedmont Substation, Camp Hill, Alabama (lat. 32° 83' N, long. 85° 65' W). The two cultivars were interplanted within a cultivar trial with 12 other red maple selections in a randomized complete block design with five blocks of two plants each. The trees were planted on a 9.1 × 10.7 m (30 × 12 ft) spacing and were fertilized with 59 g N, as 13N-5.6P-10.8K (13N-13P_2O5-13$K_2$0) per 2.5 cm (1 inch) of stem diameter at 30.5 cm (1 ft) above ground level, at planting and annually in March prior to bud break. Drip irrigation was supplied to each tree based on 100% replacement of net evaporation from a class A pan. Height and caliper increases were determined by the difference in current and previous year measurements following the 1990 through 1994 growing seasons.

Ten leaves from the midpoint of current season's growth were harvested at random from each tree monthly—May through Sept. 1993—for determination of total leaf area and petiole length.

Leaf area was determined with a transparent belt conveyer accessory leaf area meter, LICOR Mod. LI-3050A (LICOR Inc., Lincoln, NE).

Similar leaf samples were collected from each treatment within one block in Aug. and Sept. 1993. Stomatal density was calculated using an eyepiece reticule with a field of observation of 0.0156 mm^2 at 40x magnification. Means were derived for each cultivar from five leaves per tree from each propagation method, with four fields of observation per leaf, for a total of 20 observations per cultivar per propagation method.

Foliar greenness and N levels were determined in Aug. and Sept. 1993. Leaf greenness was determined with a SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ltd., Japan) and total N with a LECO CHN-600 Analyzer (LECO Corp., St. Joseph, MI). Measurements were made with a SPAD-502 on fresh leaf tissue prior to N analysis. Leaf tissue was dried at 80C, ground in a cyclone mill through a 0.5-mm sieve, weighed, and was analyzed by combustion.

Net CO_2 exchange rate was determined following the procedures of Jurik (1986). Net CO_2 exchange rate of sugar maple leaves measured at light saturation was reported to increase to a maximum near the completion of leaf expansion in early June, was constant until mid-Sept., and then rapidly declined until leaf senescence (Jurik, 1986). Gas exchange measurements (net photosynthesis {Pn}, stomatal conductance, and transpiration) were initiated in June 1992, and taken from 8:00 AM until 2:00 PM CST at an average photosynthetically active radiation (PAR) level of 1474 μmol m^{-2} s^{-1}. Measurements were repeated under similar PAR levels in September 1992, June and August 1993. Gas exchange observations were made with a LI-6250 Portable Photosynthesis System (LICOR Inc.) in a closed mode (Mitchell, 1992), which allowed leaves to draw down ambient CO_2 concentration in a 1-liter chamber over a 20-sec period. Three gas exchange observations were made on each plant within each replication. Non-destructive measurements were made on attached, mature leaves growing in full sun at the mid-point of current seasons growth and tree canopy. Assimilation rates were observed over a 45-minute period within each replication with a CO_2 concentration ranging from 320 to 390 μg l^{-1} at near constant leaf temperatures of 32C (90F).

Night respiration rates were determined in July and August, 1993, on consecutive nights between 10:00 PM and 2:00 AM. Night respiration rates were determined in the same manner in which Pn rates were generated in the day. Measurements were made under full moonlight. The only supplemental light was from the diode on the LI-COR monitor. Treatment differences were determined by Duncan's Multiple Range Test at $P = 0.05$.

RESULTS AND DISCUSSION

During the first five-growing seasons in the field, there were no differences in annual mean height increases between tissue cultured and budded plants for either cultivar (Table 1). Mean height growth attained for budded 'Franksred' was 21 cm greater annually in this study than that reported in previous evaluations at the same substation (Fare et al., 1990). Differences may be attributed to trickle irrigation for the current study, and no supplemental irrigation in the previous evaluations. Final height for 'Franksred' from tissue-culture and budded propagation were 481 cm and 465 cm respectively. Final height for 'October Glory' from tissue-culture and budded propagation were 510 cm (16.7 ft) and 492 cm (16.1 ft), respectively.

Table 1. Annual height and caliper increase of tissue cultured and budded plants of two *Acer rubrum* cultivars outplanted in a field study.

	1991		1992		1993		1994		Average annual increase	
	Height (cm)	Caliper (mm)	Height (cm)	Caliper (mm)	Height (cm)	Caliper (mm)	Height (cm)	Caliper (mm)	(cm)	(mm)
'Franksred'										
Tissue culture	80 a[z]	13 a	73 a	17 a	70 a	23 a	76 a	21 a	75 a	19 a
Budded	74 a	12 a	73 a	19 a	61 a	19 b	76 a	21 a	71 a	18 a
'October Glory'										
Tissue culture	65 a	14 a	88 a	20 a	87 a	29 a	74 a	24 a	81 a	22 a
Budded	62 a	16 a	91 a	22 a	96 a	26 a	74 a	23 a	79 a	22 a

[z] Mean separation by cultivar (tissue culture versus budded) within columns by Duncan's Multiple Range Test, $P = 0.05$.

Annual increases in mean caliper were not different for any of the 5 years for tissue cultured versus budded plants for either cultivar with the exception of 1993, when tissue cultured 'Franksred' trees had more mean caliper growth than the budded trees. Increases seen in the mean caliper growth for budded 'Franksred' were again greater annually under irrigation than those reported in the earlier study (Fare et al., 1990). Final stem caliper for 'Franksred' produced from tissue culture and budded plants were 9.9 cm (3.9 inches) and 9.2 cm (3.6 inches), respectively. Final caliper for 'October Glory' from tissue culture and budded plants were 11.9 cm (4.7 inches) and 10.7 cm (4.2 inches), respectively.

Of the additional evaluations made in an effort to detect differences that might indicate bud union incompatibility (Table 2), the only difference noted for 'Franksred' was a greater stomatal density on the trees from tissue culture than plants budded onto seedling rootstocks. However, tissue-cultured 'October Glory' had greater leaf area and petiole length, and a lower stomatal density than budded 'October Glory' (Table 2).

Table 2. Leaf characteristics[z] of tissue cultured and budded plants of two *Acer rubrum* cultivars outplanted in a field study.

	Average leaf area (cm^2)	Petiole length (cm)	Stomatal # (cm^2)	Nitrogen (%) by LECO	Chlorophyll level (SPAD)
'Franksred'					
Tissue culture	53.37 a[y]	9.26 a	76,410 a	2.17 a	52.0 a
Budded	53.83 a	9.79 a	70,192 b	2.20 a	52.5 a
'October Glory'					
Tissue culture	61.87 a	17.09 a	64,423 b	2.52 a	43.2 b
Budded	57.55 b	15.52 b	73,076 a	2.51 a	44.0 a

[z] Means by column derived from: 80, 80, 40, 1200, 1200 leaf samples, respectively.
[y] Mean separation by cultivar (tissue culture versus budded) within columns by Duncan's Multiple Range Test, P=0.05.

Often leaf greenness is considered to be highly correlated with foliar N levels. However, results of this study indicate 'Franksred', while generally considered by growers to have the deepest green foliage of red maple cultivars, had a lower foliar N than 'October Glory'; conversely, 'Franksred' had higher values for leaf greenness (higher chlorophyll) as determined by the SPAD-502 Meter. The propagation method had no effect on foliar N levels with the two cultivars. Foliar N levels for 'Franksred' were similar to reports by others (Gilliam et al., 1980).

There were no differences in daily gas exchange capacities or night respiration rates for either cultivar (data not shown). No 'Franksred' trees were lost in this study. In June 1993 one 'October Glory' died in this study as a result of bud union incompatibility. No physiological or physical evidence of bud union problems were evident prior to the tree breaking off at ground level during heavy winds.

Either method of propagation appears to be suitable for 'October Glory' and 'Franksred'. Therefore, selecting a propagation method based on production costs of a particular method is justified for these two cultivars. Bracken (1988) and Schwab (1979) address economic concerns for selecting one propagation method over another.

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Stem Cutting Propagation of Bottlebrush Buckeye

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Stem cuttings of bottlebrush buckeye (*Aesculus parviflora*) were taken monthly after vegetative bud break from May through July. Cuttings taken in May rooted at significantly higher percentages than those taken in July. In another study, cuttings were treated with 0, 2500, 5000, and 10,000 ppm IBA in solvents of water, propylene glycol, or ethanol. Cuttings treated with ethanol had the greatest number of roots per rooted cutting and the highest rooting percentage. The best treatment producing the highest rooting percentage was 2500 ppm IBA in ethanol.

INTRODUCTION

Bottlebrush buckeye (*Aesculus parviflora*) is a large, native shrub that grows up to 3.7 m (12 ft) wide and 4.6 m (15 ft) tall and is hardy in much of the eastern United States. Panicles of white flowers with prominent stamens are borne in profusion above the foliage in mid summer. Two distinct types exist. *Aesculus parviflora* flowers in late spring while *A. parviflora* f. *serotina* flowers about 3 weeks later. The fact that bottlebrush buckeye performs well in both the full sun and dense shade makes it a valuable landscape plant (Dirr, 1977). However, bottlebrush buckeye is frequently in limited supply within the nursery industry.

One reason the supply of plants is limited is that most are propagated from seed. Seed propagation requires viable seeds which are collected before they can dry out and planted shortly after collection since seed loses viability quickly and no dormancy requirements exist (Fordham, 1987). Root cuttings are frequently mentioned as the preferred method of propagation (Macdonald, 1986), but successful propagating percentage is often low.

Research (Dirr and Burd, 1977) indicated that rooting of softwood cuttings has great potential. In 1976, 80% rooting was obtained using 1000 ppm IBA in an alcohol quick dip but in 1977, this same treatment produced no rooting, while a 5000 ppm IBA quick dip produced 60% rooting. These differences were attributed to the rapid maturation of cutting wood in bottlebrush buckeye. It was suggested that since the 1977 cuttings were taken from more mature tissue, they required treatment with a higher concentration of IBA in order to root. However, they also reported that concentrations of 10,000 ppm IBA and higher appeared to be toxic.

Follow-up research (Bir et al., 1994) to help determine guidelines for commercial propagators concerning timing of cuttings and auxin rates were undertaken. A timing study was conducted at Lorax Farms, Warrington, Pennsylvania, while an auxin concentration study was conducted at the Mountain Horticultural Crops Research Station (MHCREC), Fletcher, North Carolina. Results indicated that seasonal timing is very important and that rooting was best within the first 6 weeks after vegetative bud break in spring. In addition it was reported that auxins were not essential for rooting, but significantly enhanced rooting percentage.

The timing study was conducted using IBA plus NAA in propylene glycol but questions remained concerning the efficacy of commonly used solvents. Therefore in 1994, studies were undertaken at MHCREC to determine: 1) whether water, alcohol, or propylene glycol was the best solvent; 2) whether IBA alone could provide acceptable results; and 3) to further evaluate the influence of seasonal timing on the rooting of bottlebrush buckeye.

MATERIALS AND METHODS

Seasonal Timing Study. Cuttings were taken 1, 2, or 3 months after vegetative growth began in the spring. Terminal stem cuttings of 20 cm (8 inches) length were taken in the early morning from mature plants at the Biltmore House and Gardens, Asheville, North Carolina, and placed in a cooler with ice which was kept in the shade during transportation. At the MHCREC, flower buds were removed, cuttings were re-cut to 15 cm (6 inches), and leaf size reduced by approximately one-third. Prepared cuttings were quick-dipped for 1 sec into rooting solutions consisting of 95% ethanol with 0, 2500, 5000 or 10,000 ppm IBA. Cuttings were stuck in a 1 peat : 1 perlite (v/v) rooting media under intermittent mist.

Percentage rooting and number of roots per cutting were determined 1 month after sticking. There were five cuttings in each of three replicates (n=15). Treatments were randomized within replicates.

Solvent Study: Cuttings were taken in May and prepared as previously described. Control (0 IBA) cuttings were quick dipped for 1 sec in either water, 95% ethanol, or propylene glycol. For ethanol treatments, IBA was dissolved in ethanol and serial dilutions made with ethanol. For propylene glycol treatments, IBA was dissolved with propylene glycol and serial dilutions were made with water. K-IBA was dissolved and serially diluted with water for the water solvent treatments. Concentrations of IBA and K-IBA were: 0, 2500, 5000 or 10,000 ppm. Percentage rooting and number of roots per cutting were determined 1 month after sticking cuttings.

RESULTS

Seasonal Timing Study. Rooting percentage declined with time. The highest percentage occurred in cuttings stuck a month after vegetative growth began (May). Cuttings stuck in May rooted in significantly higher percentages than those stuck in July but not significantly better than those stuck in June. (Table 1). All concentrations of IBA enhanced rooting in May, while only 10,000 ppm enhanced rooting in June, compared with the control (Table 2). With July stuck cuttings, IBA did not enhance rooting. The number of roots per cutting rooted (data not shown) did not exactly follow rooting percentage. In May and June all IBA treatments increased the number of roots per rooted cutting, with 5000 and 10,000 ppm IBA having the greatest effect (data not presented). Few roots developed with July stuck cuttings, and root number was not influenced by IBA treatments.

Table 1. Rooting percentage of bottlebrush buckeye stem cuttings stuck monthly after vegetative bud break from May through July.

Month cutting stuck	Rooting (%)[1]
May	73.3 a
June	60.0 ab
July	26.7 b

[1] Duncan's New Multiple Range Test, P=0.05.

Table 2. Effect of IBA dissolved in ethyl alcohol on rooting percentage of bottlebrush buckeye stem cuttings after vegetative bud break from May through July.

	Month stuck		
IBA (ppm)	May	June	July
0	73	60	27
2500	93	53	60
5000	100	60	60
10000	93	93	40

Table 3. Effect of three solvents used for auxin carriers on rooting percentage and root number of bottlebrush buckeye stem cuttings. All auxin treatments were pooled per solvent.

Solvent	Rooting (%)[1]	# Roots/rooted cutting
Water	62 b	5.3 b
Propylene glycol	68 b	8.1 a
Ethanol	88 a	9.3 a

[1] Duncan's New Multiple Range Test, P=0.05.

Solvent Study. The highest rooting percentage occurred when ethanol was used as a solvent (Table 3). The number of roots per cutting rooted was significantly greater when either propylene glycol or alcohol were used as solvents. The highest percentage rooting was achieved with 2500, 5000, and 10,000 ppm IBA in alcohol, 5000 and 10,000 ppm IBA in propylene glycol, or 10,000 ppm K-IBA in water. There were no significant differences in the number of roots per cutting rooted due to IBA treatments (data not shown).

Table 4. Effect of solvents and auxin concentration on rooting percentage of bottlebrush buckeye stem cuttings. IBA was mixed with the solvents propylene glycol and alcohol, while K-IBA was mixed with water.

Solvent	Auxin (ppm)	Rooting[1] (%)
Water	0	33 d
	2500	67 b
	5000	60 b
	10,000	87 a
Propylene glycol	0	40 cd
	2500	53 bc
	5000	87 a
	10,000	93 a
Alcohol	0	67 b
	2500	87 a
	5000	100 a
	10,000	100 a

[1] Duncan's New Multiple Range Test, P=0.05.

DISCUSSION

This research demonstrates that: 1) rooting percentage was greatest when cuttings were taken within 2 months after vegetative bud break in the spring; 2) ethanol was the most effective solvent for rooting percentage and both ethanol and propylene glycol treated cuttings had the greatest number of roots, and 3) when considering optimum rooting percentage and number of roots per cutting, 2500 ppm IBA in ethanol applied to May cuttings gave the best results, i.e., the lowest IBA concentration with the better solvent for maximum rooting.

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Micropropagation: The Ultimate Power Tool

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INTRODUCTION

The concept of micropropagation as a power tool is, admittedly, a silly idea, but consider the similarities. We like power tools because they get the job done quickly, save labor and resources, yield more uniform results, and generally make projects easier.

Power tools can also do great damage if you are not careful. The key to taking advantage of power tools is in learning how to use them properly to maximize results and minimize risks. One must wear the proper safety equipment. One must also continuously screen the procedures and product to make sure that what you end up with meets or exceeds the industry standards for quality. After all, only quality sells long term.

The following are some of the ways micropropagation is being used effectively in the trade today. Many of the largest and smallest nurseries in the United States view micropropagation as an essential power tool which helps them maintain their competitive edge by growing better plants more efficiently.

New Introductions. Perhaps the most obvious use for micropropagation is to get a "jump start" on growing the newest and hottest items quickly. Micropropagation cuts 3 to 10 years off the time it takes to bulk up new selections and get them to market. For example, micropropagation was used by one of our customers to establish layer beds of a new apple understock. In the same amount of time his competition had bulked up a few thousand rootstock using conventional propagation methods, our client sold over 1 million micropropagated rootstock. The world is always looking for something new and exciting. If you happen to have lots of a new product before your competition does, than this translates to money in your pocket. It also tends to build your reputation as a leader in the industry and cause customers to come back to you year after year for other plant items.

In some cases, growers use micropropagated plant material to establish mother (stock) blocks and to fill in production shortages while mother blocks are still too young to be productive. In many other cases, micropropagation remains the method of choice for a number of reasons.

Rapid Response To Market Demand. Large cutting blocks or scion orchards are time consuming and expensive to establish and maintain. It is often difficult for growers to adjust quickly to the rise and fall in popularity of a given plant. We maintain our stock block in a 3 m × 3 m (10 ft × 10 ft) cold storage unit. If our customer gets a call for an additional 10,000 liners of a particular blueberry, for example, the customer simply calls us and asks when is the earliest we can provide microcuttings, adds the time he needs for the greenhouse growing and calls the buyer back with a delivery date. He never has to tell his customer no. We call this "dial-a-date delivery."

Clean Plants. Micropropagation is inherently a cleaner system. Since the plants are grown in culture, diseases are not transmitted from the field into the greenhouse and on to subsequent generations. A single disease-free mother plant can produce unlimited disease-free daughter plants. Conversely, each virus-free plant in a field-grown mother block must be retested on an annual basis in order to maintain virus-free status. Testing fees add significantly to the expense of maintaining large mother blocks in the field. In Oregon, such fees are rapidly escalating. With lilies, insects are vectors for debilitating virus problems. By planting clean stock in the field, one can greatly limit such losses.

Ease of Propagation. Bud incompatibility on budded or grafted stock, and poor rooting percentages with softwood or hardwood cuttings makes micropropagation the method of choice or the only option on many difficult-to-propagate plants such as *Syringa* and *Cercis*. Some *Acer rubrum* cultivars such as 'Karpick' and 'Bowhall' are absolutely impossible to root from cuttings. Unreliable seedling availability and poor or unpredictable bud stands on *Betula, Tilia,* and *Morus* are problems growers are able to avoid by planting micropropagated material. Growing plants on their own root system offers major advantages for plants such as *Corylus avellana* 'Contorta' (contorted filbert), where suckering of understocks can be a major problem.

Sometimes micropropagated material provides the grower with a nucleus of "juvenile" material from which additional cuttings can be more easily rooted. Each year the customer starts over with a fresh batch of starter material from the lab.

Efficiency—Making Every Plant Count. As competition has increased in the marketplace over the past several years, growers have not been able to raise prices in order to maintain profitability. Greater emphasis is being placed on improving production practices, making every dollar spent on labor and resources count.

The bottom line in evaluating any production scheme is how many salable plants you end up with after planting, growing, pruning, digging,and grading. Losses due to seedling mortality, poor bud stands, crookedness, terminal bud loss, and poor root quality cause growers to not only lose the revenue and time they have invested in growing the stock, but also the revenue which would have come from the sale of the lost stock. Losses in various large bare-root nurseries typically runs 15% to 20% or more. For example, of the 750,000 trees planted by one grower, they were throwing away about 150,000 by grading time. By switching to micropropagated stock, they figure they are gaining about 50,000 of those trees back into the salable column. Figuring at a low-end value of $7.00 per tree (estimate very low, since this particular grower sells a combination of 1- and 2-year finished stock), this translates to $375,000 of additional income. Spending a little more on the front-end adds up to much larger profits when the whole picture is accounted for. Why waste time, energy, equipment, and resources tending plants that will end up as discarded inventory?

Faster. Research done at various universities indicates that it is possible to grow tissue-culture-produced plants much more quickly to size than is traditionally done in nurseries with conventionally propagated plants. I planted a 1-gal blueberry plant in my backyard last week that has 13 canes averaging 8 to 18 inches each. The plant came out of our lab in February 1994. Eight months ago it was 1 inch tall with no roots on it. Such rapid growth requires optimization of all growing conditions including fertilizer, light, and heat. Several field growers are now producing well-formed, small branched trees of *Prunus serrulata* 'Kwanzan', *Morus alba* 'Chaparral', and others in 1 year instead of 2 years.

Greater Uniformity. While cultural practices play a huge role in the ultimate performance of any block of plant material, the overall consensus of our customers, when asked why they prefer micropropagated *A. rubrum* and *Betula* in the field, is primarily the overall survival rate and secondly the reliability and consistency of the product when it is harvested 2 to 3 years later. The plants are not necessarily bigger, but the size and quality is more uniform and dependable.

Superior Branching. Because the internode length is greatly reduced on micropropagated plants, there is generally more opportunity to develop a fuller, better branched plant. Indeed, this is also one of the reasons why survival is often greater. If something happens to destroy the terminal bud, (for example: damage caused by freezing, hungry rabbits, or poor pruning), there are other buds below available to choose from. One grower accidentally sprayed a young block of *A. rubrum* liners twice with Surflan. The stems of the young micropropagated liners were girdled right at soil level. All was not lost, for the grower dug the soil out from around the base of the plants, removed the damaged tops and the buds below the girdling all pushed out again. The grower lost some height on his crop, (about 1 to 2 ft), but shorter plants are better than no plants at all. Having more buds to choose from also allows a grower to cut back closer to the ground producing straighter trees.

The better branching is a real advantage when it comes to growing well-formed shrubs. *Hydrangea quercifolia* Snow Queen® from rooted cuttings tends not to develop many branches at an early age, while micropropagated plants are easily developed into a bushy habit with routine pinching.

SUMMARY

Micropropagation should be considered a power tool for many reasons. Growers are learning more and more how to use it wisely to help their operations become more efficient and effective. Perhaps the most basic reason of all is that it makes producing a crop that much easier.

Evaluating New Cultivars and Getting Them Into Production

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INTRODUCTION

Humankind first used plant material ornamentally when Eve employed a strategically placed fig leaf. I can imagine that Adam thought that the fig leaf was too large; Eve insisted that the fig leaf was appropriate and Adam immediately began seeking out a new and improved smaller leaf cultivar of fig for Eve. Adam and Eve in the evaluation of their new selection began the ongoing process of seeking out plant types that offer greater value than their previously used selection.

New Cultivar Development. The emphasis our industry is placing on new cultivar development and introduction is in response to the buying public's demand for new styles, and our own realization as horticulturists that we need to produce better cultivars. Seed companies spend huge amounts of time and resources on breeding programs to develop new flower colors, plant and flower forms, heat and cold tolerance, higher yields, disease and insect resistance, and many other characteristics that both improve plants for the public and give their company a marketing edge over the competition.

In the Beginning. My topic today is not new. Perhaps because of the importance that new cultivar evaluation, production, and introduction are having on our industry, we feel somewhat pressured and probably feel inadequate to meet the challenge. Our horticultural forefathers brought roses and fruit cultivars from the old countries in the 18th and 19th century to their new country. Our horticultural forefathers imported *Camellia japonica, Ilex cornuta, I. crenata*, and evergreen azaleas from Asia to beautify our residences and plantations early in the 20th century. Our horticultural fathers and grandfathers in the 1940s, 50s, and 60s, grew millions of hollies, azaleas, and junipers. They added plants like *Ligustrum, Pyracantha, Photinia*, and *Pittosporum* to meet the tremendous demand of our rapidly expanding economy following WWII, and the Korean War.

Today, our nursery and probably yours, grow many more cultivars than 20 years ago. *Photinia*, is not a minor crop, nor is it the major crop it used to be. This trend was dramatically reversed 2 to 3 years ago because of the leaf spot blighting throughout the southeast. *Pittosporum*, *Pyracantha*, and *Ligustrum* have gone *from major to minor crops in the last 20 years. Changes in winter weather patterns* have caused the decline in popularity of these crop species and cultivars. When a major cultivar goes out of demand we must determine what will be the new plant or plants of choice.

The Cultivar Evaluation Program at Flowerwood Nursery. Some 15 years ago, our company was aware of the success of Monrovia Nursery Company. One main reason for their success was their historically aggressive new cultivar evaluation and introduction program. At that time, I was directed to expand our nursery's product list and we are still not finished. The process is ongoing and never ending. We have made some mistakes and we have had many successes.

The *Hydrangea* Program. One success at Flowerwood Nursery was the *Hydrangea macrophylla* program. When I began my work, we produced only one hydrangea cultivar, *H. macrophylla* 'Garden Blue'. We were aware that many named cultivars existed primarily for the florist trade. We purchased 12 cultivars and evaluated them for shrub compactness, foliage quality, flower color, flower size, number of flowers, and ease of propagation. After 2 to 3 years of evaluation, 'Glory Blue', 'Merritt's Supreme Pink', 'Soeur Therese' (syn. 'Sister Thérèse'), and 'Cardinal Light Red' became part of our product mix. After several years, two more red cultivars were purchased and evaluated. 'Charm' was determined the best of the two red cultivars because of spider mite tolerance, bush compactness, and flower color. Consequently, 'Charm' was added to our product mix and 'Cardinal Light Red' was dropped.

More recently Monrovia and Dr. J.C. Raulston have been promoting a compact pink form, 'Pia'. We were working on increasing inventory numbers of 'Pia' because I have faith that it is a tremendous cultivar. For at least 10 years our total production of cultivar hydrangeas has doubled each year. It is my opinion that the hydrangea opportunity is still quite big. Compact blues and whites and variations of existing types will help us realize that opportunity. But we must first collect new cultivars and test and evaluate them before adding any new cultivars to our production list.

The Azalea Program. Fifteen years ago while analyzing our azaleas, I discovered that our two most popular cultivars were 'Satsuki Gumpo White' and 'Gumpo Pink'. We were startled to realize that each Gumpo cultivar was outselling the standard Kurume, Glendale, and Indica cultivars, while commanding a much higher average price year to year. Every year we were forced to sell at the low market price of the standard cultivars, but not with the higher-priced Gumpo cultivars. Knowing this, we bought other late blooming azaleas from eastern U.S.A. and West Coast sources. Most were Satsuki and Robin Hill cultivars. Nearly two dozen cultivars were tested. We exposed them to normal weather conditions. The cultivars differed in cold and heat tolerance, legginess and compactness, flower size and blooming characteristics, disease susceptibility, etc. More than half failed to be solid performers and were not kept in production. To be added to our azalea product list, the cultivar had to: 1) propagate easily, 2) grow vigorously, 3) be relatively disease tolerant, 4) be bushy, 5) flower prolifically with good color, and 6) tolerate our heat and cold.

Out of that original group we currently produce: 'Amaghasa', 'Flame Creeper', 'Frosted Orange', 'Higasa', 'Joseph Hill', 'Pink Cascade', and 'Watchet'. Since then we have evaluated and brought into production other cultivars, i.e., 'Girard's Rose', 'Renee Michelle', and 'Girard's Crimson'. I see a trend for our company to grow fewer standard azalea cultivars because of generally low wholesale prices. Standard cultivars will be replaced with a selection of cultivars from hybrid groups, such as, North Tisbury, Robin Hill, and Girard.

The case studies of *Hydrangea* and azalea cultivar evaluation are examples of our company looking for new cultivars of existing familiar plant groups. Selection of new cultivars gives our customers a better plant and a new style. These cultivars gave our company a higher return on the investment and the excitement of growing something new. We did not actually develop these cultivars, but we took the hard work of others and through evaluation, we found those few cultivars that work well for our production system and markets.

Problems with Introducing an Obscure Plant Genus. We believe that with an obscure genus it is almost impossible to gain wide market acceptance. It would take many years to accomplish this feat. Introducing a new species of a familiar genus is difficult enough. The easiest and most likely chance of success is to select a new cultivar of an already established species. Examples would be 'Firepower' nandina instead of 'Nana Purpurea' (syn. 'Dwarf Purple') or *Nandina domestica* 'Royal Princess' instead of the common *N. domestica.*

Locating New Cultivars to Evaluate. Where do you obtain a new cultivar for evaluation besides some other wholesale nursery's plant list? We have found new forms of plants as sports within our own nursery. *Abelia* ×*grandiflora* 'Confetti' was a mutated four-leaf terminal of 'Sherwoodii'. *Ilex vomitoria* 'Bordeaux' was found growing as a population of five plants among several thousand dwarf yaupon holly. The selection of *I. vomitoria* 'Hightower' was an individual female with strong upright habit and prolific red berries growing in a mile row of seedling-grown yaupon at our Meadows Branch field production site. Roadsides and native plant acreage all offer opportunities to discover superior forms of native plants.

Botanical gardens, and especially arboretums, offer opportunities for one to see different cultivars. Such places are vast collections and many have been established long enough to thoroughly determine characteristics and value to the landscape. However, a nurseryman still must determine if those cultivars can be economically produced. A new cultivar must be reasonably easy to propagate and grow. They should grow without special care. It was with great excitement that I realized in 1993, while at the Southern Nurseryman's Trade Show in Atlanta, Georgia, that the nursery producers in the Southeast United States were displaying a progressive range of species and cultivars that I knew were an exact fit with our climate and environment. I felt that Drs. J. C. Raulston and Mike Dirr were largely responsible for what I was seeing. At the Monrovia booth I did see some new cultivars; however, what I saw may not be as well adapted to the southeastern U.S.A. as those new cultivars displayed in other nursery booths.

Opportunities for Selecting Superior Cultivars. Any time you grow a seedling population there are opportunities for selection of superior types. Some years ago I was in central Florida to visit our nursery and took the time to go to a new, large nearby wholesale nursery whose activities were of concern and interest. As I was looking around I noticed a rather large crop of 3-gal seedling-grown *Rhaphiolepsis indica* and initially laughed to myself, since no one grows seedling indian hawthorn. The market was for cultivar cutting-grown clones. Then it occurred to me that this was an opportunity to walk through the crop and select superior types, which would save me the time and expense of growing a large crop of seedlings. They allowed me to purchase 35 individuals.

After 6 years of evaluating for leaf-spot and fire-blight susceptibility, form, and flowering characteristics, we have narrowed the 35 down to 3 selections. Our first release was *R. indica* 'Rosalinda'. The selection is very vigorous, dark pink, fragrant, and with bronze new foliage. 'Rosalinda' can be grown as a specimen tree or large shrub. When picking out the original 35 plants, the original 'Rosalinda' was my last pick. It was tall and unusual, sitting along the road, pulled to the side—definitely an outcast; she was an ugly duckling that grew to be beautiful at maturity. The other *Rhaphiolepsis* selections that we are working with must be specifically adapted to the hot humid areas of the U.S., whereas West Coast selections are disease plagued and loose in growth habit. 'Olivia' and 'Eleanor Tabor' were named as cultivars along with 'Rosalinda'.

In another stroke of good luck, I ventured into a small local wholesale nursery specifically looking at their inventory of cleyera seedlings that were for sale. The time was early December and I noticed a large group of 10,000 3-qt seedling-grown cleyera. Overall the crop was of poor quality. It was explained to me that what I was looking at was a midsummer planting. I could see that the stress of the summer heat had stunted many individuals. Furthermore, on 1 November, the nursery had experienced freezing temperatures and many had frozen, as I could see. Despite all the bad conditions there were a few individuals that had thrived. I purchased 35 plants that had not suffered from the heat or cold. Those individuals were shifted at our nursery into 3-gal containers. I left them untrimmed and observed their growth and development. Ten plants were selected for propagation. Six of the 10 selections failed to propagate easily and they were discarded. Liners of the remaining four were easily propagated, self branching, and had dark green and richly colored foliage. These were planted into 3-gal containers in our normal production cycle. Three of the four selections grew quite well. Now I have to make a decision as to whether to keep 1, 2, or 3 clones and designate them as cultivars. I am confident that any of these clones will be a superior introduction. I have selected for ease of propagation, superior color, self branching, tolerance to heat stress, tolerance to early cold stress, and growth rate. The ultimate consumer will be able to purchase cloned cleyera for desired form and uniformity in the landscape.

The Selection Time Period. I have described to you the selection and evaluation of a new cultivar from naturally occurring populations of seedlings and the discovery of mutations that might be developed into a cultivar. Thorough selection and evaluation by these methods can take 7 to 10 years. I also mentioned evaluation of named cultivars that were developed by someone else. However, these already named cultivars are still evaluated by me to see if they are superior in form and tolerance and if we can economically produce them. This type of selection and evaluation normally takes 2 to 3 years.

The longest process in developing a new cultivar that I use is through breeding. These projects can take 12 or more years. In a breeding program you must define your goals. For example, we are involved in a breeding program to develop new cultivars of evergreen azaleas that are summer, fall, and spring blooming. The breeder reasoned that his goals would be best obtained by hybridizing the earliest blooming species of rhododendron with existing cultivars. Early blooming is when vegetative buds develop in the spring and mature to be reproductive and bloom by mid summer or fall. Early blooming evergreen azaleas are not the first to bloom in the spring.

The Breeding of New Azalea Cultivars. *Rhododendron oldhamii* is a summer and fall blooming species, reportedly cold susceptible. Two known gene pools of this species exist in the United States. Plants were obtained from a genotype thought to be more cold hardy than the other. The flowering time of the pollen parent *R. oldhamii* is summer and fall, and spring was the blooming period of those cultivars that were to be hybridized with it; hence, a method of pollen storage had to be developed. In this case mature pollen was collected on dry newspaper. The newspaper was folded and refrigerated until spring. The pollen remained viable. Pollination was made by hand using 40 different evergreen spring-blooming hybrid azaleas, representing several different hybrid groups. Each flower was tagged and monitored for fertilization and seed development. The seed pods were harvested in the fall. The seed were sown and the seedlings were very small and fragile. Many were weak. The seedlings grew slowly and after 4 years and three transplantings there were 10,000 small plants in 3¼-inch-liner pots!

The liners were carefully grown and 1 year later the seedlings were shifted to 3-qt containers and bloomed. At this point the 10,000 seedlings were selected down to 7,000 and shifted into 3-gal containers and observed for 12 months. In July, the seedling azaleas began to bloom in many colors, unlike the pollen parent which had light orange blooms. Single, semi-double, and double flowered plants appeared. Dwarf, semi-dwarf, and tall rangy plants showed up. The full sibling populations were varied. The one-half sibling populations were even more varied. Leaf-spot diseases affected some individuals. There were too many seedlings that looked like the pollen-parent plant, and many seedlings that were potentially desirable. Evaluations of the seedling population were made 4 h weekly for 12 weeks, and promising plants were marked. By October 31, 5,700 3-gal azaleas were of little apparent value and rouged.

Of the original 10,000 seedlings only 300 selections were left, which were shifted into 7-gal containers. The next year they were evaluated for: 1) plant form, 2) bloom period, 3) lace-bug resistance, 4) foliage quality, and 5) flower color. Evaluation for cold and summer heat tolerance continued and from that 300, 50 azaleas were selected for propagation and the next spring 200 1-gal plants of each of the 50 selections were grown. A total of 10,000 more units were evaluated for 2 years.

After all this time and money invested, the final selection of azaleas had still not been made based on all the selection criteria established. Many of the hybrids originally passed over now had desirable characteristics, and 10 acres at a permanent site were planted, since these plants were now too valuable to discard. The project became bigger and more costly than we ever imagined. After asexually reproducing and growing thousands, weaknesses in the plants were observed that became discouraging. Too many selections had apparently desirable characteristics. The question is "how does one reduce the choices to the best 6, 8, or 15 plants?" It takes patience, investment, and close observation.

I have described to you what is now a 9-year project initiated by Buddy Lee and now being carried on by our nursery. We are down to 50 selections and I see at least 2 more years of evaluation. When we make the final selections those plants will have been looked at, treated fairly, exposed to much, and will be very familiar to us. I think we will be in our 12th year after pollination before we sell our first plant. Breeding programs are a long-term investment.

Successful Cultivar Development Depends on the Support of Propagation and Production Managers and Sales Staff. New cultivar evaluation programs must have the full support of propagation and production managers to succeed. Finally, promising selections must also have the full endorsement of your sales staff. The naming of the cultivar is critical. Suggested cultivar names should be carefully considered and widely agreed upon. I don't think you can have too wide a consensus of opinion in this phase of the cultivar development. This paper has not discussed the marketing phase of new product development and production. However, our ultimate goal with new cultivars is to identify superior cultivars, to be effective in introduction and marketing, and to establish wide consumer acceptance.

Propagating from the Keyboard

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INTRODUCTION

We spend a lot of time and effort trying to keep everyone informed as to what is happening on the nursery. Try as we might, the lack of communication among divisions was creating problems that at times were frustrating. In an effort to improve this communication gap we developed a series of computer programs that have helped us in streamlining our production at Lancaster Farms. Our computer system is an Intel based PC using a UNIX operating system with programs written in Microsoft® Basic.

Developing a Computer Program for Propagation. The following discussion is a description of our simple propagation program. The first step is setting up a logical set of **standard assumptions:**

1) Number of pots/trays per house or m^2 (ft^2).
2) Production area.
3) Ingredients and their proportions used in standard mixes.
4) Rooting hormones used and their concentrations.
5) Production week calendar scheduling.

I cannot overemphasize the importance of establishment of these standards. Take your time in setting up the standards you need in your operation. Once established, they become the building blocks upon which everything is dependent.

Creation of a Propagation Work Order. The necessary coordination is done between the sales, propagation, and production divisions to decide what plants we want to propagate for the coming season. Once the cultivars and quantities of plants have been decided upon, the propagation manager creates a **Propagation Work Order**.

Decisions in the Propagation Work Order Process. Decisions are made and entered into the Propagation Work Order for the following:

Top Information: (Parameters for the Entire Work Order)

1) Order is assigned a number.
2) Scheduled production week.
3) Hormone type and concentration.
4) Size of pot, tray, and flats that will be used.
5) Propagation medium (substrate) that will be used.

Plant Species and Cultivar Information. (Maximum per order is 16 lines).

1) Plant species.
2) Quantity needed.
3) Number of cuttings per pot.
4) Total number of cuttings, which is computed if multiple cuttings are to be stuck per pot.

When all plants are entered into the Propagation Work Order, then a print-out is generated showing the above information as well as a listing of materials (production space, pots, mix ingredients, etc.) needed for the successful completion of the work order.

Once a Propagation Work Order is entered into the system, then we use this information to help in planning not only materials needed during a production week, but also in determining labor requirements during a given production weekly period.

Reporting Cutting Units Stuck in the Propagation Work Order. Immediately after the cuttings have been taken and stuck, then the propagation manager enters into the Propagation Work Order the actual number of cuttings that were made and the sticking date is recorded. Shortages are noted and if necessary, a new order is created.

Completed Propagation Order. The final step in the process is an evaluation of the cuttings after rooting. The propagation manager makes a physical count of the cuttings that rooted and the numbers are recorded. This completed propagation order is then used by the production division so that they can plan the potting and production needs of the rooted liners from propagation, etc.

SUMMARY

The production computer program developed for our propagation division has helped us to be better managers and has forced us to keep records that in the past were never made or were lost in some unfilled notebook. We have virtually eliminated the scenario of "ready-to-make-so-in-so-cuttings", when in reality we could not because of the lack of preordered supplies or available greenhouse space. The type of program we use is very simple and I urge you to consider using your computer for things other than just routine office needs.

TECHNICAL SESSIONS

TUESDAY MORNING, 6 DECEMBER 1994

The Forty-fourth Meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:00 AM in the Adam's Mark Hotel, Philadelphia, Pennsylvania, with President Tom McCloud presiding.

President McCloud: It's a beautiful day in Pennsylvania and it is my pleasure to call this session of the Forty-fourth Annual Meeting of the International Plant Propagators' Society—Eastern Region, to order. I can guarantee that the weather will be improved from yesterday and you will have much improved tours. We have an excellent program lined up for you and look forward to the next 3 days of seeking and sharing. If you are new to our Society you should be aware that we have a question box. As the meeting progress we know that you will have questions for speakers. Put your questions in the question box and we will have them answered for you. Ralph Shugert and Bruce Briggs are in charge of the question box.

AWARDS PRESENTATIONS

President McCloud: This morning we are departing from our normal procedure of awards presentations and we will be presenting the awards at this time. The first to be presented is the Fellow recipients. Each year the Eastern Region nominates and selects members who have contributed significantly to our Region. Anna Knuttel is chairperson of that committee will and make the presentations.

FELLOW RECIPIENTS—EASTERN REGION

Anna Knuttel: This is the fourth year that Fellow recipients have been given. We have an outstanding group of individuals for you today. They are recognized for their contributions to the field of propagation, but also for their contribution to the Eastern Region at large. The recipients are the following:

- **Dr. Paul Smeal.** *The first person is a retired professor from* Virginia Poly Tech. In his spare time he is executive director for the southern region of ASHS. He has been one of the most effective presidents in this organization. His leadership has made a significant difference in how effectively this Society is run. It is my pleasure to present it to Paul Smeal.
- **Clayton Fuller.** The second recipient is a very special person to me. This man has inspired my young people to become propagators. He has shared many of his propagation techniques with members of this Society. He has served the Eastern Region as Director and President. My mentor and close friend is Clayton Fuller.
- **Chris Graham.** The next recipient has quietly and diligently served the I.P.P.S. in many ways. He propagates for the Royal Botanical Gardens, Hamilton, Ontario. He has served as Director and President of the Eastern Region, and has most recently just finished a stint as the Eastern Region Director to the International Board. I am pleased to present this award to Chris Graham.

- **Kris Bachtell.** The next recipient is a newer member of this organization. He works for the Morton Arboretum as director for the plant collections. He has travelled to China three times on plant hunting expeditions. He has served as a Director on the Eastern Region Board and will come on next year as the Second Vice President. He is being recognized for his diligent work on the Membership Committee. Our next recipient is Kris Bachtell.
- **Charles Heuser, Jr.** Last but definitely not least, the recipient is the editor of the Eastern Region, editor I.P.P.S. International, and editor of the North American Plant Propagator. He is currently an Associate Professor of Horticultural Physiology at Penn State. He knows more about mung beans than anyone else and he is an all-around great guy—Charles W. Heuser, Jr.

AWARD OF MERIT—EASTERN REGION

Anna Knuttel: The next award is the Award of Merit and Ralph Shugert will present it.

Ralph Shugert: I am extremely honored to present to you the recipient for the 1994 Eastern Region Award of Merit. For the edification of our guest, and newer members, this is the highest award of the Eastern Region. The recipient must have minimum of 10 years of active membership within our region, as well as outstanding contributions to plant propagation within the industry, research, teaching, or extension. Ballots are sent to all members,and the Award of Merit committee, chaired this year by Deb McCown, selects the winner.

This prestigious award started in 1957 with Dr. L.C. Chadwick receiving the award. Our Proceedings state that Chad was presented with the award at the 1958 banquet. I remember the 1957 meeting since we then exceeded 300 members and had one person serving as editor, secretary, and treasurer. From 1958 to the present, the office of editor stands alone.

Over the years, presenters have given lengthy background data to this award recipient. I am not going to tell you where this person went to grade school or if they prefer chocolate over vanilla! I will state that our awardee became an Eastern Region member in 1963 at our meeting in St. Louis, Missouri.

My friends the two most important executive positions at the International and regional levels are the secretary-treasurer and editor. These two offices give our beloved Society the coherence needed for continued success.

We are blessed, and extremely fortunate to have an Eastern Region member who is not only our regional editor, but also International Editor. He presented us with two Proceedings in 1994!

President McCloud, ladies and gentlemen, the 1994 Eastern Region Award of Merit is presented to my friend, Dr. Charles W. Heuser, Jr. Charles exemplifies our motto of "Seek and Share"—our congratulations, sir!

President McCloud: Charles, my congratulations to you and to all of the Fellow recipients.

Vice-President Beattie: It is my honor to present to President McCloud this plaque for his service to the Eastern Region as president during 1994. Tom, thank you very much.

The first part of the morning session was moderated by Tim Brotzman.

Plant Exploration in Hubei

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In 1879 after ascending the Ygantze River as far as Inchang, plant explorer Charles Maries reported that all the Chinese species of any merit had already been introduced. His view was widely accepted for over 20 years. In fact, in 1899 when Ernest Wilson was dispatched in search of *Davidia involucrata,* on behalf of Veitch Nursery of England, he was instructed, "Stick to the one thing that you are after, and do not spend time or money wandering about. Probably almost every worthwhile plant in China has now been introduced" (Wilson, 1929). Fortunately, Wilson did not follow this charge too closely and in the course of his Asian journeys over the next 11 years, he introduced well over 1000 new plants and literally changed the face of Western gardens.

Today, a hundred years later, attitudes similar to those of the 1880s still prevail. Even in botanical gardens, many people feel that any temperate garden plant species of worth has already been collected and tested. Yet, in my travels in China and Korea, I found a tremendous wealth of plants waiting to be tapped. For example, a quick review of the modern botanical literature reinforces this impression. In Fang, Wen-Pei's monograph of Chinese maples, he acknowledges 143 species (Fang, 1981). Of these, only six can be found readily in the American nursery trade and another 14 species can be readily located in botanic garden collections. One might quibble about the taxonomic status of some of these species, or a careful search might turn up a few more of these species growing in American nurseries or botanic gardens, however, the fact remains that less than 15% of all Chinese maple species are widely known in North America. Furthermore, a few undescribed species are probably still lurking in remote areas of China.

A high priority of current plant exploration programs is the reintroduction of new germplasm for species that are already under cultivation. Several widely grown landscape plants introduced from China are already showing loss of vigor from successive generations of inbreeding. Often the genetic pool was narrow from the start and successive generations of inbreeding have exacerbated the problem. Poor vigor in some lines of *Cornus kousa* has been attributed to this problem. Dr. Elwin R. Orton of Rutgers University, who has been active in hybridizing *C. kousa* and *C. florida*, reports: "Growers are urged to exercise caution in the selection of their seed source for growing seedlings of this species (*C. kousa*) as the seedling material in commerce today exhibits tremendous variation in plant vigor and quality. It is my belief that seed sources utilized at the present, in some cases, represent a relatively narrow genetic base as result of brother-sister matings among seedlings that trace to a single introduction of seeds collected abroad from a limited number of plants" (Orton, 1985).

Furthermore, when plants growing in North America originate from a single collection, these collections do not fully represent the potential genetic variation capable of expressing differences in size, habit, flower color, foliage quality, hardiness, and adaptability to various environmental stresses. Many species like *C. kousa* are distributed over a wide geographic range and plants originating from different parts of that range will have different adaptabilities. For example, plants from the southern part of the range might be more heat tolerant while those from the north are likely to be more cold hardy.

With these issues in mind, a group of botanic gardens has come together to encourage active scientific exchange between Chinese and North American Botanical Institutions. Efforts to build collegial relationships in China began in 1991 when a NACPEC (North American China Plant Exploration Consortium) sponsored team composed of Lawrence Lee, U. S. National Arboretum; Peter Bristol, Holden Arboretum; and Paul Meyer, of the Morris Arboretum of the University of Pennsylvania to develop the foundation for a 10-year program of scientific collaboration.

The NACPEC plan involves the active two-way exchange of scientific information, plants, and seed, and personnel between China and North America. In addition to plant exploration trips in China, several American arboretums will host senior staff from the Nanjing Botanical Garden in 1995. The director of Bejing Botanic Garden plans to visit several NACPEC institutions to evaluate methods of promoting conservation in China. We are also exchanging North American and Chinese forestry species for timber research. All of these NACPEC initiatives seek to broaden our understanding of the diversity found in native plant populations; expand scientific exchange between our institutions; and provide nursery professionals with plants adaptable for use in North American gardens.

In the autumn of 1994, a NACPEC team visited Wudang Shan range, located in northwest Hubei Province. Explorers included representatives from the Arnold Arboretum, Longwood Gardens, Morris Arboretum, U. S. National Arboretum, and Nanjing Botanic Garden. The targeted area is famous for precipitous peaks, ancient palaces, and Taoist temples. Though the central peak of Wudang Shan has been visited by Taoist pilgrims for centuries, we found ourselves to be the first western visitors ever to visit the nearby villages.

As plant collectors, we selected this area for its exceptional diverse flora, among the richest in the temperate world. Unexplored by plant explorers who visited China early this century, this area now yields a rich diversity of seed of plants from a variety of microclimates. The plants are likely to be well-adapted to areas of Eastern North America ranging from Atlanta to Boston.

High on the list of targeted collection species is the paper-bark maple (*Acer griseum*). This maple is cultivated for its outstanding shiny exfoliating orange bark. It has been grown in the U.S.A. since the early twentieth century. All the plants in this country can be traced to one or two early collections. It is likely that this is an example where successive generations of plants in the United States have become inbred. After a number of days of searching, the team discovered several colonies of paperbark maple growing in the forest understory, in the shade of *Quercus aliena, Juglans regia, Pinus tabuliformis,* and *Castanea mollissima.* The trees were spotted growing both on thin soils over rock outcrops as well as in deeper, moister soils at the base of rocky cliffs. As might be expected, the trees growing in the deeper, richer soils were larger and more vigorous. As in cultivation, a high percentage of the seeds collected were hollow, not containing an embryo. A small percentage of the seeds, however, perhaps 5% to 10%, did contain embryos.

Another species that has generated much excitement is *Emmenopterys henryi.* This tree species, a member of the *Rubiaceae,* has been given an official conservation status of "vulnerable" because its forest habitat has been rapidly cleared for agriculture and by indiscriminate cutting. This large tree grows to 90 ft with showy clusters of white flowers in late summer. The bracts of the flowers persist into mid autumn, taking on tan to rose tints as the small capsules ripen. Only one group of two trees was found during the Hubei expedition, fortunately, one of these trees produced a heavy crop of seed.

Another high priority of the expedition was to select trees that might be well adapted to stressful urban conditions. The oriental cork bark (*Q. variabilis)* is one such urban street candidate. This tree has dark green, shiny leaves similar to those of chestnuts and its corky gray bark is attractive year round. It is well-adapted to poor disturbed soils in China and it vigorously resprouts following forest cutting or disturbance.

Chinese zelkova (*Zelkova sinica)* is another species that has potential as an urban street tree. In many ways it is similar to the more common *Zelkova serrata.* However, its bark exfoliates more dramatically, revealing a bright orange inner bark. Several mature specimens of this species now grow in American botanic gardens including the Arnold Arboretum and Brooklyn Botanic Garden. They are both beautiful and well adapted to urban conditions, but this species is virtually unknown in the American nursery trade.

Chinese witchhazel *(Hamamelis mollis)* and its hybrids are rapidly gaining favor in American gardens. They bloom in mid-winter when few other plants provide color. The species grows on dry, rocky cliffs in the forest understory to a height of 6 meters in association with *P. tabuliformis* [syn. *P. tabulaeformis*], *Q. aliena, Platycarya strobilacae,* and *C. mollissima.*

In all, the Hubei expedition yielded over 130 collections of seeds and cuttings. Each collection from the expedition was carefully documented with multiple herbarium specimens that will be filed in both Chinese and North American herbariums. Detailed collecting notes also back up each composite collection. Plants will be grown and evaluated in NACPEC cooperating gardens and surplus plants will be disseminated to other gardens and commercial institutions for further evaluation. Each of these collecting trips is only the first step in a long-term program of evaluation and introduction.

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Why Some Native Plants Aren't Mainstream . . . Yet

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INTRODUCTION

To generate abundant nursery sales a plant must fulfill certain requirements. Among these are that it should have market appeal from superior flowers, foliage, fruit and/or form. It has also been suggested that the plant should be attractive in spring when most plant sales occur. For retail sales, eye appeal seems more important than disease or insect resistance. In fact, if the plant can be marketed while in flower certain other characteristics, such as tolerating widely varying landscape conditions, may not be as rigorously questioned (Raulston, 1990).

For nurserymen, at least one other requirement must be met—it must be possible to produce the plant profitably. This usually means that propagation problems have been solved. In addition, growth must be rapid enough that the plant can be brought to the undervalued North American landscape plant market at a low enough price to attract sales as well as profit potential for both the wholesaler and retailer.

If a plant is thought to have commercial landscape production potential, it needs to be evaluated to determine whether it is suitable for landscapes over a broad range of cultural conditions. Arboreta, botanical gardens, and university trials provide valuable insight concerning landscape plant suitability. If a plant possesses superior landscape characteristics but remains unknown, it still will not make it into the horticultural mainstream. The plant must be marketable plus it needs an advocate, i.e., an individual or group that will promote the plant to the nursery and landscape trade as well as to consumers. In summary, for landscape trade success a suitable plant must be discovered, promoted, and profitable.

MARKETING

North American natives, hybrids, and exotic plants must all meet these same criteria. If a native is not a good plant for the landscape, it should not be foisted on the public just because it is native. For example, black locust, *Robinia pseudoacacia*, has many desirable characteristics. Its beautiful and often abundant spring flowers provide pleasant fragrance as well as being the source of nectar for superb honey. Its wood is among the most durable and early growth is rapid. However, this tree also provides thorny root sprouts, has disease and insect problems, is a self pruner which drops branches throughout the year, and frequently defoliates by late summer. As a result, black locust presents more landscape problems than solutions and should not be considered a worthy tree for most landscapes.

Another North American native that has not been widely known by consumers is witch alder or bottlebrush shrub, *Fothergilla*. Plants people have long recognized this spring flowering shrub as having potential for abundant blooms which are often fragrant. *Fothergilla* displays spectacular late fall foliage color and is nearly pest free. Unfortunately, it once had the undeserved reputation for being difficult to propagate. It also lacked a salable name and an advocate. However, the *F. gardenii* selection 'Blue Mist' was given the Styer Award by the Pennsylvania Horticultural Society and recognition increased. More recently, Dr. Michael Dirr introduced the selection 'Mount Airy' (Dirr, 1990). It appears to be a naturally occurring hybrid between *F. gardenii* and the larger growing *F. major*. It propagates easily from stem cuttings, responds to fertilizer in container culture, has flowers that are more abundant and 1.5 times as large as 'Blue Mist', plus can have more vivid fall foliage color than 'Blue Mist.' 'Mount Airy' has been selected as a gold medal winner by the Georgia Plant Selections Committee, Inc. As a result, it will be promoted by the Georgia landscape and nursery industry. However, 'Mount Airy' also has another factor in its favor—Dr. Dirr. He has mentioned this plant prominently in his many public lectures, in his *Nursery Manager* column and it was featured on the cover of *American Nurseryman*. This plant has not made it— yet. However, I expect it to be a mainstream plant shortly. It is both worthy and has an aggressive advocate.

For those involved with herbaceous plants, another Georgia native selection, *Verbena canadensis* 'Homestead Purple' followed a similar route to fame with the co-sponsorship of Drs. Armitage and Dirr. This verbena is a vigorous, disease- and insect-resistant herbaceous perennial (USDA Zone 7, Zone 6 if not pruned in fall) that is currently being sold in enormous numbers in the U. S. as well as having been introduced and accepted in Europe within a decade of its rediscovery. This occurred because advocates and a promotion program existed once garden suitability and ease of both propagation and production were established by university researchers.

PRODUCTION PROBLEMS

If a plant is truly a superior landscape plant, but possesses some flaw within the production cycle, then research to unlock the secrets of propagation and production seem warranted. During my travels on the native plants and gardening lecture circuit this year, the herbaceous perennial (hardy to USDA Zone 5 or 8, depending upon the reference) that seems to be on everyone's wish list is indian pink or pink root, *Spigelia marilandica*. It is touted as producing abundant red and yellow flowers in partial shade and moist soils. However, inadequate numbers have been available for sale. Indian pink can be propagated by division and Royal Horticulture Society's *Dictionary of Gardening* (Huxley [ed.], 1992) suggests seeds but few if any seeds were germinating for those with whom I talked.

Eight of the standard propagation reference texts on my shelf ignore this plant completely. Growers suggested that immature embryo is the primary germination problem. Others suggest that scarification and/or stratification are required. Some said they were not getting viable seeds and wondered about pollination problems. No one mentioned cuttings, which seemed an obvious answer to this person. At any rate, it seems like getting enough plants together for some research could produce positive results quickly. Once propagation problems are overcome, dealing with a plant that is "somewhat difficult in culture" (Everett, 1960) is the next step; then a good name, an advocate, and a marketing program seem appropriate.

Organized propagation research has been a signature of I.P.P.S. and is responsible for bringing many worthy plants to market, including North American natives. Bottlebrush buckeye, *Aesculus parviflora*, has enjoyed irregular popularity but plants are frequently only available in small quantities. Part of the problem is misinformation concerning seed propagation. To obtain viable seeds cross pollination appears to be required and a growing season both long and warm enough must exist for seeds to ripen, particularly those of the late variety, *A. parviflora* f. *serotina*. Therefore, those collecting seeds from the northern U. S. and Canada may not have been obtaining viable seeds. In addition, at least one text states that epicotyl dormancy requires cold stratification to be overcome (Macdonald, 1986). This has not been our experience if seeds are harvested fresh and planted immediately. Handled this way, the radical emerges within a few days with the shoot emerging within a month.

However, seed propagation does not allow for the propagation of superior clones such as *A. parviflora* f. *serotina* 'Rogers'. While root cuttings are often cited as a preferred method for propagating bottlebrush buckeye, stem cuttings are used successfully by at least a couple of nurseries. Dirr and Burd (1977) published research on the propagation of bottlebrush buckeye but there were still only a few nurseries offering it by the early 1990s. In 1994, Bir et al. (1994) reported further research that demonstrated techniques for 90% or better rooting of bottlebrush buckeye stem cuttings so the stage appears to be set for selection of superior clones, their evaluation and promotion.

Similar problems exist with red buckeye, *Aesculus pavia*. This small tree can have brilliant scarlet, red-orange, or yellow flowers. It is also reported to be an excellent cut flower and attractive to hummingbirds. There are forms that sun scorch and some that do not, as well as a trailing to prostrate form. With all this variation on a small tree with neat habit and dark green leaves, the potential for selecting superior clones exists but asexual propagation problems also exist plus growth is very slow in young plants. While we have rooted some stem cuttings, success has not been consistent and research continues. When we have enough plants, research into cultural practices to speed up growth will be initiated. Only when production problems are solved will it be time for the promotion needed to get red buckeye to the marketplace.

Asexual propagation problems are frequently the limiting factor in selection of superior forms of native landscape plants. If a disease-resistant form of garden phlox, *Phlox paniculata*, such as the mildew-resistant forms 'David' and 'Speed Limit 45' introduced in recent years, are discovered standard propagation techniques frequently work and plants are available to the trade within a few years. In other herbaceous plants, such as the double-flowered trillium 'Whitemore', standard propagation techniques are agonizingly slow and impractical for the nursery trade. Tissue culture will probably be the answer here.

With woody plants both manipulation of currently available techniques and tissue culture may be the answer. Many of the superior forms of redbuds will soon be available from tissue culture so that those enticed to try these plants by Dr. Raulston will be able to have their own *Cercis reniformis* 'Texas White', *C. canadensis* 'Forest Pansy', or *C.* 'Appalachian Red'. For others, woody plants such as Grancy grey-beard or fringe tree, *Chionanthus virginicus*—which has beautiful panicles of flowers colored from ivory to bright white, some with striking floral displays on male trees and fragrance that is anywhere from non-existent to enchanting—great market potential for clones would seem to exist if we can propagate the superior selections. By manipulating juvenility, hormones, and lights H. W. Barnes has been able to experimentally root fringe trees—I've seen the plants. However, he is still a few years away from the level of confidence required to provide clonal liners in great numbers. With persistence may come the level of success required by the nursery industry. Then we will have the pleasure of expanding the landscape palette even further while providing the essential evaluation and promotion of these worthy North American native plants.

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New European Perennials—How Do They Get Here?

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Plant breeding and selection of herbaceous perennials have been occurring for a long time in Europe. Many select European perennials have been in North American nurseries for many years. However, there are other perennials that are just now appearing in North American nurseries that have been in commerce for decades in Europe. These selections are being discovered or rediscovered by nurserymen and other plant importers who are searching Europe for exciting plants to add to their catalogs. These individuals are touring individual nurseries, public trial gardens, and horticultural expositions where perennials can be seen and compared. This presentation will highlight the individuals and nurseries in several European countries that, over the last 75 years, have provided a motherlode of select perennials. Nearly all the plants discussed are presently in production or are in trials in North America.

ALAN BLOOM

Alan Bloom of Blooms of Bressingham, Ltd., in Diss, England, has been responsible for a number of perennials that grace our North American gardens. Alan Bloom has raised, named, and introduced 170 new cultivars of alpines and hardy perennials. *Geranium cinereum* 'Ballerina' is considered by many plantsmen to be the finest alpine geranium. This vigorous 1962 selection has bowl-shaped flowers with crimson markings carried on low branching stems that are 4 to 6 inches tall. He released a very similar plant with darker flowers in 1980 and named it 'Lawrence Flatman' in honor of a long-time nursery employee. Most plantsmen do not feel that there is a great difference between these two hardy geraniums.

One of the most popular introductions from Blooms of Bressingham is *Achillea* 'Moonshine'. This 1954 hybrid of *A. clypeolata* × *A. "taygetea"* [Botanical editor's note: *A. taygetea* is not a valid name] has bright yellow flowers borne on profuse gray feathery foliage. 'Moonshine' is valued for its long summer display and non-spreading habit. Alan Bloom continued to refine this selection and in 1982 raised *Achillea* 'Anthea'. 'Anthea', named for Alan's daughter, is more upright, bears primrose-yellow to creamy-yellow flowers and is excellent for cutting. Although developed in the 1980s, 'Anthea' was new to North America in 1993.

Fragaria ×ananassa 'Frel', Pink Panda® hybrid strawberry, has large, pink flowers with rapid growth, making it an ideal ground cover. This recent introduction from Blooms of Bressingham, Ltd., is a new perennial now available in North America.

The 1994 Perennial Plant of the Year by the Perennial Plant Association is *Astilbe* 'Sprite'. This selection of *Astilbe simplicifolia* has spikes of delicate shell-pink flowers which are held above dark bronzy-green lacy foliage. Alan Bloom raised this cultivar in 1969 from a collection of seedlings which utilized *Astilbe simplicifolia* as one of the parents.

KEW GARDENS

Heuchera micrantha var. *diversifolia* 'Palace Purple' is an example of a native American perennial that went from North America to England and returned to North America as an outstanding perennial. 'Palace Purple' is highlighted by large bronze-purple leaves which remain colored throughout the season. The story of the enhancement of this North American native is the following. In the 1970s, Mr. Brian Halliwell was curator of the herbaceous and alpine collections at the Royal Botanic Gardens at Kew, England. At that time he was redoing the Queen's Garden behind the Kew Palace. The original garden contained only plants that were in cultivation before 1700 and *Heuchera americana* was a popular plant during that period. Mr. Halliwell sent for seed from a now forgotten American botanic garden. The seedlings contained a population of plants with reddish-bronze colored leaves. To commemorate the Queen's Garden, the plant was named 'Palace Purple'. In 1986, Holbrook Farms, Fletcher, North Carolina, reintroduced *Heuchera* 'Palace Purple' to the North America nursery industry. In 1991, 'Palace Purple' was listed as the Perennial Plant of the Year by the Perennial Plant Association.

GEORG ARENDS

The Georg Arends Staudenkulturen (perennial nursery) in Ronsdorf, Germany, was started in the 1880s. Georg Arends was responsible for the introduction of over 30 cultivars of *Astilbe*, as well as *Sedum* 'Herbstfreude' [syn. 'Autumn Joy'], five *Bergenia* cultivars, and several garden phlox. There is probably no other continental perennial plant nursery that has produced a greater variety of new plants.

Many of the *Astilbe* cultivars available in North America were developed at the Arends nursery. Three excellent cultivars, 'Deutschland' (white), 'Rheinland' (pink) and 'Emden' (pink) were introduced in 1920. However, it has only been recently that these cultivars have been readily available in North America. Another very popular red cultivar, 'Fanal', was available in Germany in 1933. Georg Arends crossed four different species (*A. chinensis* var. *davidii, A. japonica, A. astilboides, and A. thunbergii*) in developing the hybrid astilbes listed under *Astilbe* ×*arendsii.*

In 1966 Arends introduced a hybrid garden phlox with fragrant pink blossoms with good mildew resistance. 'Anja' is a hybrid of *Phlox paniculata* × *P. divaricata.*

PRESENT DAY GERMAN HYBRIDIZERS

The Heinz Klose Nursery near Kassal, Germany, continues to release cultivars that have excellent market potential. *Salvia* ×*sylvesrtris* 'Viola Klose' [syn. *S.* ×*superba* 'Viola Klose'](1975) is dark blue, 18 inches tall, and blooms earlier than 'Mainacht' [syn. 'May Night']. *Astilbe* 'Veronica Klose' is 20 in. tall, with flower spikes of rose-purple flowers in late July.

One of the best perennial authorities is Dr. Hans Simon of Marktheidenfeld, Germany. Dr. Simon has been president of the International Stauden Union and is also an avid collector of perennials with a nursery of over 6,000 different species and cultivars. *Geranium* ×*cantabrigiense* Biokovo' is a recent discovery. This natural hybrid of *G. dalmaticum* and *G. macrorrhizum* was found in the Biokova Mountains of the former Yugoslavia. This new geranium combines the low-growing habit of *Geranium dalmaticum* with the profuse flowers and fragrant foliage of *Geranium macrorrhizum.*

Ernst Pagels in Leer, Germany, was a student and friend of the famous Karl Foerster. Mr. Pagels has selected cultivars of *Miscanthus* as well as new cultivars of *Achillea*. The recently introduced *Achillea* 'Credo' is a hybrid of *A. filipendulina* × *A. millefolium*. It has large yellow flowers, a good texture, and best of all, strong stems which eliminate the need for staking. Other selections that may be seen in the future are 'Inca Gold' and 'Feurland' [syn. 'Fireland']. These are 4th-generation hybrids of *A. filipendulina* × *A. millefolium*. These selections also have stouter stems which reduce the potential for lodging.

OTHER EUROPEAN PERENNIAL INTRODUCTIONS

Other German selections include *Helenium* 'Goldrausch' (Karl Foerster, 1942) and 'Goldkugel'. 'Goldrausch' is 4 to 5 ft tall with golden-yellow blossoms with brown centers while 'Goldkugel' is 4 to 5 ft tall with light golden blossoms.

Origanum laevigatum 'Herrenhausen' is a sun plant from Germany with whorled clusters of half-inch lanceolate shaped leaves and small groups of purple blossoms which are excellent with gray foliage plants. 'Herrenhausen' is presumably named for the Herrenhausen Gardens in Hanover, Germany.

Salvia verticillata 'Purple Rain' was originally introduced in Holland by Piet Oudolf. This exciting selection of a native European species has smoky or grayish-purple blossoms from June to August provided spent flowers are removed. Plants are 24 inches tall. This cultivar is destined for greater use in North America where it can be combined attractively with grey foliage plants.

The Frikart Nursery is located near Zurich, Switzerland. *Aster* × *frikartii*, a cross of *A. thomsonii and A. amellus* was raised in this nursery in the 1920s. Four cultivars were selected from this hybrid with three named after the Bernese Oberland mountains, 'Jungfrau', 'Eiger', and 'Mönch'. 'Mönch' and the fourth selection, 'Wunder von Stäfa' [syn. 'Wonder of Stafa'], are most known in North America and 'Monch' is often considered the best cultivar. It has lavender-blue flowers and grows 30 to 36 inches tall with a 36 inch spread.

Perovskia atriplicifolia has been named the 1995 Perennial Plant of the Year by the Perennial Plant Association. This 3-ft tall plant with ghostly gray foliage is capped by violet flowers in late summer. *Perovskia* 'Longin' is equally nice with a more upright habit of growth with leaves not as serrated as the species. 'Longin' is presumably named for Longin Ziegler, the present owner of Frikart Nursery.

Cimicifuga simplex 'Brunette' and *Ajuga reptans* 'Braunherz' were first noticed by the author in a trip to Denmark. 'Brunette' has deep bronze foliage with white flowers during the late summer. It is probably an introduction from the nursery of Greta Peterson and selected by her father. The bugleweed 'Braunherz' has very dark metallic-purple foliage. It was first found by the author at the Ikast Nursery in Northen Europe.

A final plant for discussion is *Veronica* 'Sunny Border Blue'. This Perennial Plant of the Year for 1993 had its beginnings in Denmark. In 1947, Robert Bennerup imported several cultivars of *V. spicata* and *V. longifolia* from Denmark. These selections had clean violet flowers which were darker than selections in the United States. Mr. Bennerup began a series of crosses and finally selected a seedling which maintained a good flower for nearly 3 months. This hybrid had been lost and rediscovered and now, 40 years later, it has been sold throughout North America and has made its way back to Europe from where the parent plants originated.

The message in this presentation is that new selections of perennials are constantly being produced in all parts of the world. The European continent, in particular, continues to be a rich area where perennial nurserymen can search for that "new" perennial that may be better than or a pleasant change from the selections presently available.

Seed Germination

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Fifteen years ago I began a study of seed germination. At present over four thousand species have been studied. These studies differ from all previous work in that variables are precisely controlled, rate curves are emphasized rather than just percent germination, and the rate curves are analyzed by chemical rate theory. The results dramatically revise concepts in the field and pave the way for highly efficient methods of propagating plants from seeds. The following examples illustrate some of the highlights of the work.

Gibberellins have a powerful effect on the course of germination for many species, and they can be an absolute requirement for germination. Many cacti such as *Echinocereus pectinatus* are tiny plants growing in harsh environments. To survive the blazing sun and infrequent rains the seeds must germinate in shade in a pocket of deep leaf mold. The seeds have evolved a clever method for detecting such a place. This is to require for germination a specific chemical, a gibberellin, which is produced by action of the fungi on the leaf mold. Seedlings were obtained by treating the seeds under moist conditions at 70F with gibberellic acid (GA_3). In samples of over 2000 seeds not a single germination occurred in any other treatment. The germination follows a first order rate equation precisely out to over eight half lives which is a precision rarely seen even with small molecules in a chemical laboratory. The induction period was six days and the half life was 4.9 days. The GA_3 treatment is absolutely essential for the growing of this species from seed.

Over two hundred species of cacti have been studied and about half were found to require GA_3 for germination. Other species with this germination requirement are the rosulate violas from the Andes, *Ranunculus lyalli* from Mount Cook in New Zealand, and a number of plants from the cold deserts of Nevada and Eastern Oregon and Washington such as *Romneya coulteri*, *Ribes cereum*, and *Dendromecon*.

The gibberellin requirement is also found in a few species from the woodlands of Eastern North America such as *Sambucus pubens* and *Cornus canadensis*. The shrub *Alangium platanifolium* also has this requirement. There is clear evidence that *Caulophyllum thalictroides* and *Sanguinaria canadensis* require gibberellins other than GA_3 so that this field is complex and needs much more study.

In order to control variables such as the gibberellin factor, all experiments were conducted in sterile high-wet-strength paper towels and polyethylene bags. The techniques were highly efficient, and five hundred experiments can be conducted in a space of 1 ft^3.

An interesting group are species that require oscillating temperatures for germination. Daily oscillations between 40 and 70F are typically effective. Obviously such a pattern is designed to cause the seeds to germinate in spring or fall. Examples are *Trollius laxus* and *Cornus florida*. Such seeds can be germinated by placing the seeds outdoors in moist media, but the oscillating temperatures can be duplicated in the laboratory. A set of experiments were conducted on *Cleome serrulata* in which the periods at 40F and 70F were varied over wide ranges. As might be expected daily oscillations (12 h) were about optimum. This pattern is in accord with chemical rate theory.

In many species specific time-temperature cycles are needed to effect germination as in *Eranthis hyemalis*. The seeds must be kept moist at 70F for three months to complete the destruction of the first blocking mechanism and then shifted to 40F where a second blocking mechanism is destroyed. After exactly 55 days at 40F an extremely rapid germination suddenly commences. This follows an exact zero order rate plot with a rate of 25% per day so that germination is complete in four days. The period at 70F and the 55 days at 40F are periods of maximum metabolic activity in terms of the chemical reactions destroying blocking mechanisms. Terms such as "breaking dormancy" or "double dormancy" are hopeless misconceptions and must be immediately abandoned.

Many species germinate at 40F and will not germinate at 70F. This is typical of plants from cold desert areas where they must get off to a fast start in spring as soon as the ground thaws in order to escape the desiccation of summer. *Rhodophiala montanum* from the Andes is a good example. Incidentally I am hybridizing these rhodophialas as they have the potential to become hardy garden amaryllis.

Many species have induction periods as for example *Abeliophyllum distichum*. After 25 days moist at 70F germination begins and follows a zero order rate law with a rate of 7% per day. The 25 day induction period is a time when a blocking mechanism is being destroyed and not a period of dormancy.

Light has long been known to initiate germination in certain species, but it has not been appreciated that the effect of light is to destroy blocking mechanisms and that the behaviors can be complicated. Fresh seed of *Buddleja davidii* requires light to germinate, but this requirement dies off with time so that after 2 years of dry storage, the seeds germinate about equally in light or dark. The common watermelon (*Citrullus lanatus* syn. *C. vulgaris*) and others cucurbits show this pattern. *Weigela florida* is typical of many species whose seeds germinate either in light or in dark with GA_3. The effect of light can be combined with other patterns as with *Primula kisoana*. This seed will germinate only if dry stored for 6 months followed by moist condition with light. Incidentally, this is one of the best primroses for gardens in eastern U.S. and should become a great favorite now that its germination pattern is known.

Some species, such as *Halesia tetraptera* (syn. *H. carolina*), have not germinated until after 1 to 4 years of temperatures alternating between 3 months at 70F and 3 months at 40F. Perhaps a way will be found to increase the germination rate, but for the moment the most efficient method of handling such seeds is to keep them in moist paper towels in polyethylene bags for the long period until germination starts. This much reduces the cost of labor and capital investment.

The above patterns all involve a chemical mechanism for blocking germination and about 95% of the 4000 species studied use chemical methods. The remaining 5% use a physical method for blocking germination and this is almost always an impervious seed coat. An example is *Laburnum vossi* which germinates within a few days if the seed coat is punctured and the seeds placed in moisture at 70F. The old terminology of calling this "scarification" is misleading because scratching the surface is not effective. A particularly troublesome and misunderstood group are the asiatic maples. These have a tough hard outer seed coat and a thin pliable inner seed coat. However, it is the inner seed coat that is impervious. I have done considerable experimentation to develop an efficient method of removing the tough outer seed coat.

Every aspect of seed germination involves chemical processes that have precise and reproducible rate plots. This includes the dying of seeds in dry storage and the dying of seeds in moist conditions unsuitable for germination. There is no substitute for knowing all of these rates precisely. Only then can one organize the production of plants from seeds with the maximum efficiency in the use of labor and capital investment.

The mid morning session on Tuesday was moderated by Scott Clark.

Patenting and Trademarking—Do's and Don'ts

Steven B. Hutton
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Patents and trademarks belong to a very important group of rights referred to as Intellectual Property Rights. Like more tangible forms of property, such as real estate or a piece of machinery, they can be bought and sold. And like real estate and machinery, they are crucial elements in commerce today.

Let's turn our attention first to the concept of patents.

The importance of innovation and investment in research and development was recognized by the framers of the U.S. Constitution back in 1789. In Article 1, Section 8, the Constitution states that: The Congress shall have power . . . to promote the progress of science and the useful arts, by securing for limited periods of time to authors and inventors the exclusive right to their respective writings and discoveries.

In 1793 Congress formalized this sentiment by adopting a patent act, authored by our third President, Thomas Jefferson.

A fundamental rationale for granting a monopoly to an inventor was the recognition that society was benefiting by getting something that never existed before. Thus, the patent grant is a reward for making something new available to the general public. The grant takes nothing away from the public which the public already possesses.

In the United States, patent protection of virtually all types lasts for a period of 17 years. During this 17-year period, the patent holder is granted a monopoly that conveys the right to exclude others from making, using, or selling his invention. After that 17-year period the invention falls into the public domain.

As the industrial revolution of the 19th Century gave way to a revolution in plant breeding and genetics in the early part of the 20th Century, Congress became interested in extending a similar type of protection to plants that was already afforded to industry. Individuals such as Luther Burbank and Thomas Edison actively promoted the concept of plant patenting, and finally, in 1930, the U.S. Plant Patent Act was enacted.

The scope of patentable subject matter under the Plant Patent Act is defined as: Whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly found seedlings, other than a plant found in an uncultivated state, may obtain a patent therefore . . .

Key words in this section of the code are "asexually reproduces," "distinct and new", and "variety."

The requirement that the plant be asexually reproduced automatically disqualifies all seed-produced crops, whether horticultural or agricultural. This stipulation ensures that all the individual plants propagated from the original new plant are genetically the same; that they are, in other words, clones of the original "variety."

The requirement that the subject of a plant patent be "distinct and new" is at the center of any type of patent anywhere in the world. The inventor, or breeder, is only going to be granted a patent if he can show that his new creation is novel and distinct from anything that has come before.

Finally, the above section of the Code strictly prohibits the granting of a plant patent on any plant found in an “uncultivated state.” This means, quite simply, that any new and distinct plant found in a natural state, such as the woods, cannot be patented.

If a breeder or discoverer of a new variety of plant can demonstrate to the U.S. Patent and Trademark Office that his new variety meets all the above criteria, a plant patent will be granted. The basic right a plant patent conveys the patent holder is the “right to exclude others from asexually reproducing the plant or selling or using the plant so reproduced.” This right, as mentioned earlier, lasts for 17 years from the date of the grant.

Since the Plant Patent Act was enacted almost 65 years ago, over 8500 plant patents have been granted. Current rates of applications for new plant patents are between 300 and 400 per year.

When one applies for a plant patent on a new variety there are a few legal requirements that are important for one to satisfy. First, a plant patent must be applied for within 1 year from the date of the first offer of sale for that variety. There is nothing to say that one can't apply for a plant patent long before one places the variety on the market. However, the Plant Patent Act specifically requires that one wait no longer than 12 months from the first offer of sale for applying for patent protection. The primary reason for this is to guarantee that the public is indeed getting something that is truly new. If a variety has been on the market for several years it by definition cannot be completely new.

Only the breeder or the discoverer of the new variety can apply for a plant patent on that variety. The applicant does not necessarily have to employ the services of a patent attorney, but most commercial breeders do employ such a service. Patent attorneys can effectively respond to the increasing amount of questions that patent examiners are asking and can much more efficiently prosecute the application throughout the examination process. A good rule of thumb is that a patent attorney's fees will be about $1000 to $1500 for a single plant patent. In addition to these fees are government fees, which change from time to time, but which are currently a total of $1700. For companies with less than 500 employees this figure is reduced by 50%.

The patent and trademark office requires that the new variety be designated by a name. This name can never become the trademark. It is the variety name for that specific variety and will remain so forever.

In the patent application the breeder must satisfactorily describe the new variety, how it came into being, and how it differs from other closely related, previously existing varieties. Additionally, the breeder or discoverer must indicate that the variety has been successfully asexually propagated and that the essential characteristics of the variety are maintained through asexual propagation.

These are the fundamental aspects of applying for United States Plant Patent. The application process is fairly straight forward and not extremely expensive and can be undertaken by any individual of any country in the world; U.S. citizenship is not a requirement.

The subject of trademarking—especially as used in horticulture—is as complicated as plant patenting is simple. And the fact that there are both federal and state trademark laws adds to the confusion. For purposes of this talk, I will discuss only federal trademarks.

Current trademark law follows the Trademark Act of 1946, as amended, which is commonly known as the Lanham Act. The Lanham Act defines a trademark as "a word, name, symbol, or device ... used by a manufacturer or merchant to identify his goods and distinguish them from those manufactured or sold by others." The primary function of a trademark is, therefore, to indicate origin.

A related function of a trademark is to indicate a certain consistent level of quality for the goods bearing a specific mark, and through advertising to create and maintain a demand for the product.

As an illustration of this point, when you buy a Big Mac® hamburger at McDonald's it is going to be pretty much the same whether you buy this hamburger in Philadelphia, Pennsylvania or in Pocatello, Idaho. You have a level of confidence that the quality and other attributes of the product are going to be consistent wherever the product is found.

Because McDonald's has spent a considerable amount of time assuring consistent quality, and a considerable amount of money promoting the product, it would be unfair for any other restaurant to use the words "Big Mac." Doing so would clearly undermine the creativity and the investment of McDonald's and would constitute unfair competition. It is largely for these reasons the government will grant the right to private ownership of a word or phrase in association with a certain type of goods.

McDonald's, however, cannot claim universal ownership of the words "Big Mac" for any type of product. One could conceivably use the words "Big Mac" as a trademark for a daylily. In fact, I know of a lot of daylilies with names that are ever more ridiculous than "Big Mac." It is clear that such a use would not constitute infringement of McDonald's trademark, as there would be little chance for confusion among the public with the Big Mac® Hamburger.

There are currently 42 international classes of goods and services under which trademarks can be registered. The class covering agricultural, horticultural, and forestry products is International Class 31.

Although it is preferable for many reasons, a trademark does not have to be registered with U.S. Patent and Trademark Office to be a valid trademark. Trademarks derive their status solely through their use in interstate commerce. Simply the proper and consistent use of the word or words that one applies to ones goods gives one a de facto common law trademark.

In many incidents one sees the letters "TM" following a word or phrase. This notation puts the public on notice that the user considers the word or phrase to be his trademark, but that he is not yet registered that mark with the Patent and Trademark Office. Only those marks which have been officially granted registration status can be followed by the ® symbol, which is the legal symbol for a registered trademark.

A trademark is, in its most basic form, a brand name. Well known examples include Kleenex® facial tissues, Tylenol® pain reliever, or Dorritos® corn chips. The best way to think of a trademark, or brand name, is that it is always an adjective and never a noun. Therefore, to properly use the trademark one should always say: I would like to buy some Kleenex® tissues, "not" I would like to buy some Kleenex®.

It is this distinction between adjective and noun that lies at the center of the loss of several important trademarks over the past decades. Perhaps the best known example of this loss of trademark status is the word "aspirin," which was originally a brand name for acetylsalicylic acid owned by The Bayer Company. Because the Bayer Company over time let the word aspirin become a noun, and therefore become generic, they lost their right to ownership of the word. That is, because of the way the company promoted its products to the public, the word aspirin ceased to be a brand, and rather became a generic word for a type of pain reliever. People were referring to the product in terms of "I'm going to buy some aspirin," and not "I'm going to buy some aspirin pain reliever."

All this is fairly technical, and this is the easy part. Trademarking products is extremely tricky, but in the world of commerce it has become more and more important.

In our own world of horticulture, the use of trademarks takes two general forms—one controversial and one not. Taking the easy one first, the non-controversial form of trademark usage involves house brands. Examples of these family brands would be Burpee® Seeds, Optimara® African Violets, and Star® Roses. In these examples, the registered trademark covers a range of products and denotes their origin.

Where the debate gets louder is when trademarks are used at the variety level. Here it is important to remember what was mentioned earlier—a trademark can never be the **name** of a plant, because the name is by definition generic. Rather, a trademark is the brand of that specific plant.

Let's take a hypothetical example of a horizontal juniper named Tapestry. From the standpoint of proper nomenclature, this plant would be referred to as *Juniperus horizontalis* 'Tapestry'. Tapestry is the name of this specific variety and as such can never be used as a trademark.

If one wanted to apply the word Tapestry as a trademark, one would be obliged to give a variety name to the variety completely distinct and separate from the trademark, Tapestry. For example, one could call the variety Hartap, resulting in the full designation, *Juniperus horizontalis* 'Hartap'. In applying the trademark Tapestry, the appellation could be written *Juniperus horizontalis* TAPESTRY® (variety: Hartap) or Juniperus horizontalis TAPESTRY® / 'Hartap.'

Proper trademark usage would require one to refer to the plant as TAPESTRY® juniper, or better yet, TAPESTRY® brand juniper. One should never call the plant *Juniperus* 'Tapestry.'

What this example says, and what every example of proper trademark usage on any type of product says, is that the public must always have a way to refer to a specific item which is in the public domain. In the above example of Tapestry, the public would have the word Hartap by which to refer to the variety. Tapestry becomes the trademark, or brand name, of that type of juniper.

In the case of trademarks applied to plants, it is essential to realize that a trademark gives its owner absolutely no control over the propagation and subsequent sale of the plant. It only gives the owner the right to exclude others from using his trademark in association with the plant.

Therefore, in the above example, if one wanted to propagate and sell plants of *Juniperus horizontalis* 'Hartap' one would be free to do so under that name so long as one didn't apply the trademark Tapestry to that variety. In fact, one could conceivably propagate and grow Juniper 'Hartap' under a completely different trademark if one wanted.

In terms of the grant, the essential difference between a patent and a trademark is very clear. Patents cover an invention for a 17-year period of time, during which a patent holder can prevent others making, using, or selling his invention. A patent cannot be renewed.

A trademark, however, does not grant any sort of proprietary rights to a product or an invention itself. It is merely a fancy name applied to a product which denotes a specific source of origin and connotes a certain level of quality. A trademark is valid for a 10-year period and is renewable for successive 10-year periods, so long as the mark continues to be used in interstate commerce. Should the mark fall into disuse for a sufficient amount of time, it will be assumed to be abandoned by the Patent and Trademark Office, and could conceivably be picked up and used by another individual or firm.

Something There

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INTRODUCTION

Around 1450, long prior to the voyages of Columbus, Portuguese sailors were sent westward by their king to see what lied beyond the Atlantic horizon. According to ship's logs, they sailed out about a hundred miles. Then they returned and pronounced their judgment "nothing there." Of course the king and everyone knew this to be the case anyway, and it would be 40 years before this assumption would again be challenged.

Unfortunately, their tragic mistake didn't die with them. In our search for new marketing territory, we too, make abbreviated voyages of discovery, turn back, and pronounce "nothing there."

Today we live in a world that demands a global perspective. The popular country-western star, Joe Diffe eludes to global perspective when he sings: "Welcome to the earth: third rock from the sun." What we earthlings often fail to do (and I am as guilty as the next earthling) is to venture a bit farther, to try an alternative direction, to believe that if infinity lies ahead, then there must be infinite possibilities.

MARKETING POSSIBILITIES

Centerton Nursery. Our company, Centerton Nursery, has run into a few marketing possibilities. Although I've often been accused of being spaced-out, these were not necessarily discovered via interplanetary journeys lined in the star dust of persistence or intelligence. It was more that we tired of our surroundings, ventured out, got lost, and in searching for a way back, stumbled upon something, looked it over, and suspected that it contained value.

The fact is, we stumble over things all day long, but they don't always jump up and grab hold of us. In James Redfield's study of higher consciousness, *The Celestine Prophesy,* he theorizes that there is a higher-intended, gainful purpose behind every situation we stumble upon in our daily lives—no "chance meetings."

It's as if a higher being sits up there, like Monty Hall and Let's Make A Deal, and creates all sorts of potential situations to see where we go with them. Is it going to be door #1, door #2, or door #3? It's up to us as to whether or not we pick a door and discover what lies behind it.

But usually, we don't see it. Assuming them to be walls, we pass by millions of doors every day. And as the sun sets we plop down and declare "nothing there." On the very rare occasion we recognize a door for what it is, open it, and find that it does indeed contain something of value. Trophytaker™ Daylily was one of these rare occasions for Centerton Nursery.

Trophytaker™ daylily. The first door opened when we purchased our first daylily. We loved the nature of the beast and purchased more cultivars to grow. Then we became frustrated because we felt the product had more potential than sales figures showed. A second door opened. That led us to an investigation of the species. We discovered that there were over 35,000 registered cultivars of this plant. Hmm. Overwhelming.

If there are that many cultivars, chances are that 99% are average, and 1% are exceptional. I could be wasting my time and money. "Which are the really good ones?" We learned that no one had ever tried to answer that. Hmm. Even more overwhelming. "Ah-ha!!!." (An ah-ha experience occurs here). Consumers weren't buying for the same reason we didn't know what to produce: we were overwhelmed!

How are we going to find out which are the good ones? That opened yet another door. I'd heard of the daylily authority, Dr. Darrel Apps of Chadds Ford, Pennsylvania. Dr. Apps was recognized world-wide as a cutting-edge leader in daylily hybridization and evaluation. It was time I paid this fellow a visit.

Almost fatefully, we found our concerns running on a collision course. We came to an agreement and immediately set up tough standards, because if it was going into our system, it had to be exceptional. We evaluated cultivars for vigor, increase, flower durability, foliage durability, bloom season, and general garden performance. From the first 5,000 cultivars evaluated, we gleaned 30.

Next came production—another challenge. Mostly, our "picks" fell under the NWA-HEAH hemerocallis classification: if you're not familiar with it, that's the "not-widely-available-hence-expensive-as-heck" category. So we had to start with small numbers of very expensive plants and begin the process of growing and dividing, dividing and dividing, dividing, and dividing. After 3 or 4 years of dividing and dividing, our selections multiplied.

Since we knew these exceptional cultivars were deserving of awards, we named the concept "Trophytaker." How could we protect our investment? Another door. I called my friend Steve Hutton at the Conard-Pyle Company in West Grove, Pennsylvania. Steve gets patents and trademarks on plants just about as often as I get up in the morning. Steve said: call this number and ask for this guy. He'll fix you right up with one of his specials—so I did, and he did. And after a few months waiting, a few dollars paying, and a whole lot more than a few paper signings, we got our trademark on Trophytaker™.

Dr. Apps and I devised a plan of promotion. The first people we approached were our sales reps (they can't sell it if they're not enthusiastic about it). We asked them, "What if we could produce, in volume, a line of daylilies that are so exceptional that only collectors possess them, at a price that would be a fraction of what collectors charge?" They said "when can we get started?"

We dedicated a large portion of the catalog to Trophytaker™ daylilies. We made big labels for the product. We designed large sales-aid placards. We featured Trophytaker™ daylilies in major trade shows. We went to garden center open-houses and talked about Trophytaker™ daylilies. We wrote articles for magazines, explaining the merits of Trophytaker™ daylilies. After 2 years of sales Trophytaker™ daylilies has added a quarter of a million dollars to our business and it's just getting started.

Well, that's the story. Let's examine what happened. Did we create the plants? No, they already existed. Did we create the data? Most of that existed, albeit spread about and largely unused. Did we create the method of propagation or production? We didn't do that either. The truth is, we created nothing!

However, let's not overlook one very important point that goes back to my original story. We did open a door that had something there. We did not attempt to make a mountain out of a molehill. It's more that we found ourselves in molehill valley, removed a bunch of exceptional molehills, and stacked them up to form our own rendition of a mountain.

Hasslefree™ Roses. Now let's talk about Hasslefree™ roses. The door opened for Hasslefree™ roses when Mom found an article on roses in a garden magazine. "Article on roses in this garden magazine, son." "No thanks, Mom. Hate Roses. Too many diseases. Too many insect problems. Too many hassles." She stuck it in my nose and said "read, son."

So I read. Article says these roses do well without lots of care. Hmm. Interesting. Trash can. Two months later, Mom comes through with another article. Article says these roses do well without lots of extra care. Different author—same roses. Hmm. Coincidence. I'm sitting in the doctor's office. Article on easy care roses. Again, different author, same roses. This is a conspiracy! Go to the rest room. Reach for a magazine. Article says "come down off your throne and consider low-care roses". I become a believer!!!!

First thing I do, I try to give the idea away. Great idea but we had too many other projects going on. So I call up my rose-growing buddies. "Hey rose-bud, have I got a product line for you. It's a natural that'll fit right into your system. There's a whole segment of consumers who aren't buying roses because they're too much hassle. They'll jump on this collection of strictly easy care roses." One by one my rose-buddies looked it over and proclaimed "nothing there." Now, I don't have dumb friends. Quite the contrary, but my friends know me and they're smart enough to know most of my ideas look more at home in a straightjacket.

But this, I could not accept. I was handing them my best on a silver platter and they weren't going for it. It was like throwing a party, opening a box of Godiva™ chocolates, and failing to give any away. So there I sit, with the chocolates, in my lap, staring up at me. You see, chocolate and I have this agreement. If it doesn't bother me, I don't bother it. But if it stares at me, I punish it by crushing it between my teeth.

Among my many weaknesses I am also color-blind, and I can't tell the difference between chocolate and ideas. So we sunk our teeth into this idea. Over a 2-year period we tested the product, secured the trademark, and in 1995 we'll be in full swing business on Hasslefree™ roses. It'll do $100,000 its first year. Not earth-shattering, but not bad for a first year product.

Again, let's examine what happened. Did we create the plants? No. Did we develop the data? No. Did we pioneer the production? No. All we did was look over a system that had something. We did not attempt to make a mountain out of a molehill. We found ourselves in molehill valley, removed the molehills that had a specific, desirable characteristic, and stacked them up to form our own little mountain.

CREATING OPPORTUNITIES

Do you remember the hit TV series, MacGiver? It was the escapades of a guy that constantly found himself in near death situations, trapped in the middle of nowhere, with no likely means of escape, and yet he always manages to create some contraption, weapon, or diversion out of leftover junk, that helps him save the world from nuclear proliferation.

Steven Covey, author of *The Seven Habits of Highly Effective People* writes that one of the essential ingredients to hit home runs in this life, is the MacGiver factor. With the MacGiver factor we don't aim for home runs: we aim for opportunities, and in the process, we hit some home runs.

Let's Do an Exercise. Imagine yourself in a hallway. We are looking for doors containing mathematical equations totaling up to the number 4. How many doors do you see? If you're like me you see the 2+2 door, and the 3+1 door. But how many doors do we see when we employ the MacGiver factor? What about the 4+0 door and the 5-1 door? There's the 108 ÷ 27 door. There's the 687-683 door, 431-427 door. There's the square root of 16 door and the cube root of 64 door. There's the (39 × 6)-230 door. When we employ the MacGiver factor, there are infinite possibilities. When we aim for opportunities, we don't get hung up on shooting only for home runs.

My Grandfather Was a Big Baseball Fan. He loved our Philadelphia Phillies. He never attended a live game, but when he was milking cows, he'd have the radio blasting. When he was sitting in his easy chair, he'd be watching the game, fingernails deeply seated in the arms of the chair. Although I never developed my grandfather's love for baseball, I dearly loved my grandfather. And it hurt me when he began to develop Alzheimer's.

It was the fall of 1980 and the Phils had won the pennant. I thought "wouldn't it be great if I could get World Series tickets? I could take my grandfather to a game and give him the dream of a lifetime." But tickets were sold out. Back in those days I lived hand to mouth because I lived foot in mouth, and the scalpers wanted more money than I could spare.

And then a friend of mine who I hadn't seen in months, happened by. We got to talking about anything and everything, and I mentioned the situation with my grandfather. He opened his wallet and said "My company bought a block of tickets and they gave me two. An unexpected meeting has come up. They're yours."

The tickets, were for game 6, October 18th, 1980, the night the Phillies won the World Series. There was so much partying going on in the streets that it took us 3 h to drive the 1 mile between the stadium and the bridge over to Jersey. That was okay: we had a great time.

I learned a lot of things from that experience. Never underestimate the potential in chance meetings because they provide us with more times at bat. When we keep our minds open we'll get a lot more pitches to swing at, and when we're swinging for opportunities, we'll hit some real home runs.

The Wednesday morning session was moderated by Tom Kimmel.

Cleaning *Cercis* Seed with a Lawn Boy Mower

Thomas L. McCloud and Lance W. Hammond
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Cercis canadensis (eastern redbud), being a member of the Leguminosae family, bears its seed in a true pod 2 inches to 3 inches long which ripens in October to November. It is our experience that if the pods are picked early while still pliable, they remain tough and do not easily split open to release the seeds even after drying indoors. If left on the tree longer, the pods start to open and the seeds can be lost even as they are being collected.

We have opted to collect the pods while they are still in the pliable stage and just starting to dry but are definitely not green. To remove the seeds from the pods, we use a Lawn Boy mower with a grass bag attachment. This has been very effective for either a small or large amount of seed. Some key points are as follows:

- Spread pods on a hard surface—preferably concrete.
- Spread pods in a low pile, slightly narrower than the mower.
- Adjust mower height to clear the pile of pods.
- Be sure mower bag is empty and clean of weed seeds.
- Mowing the pods once is usually sufficient to break them open and release the seeds.
- A cardboard barrier around the pile to be mowed helps to contain the seeds that blow out from the sides of the mower.
- Debris can be sifted out as usual to retrieve clean seed.
- The only drawback to this method is that some seeds are damaged, but the number of damaged seeds is not great enough to offset the efficiency of this procedure.

Grasses from Cuttings

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INTRODUCTION

Most grasses are produced by seed or division. Much has been done in this regard and references abound for seed and division techniques. However, many grasses are sterile, seed supply is limited, and division of clumps can be time consuming and inefficient. Grasses from cuttings would be an important propagation tool.

Corley (1989) did a thorough study on grasses suitable for the southeastern United States. Species that he found that would propagate from cuttings were *Phalaris, Chasmanthium, Uniola, Elymus, and Pennisetum.* Thomas (1987) wrote a brief description of rooting *P. setaceum* 'Burgandy Giant' from cuttings.

PRESENT TECHNIQUES

Species that have proven to be effective for large-scale production purposes are: *P. orientale, Panicum virgatum* 'Heavy Metal', *P. virgatum* 'Cloud Nine', *Imperata cylindrica* 'Rubra' (syn. 'Red Baron'), and *Sorghastrum avenaceum* (syn. *S. nutans*). Stock plants should be grown in containers; a 3-inch × 3-inch square pot is ideal. Lateral shoots are removed from the main clump with a very sharp knife. The break-off knives found at the hardware store are perfect for this type of work. The cutting is removed when the shoot is 3 to 6 inches long. It is important that the cutting has a slight curve at the basal end, resembling a #9 golf iron. If the cutting is too straight it will not root. Also it is important to make the cutting in an area just below a node

Cuttings are direct stuck in media. Thomas (1987) recommends sand; we used W.R. Grace 360 Metro Mix with excellent results. No hormone is needed. Corley (1989) could find no effect with applied IBA in talc. Many monocots and especially grasses do not respond to auxins until concentrations reach lethal concentrations. The tops of the cuttings can be trimmed but it is not necessary. Bottom heat appears to be stimulatory and should be used if it is available.

In a large study with *P. virgatum* 'Heavy Metal', 7200 cuttings were stuck and by 10 days 6700 cuttings were rooted. A 93% success rate.

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Seed Propagation Techniques That Work for Me

Shelley Dillard
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The Morris Arboretum of the University of Pennsylvania has been actively involved in many seed collecting trips in Asia over the years. Because of these trips and our goal of growing plants of merit from all over the temperate hardy regions of the world, as much as 75% of my propagation has been with seed—usually wild collected.

There are many obstacles to overcome to get these seeds to germinate. With the exception of well organized collection trips, these seeds come with many unknowns, such as when they were actually collected, if they are viable, and how they were stored. Sometimes I've never even heard of the genus, and can only track down the plant family to give me some clue as to how it can be processed. If possible, I do a cut test to determine seed viability when I have enough seeds.

There are two techniques I use which I will share with you. These have dramatically improved my germination rates with seed from species that require stratification.

The first technique involves the use of coarse perlite as a stratification medium. I previously used sphagnum moss, but always had it too wet and everything rotted, or it was too dry and the seeds dried out. Perlite after wetting is the perfect medium for germination because it doesn't absorb water, it only covers the surface after excess water is drained off. Seeds also need oxygen while in stratification. Since perlite doesn't compact in the bag like sphagnum moss, there is always air space. If seeds need to be soaked before placing in stratification, I let the bag sit at room temperature for a week before placing in a refrigerator or on a shelf. Since seeds don't get oxygen when they're soaking in water, there is less chance of rotting in the perlite. It is important to check the moisture of the perlite after the one week of sitting—you'd be surprised how much water the seeds imbibe in one week. I use a spray bottle to remoisten the perlite if it is needed. After that, I check all bags once a month for moisture, shake them, and do not press air out of the bag. This is also a good time to see if any seeds germinated in the bag, since many stratification times are variable. This use of perlite was suggested by Bill Barnes (Lorax Farms, 2319 Evergreen Ave., Warrington, Pennsylvania 18976), my thanks to him.

The second tip I'd like to share is the use of granite grit on the tops of seed flats after sowing to suppress moss, algae, and weeds. I use the same grit that is used for raising chickens. Grit is commonly used in England, but I don't see it used often in the States. I don't routinely use chemicals because many of the plant species I grow are relatively unusual and I'm concerned that chemicals might kill the seeds or seedlings. I simply place a ¼-inch layer of grit over my seed flats after sowing. This can be done over the media, or used alone over the seeds. I also use this method when I plant very small seeds that are too small to sow in plastic bags.

If you've been having trouble germinating seeds after stratification in sphagnum or peat moss and algae growing into an impenetrable barrier, I hope you'll try my tips.

Gibberellic Acid to Extend Shoots and Bud Break on *Heuchera* and *Scabiosa*

Rod Ackerman and Harlan Hamernik
Bluebird Nursery, Inc., 519 Bryan Street, P.O Box 460, Clarkson, Nebraska 68629

INTRODUCTION

At Bluebird Nursery, we have been using gibberellic acid (GA_3) for several years; primarily to break dormancy and get a more uniform stand of plants, or to obtain an early batch of cuttings before the shipping season begins in March. In the fall of 1993, we were faced with a dilemma. We had added *Scabiosa* 'Pink Mist' and 'Butterfly Blue' and *Heuchera* 'Snow Angel' (a Bluebird Nursery introduction) to the catalog and as of November 1993 we had not gotten any side shoot development (cuttings) from either of the *Scabiosa* and very few cutting of the *Heuchera* since spring. To compound the problem, the above plants had all started showing signs of going dormant. At this point, we decided we better do something if we were going to have any of these plants to offer and decided to try GA_3. In the past, we have had mixed results using GA_3, ranging from little to no reaction to extreme rates of growth.

MATERIALS

Pro-Gib 4% GA
Solo pump-compression backpack sprayer
500 *Heuchera* 'Snow Angel' in 4-inch pots
1500 *Scabiosa* 'Butterfly Blue' single shoot in 4-inch pots
1500 *Scabiosa* 'Pink Mist' single shoot in 4-inch pots

PROCEDURE

Twenty-five milliliters of Pro-Gib (ProGibb 4%, Abbott Laboratories, Chem. & Ag Products Division, North Chicago, IL 60064) was added per 10 liters and sprayed on the foliage of the plants as a light mist at 2-week intervals until the desired growth rate was obtained. Ten liters of gibberellic acid solution was sufficient to spray approximately 5000 4-inch pots on the initial application and approximately 3000 4-inch pots on the second application.

Helpful Hints.

- Fertilization should increase as growth rate increases. At peak growth rate, we fertilized weekly with 20N-20P-20K at 200 ppm N, Stem trace elements, and Fe-Hampene. Lack of fertilizer will cause the plants to become scraggly and chlorotic.
- Growth that has been predetermined to terminate in flower buds before GA_3 treatment should be pinched back as soon as possible. Auxiliary buds stimulated by GA_3 will rarely terminate growth if they are receiving sufficient fertilizer; this is particularly true for *Scabiosa*. Pinching back stem growth that is terminating will also release auxiliary buds.

RESULTS

Two weeks after the initial application, a spring-like flush of growth had just started to develop. Nodal buds (previously dormant) had started to swell and terminal leaves started expanding. Two weeks after the second application, a sufficient growth rate had been obtained to make it unnecessary for any further applications. In less than a 2-month period, we had obtained over 25,000 cuttings of each of the *Scabiosa* and 6000 cuttings of *Heuchera* 'Snow Angel'.

CONCLUSION

As the race to get new plants to the market intensifies, it becomes critical to constantly look for new tools and techniques. GA_3 can be one of those tools if used sparingly. Based on our experience with *Heuchera* and *Scabiosa*, GA_3 can be used to break dormancy, promote shoot elongation (2 to 3 times normal length in heucheras), promote auxiliary bud development, and increase vegetative growth rates.

Gibberellic acid can be a useful tool for the propagation of a wide range of plants, but only practical experience under your conditions can determine its usefulness.

Production and Marketing of Unusual Dwarf Conifers

W. David Thompson
Foxborough Nursery, Inc., 3611 Miller Road, Street, Maryland 21154

INTRODUCTION

The market for dwarf conifers has changed greatly over the past 20 years. What were once considered to be collectors items have now found their way into the vast nursery plant market, in large production numbers. We might ask why this has taken place. Basically, this has occurred because of need and not out of collector interest. Our landscapes are changing, and our clients are attempting to satisfy the new generation. Properties are smaller, free time for plant maintenance is less available, and the need for self-contained plantings exists.

PROPAGATION

Our company started out very small with low production numbers of many different cultivars. However, today we have found ourselves selecting certain high-demand cultivars and producing them in greater quantities. To accomplish this, our first step was to set aside an area for stock plants that could be maintained in strong, healthy vigor at all times. It has become evident that we can never have enough stock plants. For example, it may be necessary to take 5000 scions of one cultivar of dwarf blue spruce. To achieve these numbers, it is necessary to have on hand and maintain several stock plants of this cultivar. In addition, in order to maintain a healthy structure, stock plants should be cut every other year.

The second step in this production process is to have adequate propagation facilities. Production of conifers is basically started in the dormant season. We begin the first of December with rooted cuttings and the grafting of *Cedrus*. Throughout the winter, we continue to graft and stick cuttings simultaneously. Although, the optimum time to produce conifers is December through February, evidence has shown that most conifers root during a period starting with the first killing frost and continue until the first of April. Grafting begins with cedars, followed in order by spruces, pines, firs, and hemlocks. The season is concluded with *Chamaecyparis* and *Thuja*.

No specific plant order is followed for rooting cuttings. This is dependent on the season and the market demand. Cuttings, with the exception of those that are to be sold in the fall as heavily rooted cuttings (these are maintained in our production area and bare rooted in the fall for shipping), are potted in March/April. Grafts start to market by May 15, although some cultivars are fit for shipping at an earlier date. Liners are potted in 1-gal containers beginning in June. Depending on available space and market requirements, the potting process continues through August.

GROWING AND MAINTENANCE PROGRAM

Our growing and maintenance program is fairly basic. We begin with a media of pine bark, sand, and peat and add to that fertilizer and lime. As plants are potted, they are checked for proper tagging and then staked if necessary. Staking gives vertical or weeping plants a more uniform appearance, as well as providing the terminal leader with an extra boost. We have discontinued liquid, overhead fertilization and rely solely on our slow-release program for fertilization. As fall approaches, we begin to prepare for overwintering. By building portable huts, we have reduced the number of plants that have to be laid over. This is done by driving reinforcing rods into the ground at 3-ft intervals, and then placing conduit bent in a hoop form over the reinforcing rod on either side of the plants. These hoops, as well as our other houses, are covered with white poly.

FIELD PRODUCTION

Field production provides us with the ability to plant out many different forms of conifers, and at just about any time. Prior to planting, our liners are prepared by pruning, tagging, and bare rooting. The plants are then packed in box pallets and taken to the field where they are planted mechanically. The tree planter we use has the ability to handle plant material from peat-pot size up to a 7-gal container. All fields are prepared in advance, and all rows are marked and recorded.

A cover crop is worked in after planting, and we complete our herbicide banding at the same time. As most nurseries have found, the weather is a major influence on herbicide use. We start out with pre-emergence and follow up with post-emergence herbicides. Follow up staking and additional maintenance is done soon thereafter. Most dwarf conifers are grown in our fields for at least 6 to 7 years before they are harvested. Because of the variables in growth rates and market stability, we usually will start replanting a field when it is 60% to 70% harvested.

Digging is usually done mechanically, but often we do hand dig. We prefer to place all field-dug plants in wire baskets, as this gives the entire plant stability. Rotation of plant material varies from year to year because we believe it is advantageous to present new material to our clients. However, we do attempt to rotate the same culitvars at least every 3 years.

MARKETING

Marketing these plants is in itself the true test of worth. When presenting an 18- to 24-inch dwarf plant that is 8 years old at an $85.00 wholesale price, justification of its value and quality of investment to the buyer is essential. This means that a thorough knowledge of these plants is vital. Growing dwarf conifers requires patience, financial investment, and marketing ability. If you are growing a true dwarf form in the conifer family, you must be prepared to not only invest time but also acreage. Production from a propagule to a market specimen requires commitment of your growing area and finances for a minimum of 4 to 10 years. Dwarf conifer production varies from nursery to nursery. Some nurseries can produce the plants more quickly, and some may take longer. The end result is the same. The need is there and we must fill it. Know what you grow, and teach what you sell.

The mid morning session on Wednesday was moderated by David Sanford.

New Plant Forum

Complied and moderated by Jack Alexander.

PRESENTERS:

Carlo Belgiorno, Belgiorno Norsery, Central Islip, Long Island, New York.
Pieris japonica 'Sweetwater'®

Susan E. Bentz and **Ruth Dix**, U.S. National Arboretum, Washington, D.C.
Ulmus 'Frontier'
Ulmus parvifolia 'Pathfinder'
Ulmus wilsoniana 'Prospector'

Vern Black, Bailey Nurseries, St. Paul, Minnesota
Rosa 'Winnipeg Parks'

Bruce Briggs, Briggs Nursery, Olympia, Washington.
Rhododendron 'P.M.A. Tigerstedt'
Rhododendron 'Consolini's Windmill'

Susan Milliken, Kate Brook Nursery, RD#1 Box 2025, Wolcott, Vermont 05680.
Pinus strobus 'Louie'
Picea abies 'Perry's Gold'

David Schmidt, Royal Botanical Gardens, Hmilton, Ontario.
Iris sibirica 'Red Royale'
Iris sibirica 'Sapphire Royale'

Kim E. Tripp, Arnold Arboretum, 125 Arborway, Jamaica Plain, Massachusetts 02130.
Cephalotaxus koreana
Thuja 'Giganteoides' (syn. *T. occidentalis* 'Gigantea', 'Giganteum', 'Giganticum')

Matthew J. Vehr, Spring Grove Cemetery and Arboretum, Cincinnati, Ohio
Cornus florida 'Spring Grove' Plant Patent #8500
Cornus mas 'Spring Sun'

Nancy Vermeulen, Vermeulen & Son, Neshanic Station, New Jersey
Acer palmatum 'Red Feather'
Tsuga canadensis 'Vermeulen's Wintergold'

Tom Ward, Arnold Arboretum, Jamaica Plain, Massachusetts
Pseudolarix amabilis

Michael Yanny, Johnson's Nursery, Menomonee Falls, Wisconsin.
Fraxinus pennsylvanica 'Johnson', Leprechaun™ green ash. PPAF

Acer palmatum 'Red Feather'

In the mid 1980s our mother 'Burgundylace' bore a delightful offspring, a red head like herself, but very petite and extremely delicate. We've watched her mature with consistently fine features and feel she is now ready to go out into the world.

'Red Feather' makes up faster and fuller than 'Red Filigree Lace' without manipulating it to do so. The leaves are just as fine but the color is a bit more subtle, almost smokey. The branches layer attractively and the leaves feather out all over the plant. Discovered by former manager, Ronald Byleckie.

***Cephalotaxus koreana* (syn. C. *harringtonia* var. *koreana*)**

Cephalotaxus, plum yew, continues to gain attention as a handsome evergreen, needled conifer unique in its combination of deer resistance and diverse adaptability. Most attention to date has focused on cultivars of C. *harringtonia,* Japanese plum yew, because they have been the most widely available *Cephalotaxus.* However, there are other species of *Cephalotaxus* with great promise for nursery and landscape production and use. *Cephalotaxus koreana,* Korean plum yew, merits special attention among *Cephalotaxus.* It is a relatively dense, upright, shrubby plant with black-green, very glossy, coarse foliage of extraordinary year-round quality. It is the most ornamental upright plum yew to my eye. Some of the most handsome plants I have seen are a group of seedlings at the Arnold Arboretum (Boston, Massachusetts). Korean plum yew makes an exceptional hedge or mass with the unique ability to thrive in diverse soils and to perform well in both shade or sun—with full shade resulting in, a more open habit. Growth rate is slow, which can be a positive marketing niche for landscapers dealing with urban and suburban clients on small properties who don't want to have to sheer or prune. Plants can reach 5 to 10 ft with a spread of 3 to 6 ft after 5 to 10 years, depending on the region they're grown in. In the southeast, with high light year-round, and high night temperatures during the growing season, plants can reach 6 ft in as many years, but in the northeast, growth is considerably slower with plants taking as long as 10 years to reach 6 ft. Korean plum yew currently found in the U.S. is hardy to at least USDA Zone 6, and possibly colder (it needs trial in colder areas), but we haven't collected seed (and grown plants) of this species from the full extent of its natural range. *Cephalotaxus koreana* is easy, but slow, to root almost any time of the year from stem cuttings under mist—avoid the spring flush and heavily flowering branches if possible. Standard conifer rooting techniques apply: bottom heat, treatment with moderate concentrations of KIBA (avoid alcohol-based solutions), cool air temperatures, and good light will generally increase rate of root development on cuttings. Large cuttings seem to root as well as small ones under mist and use of larger cuttings can speed time to a salable plant. Make sure to use terminal cuttings to insure upright growth of plants after rooting. Seed requires stratification (can be sown outdoors as well) and can be very slow to germinate. Be careful when harvesting seed to note if you are potentially collecting hybrid seed—species of *Cephalotaxus* appear to hybridize successfully. Therefore seed from locations with multiple species are likely hybrid (which is not to say that such hybrid seedlings might not be of horticultural interest, just that they may not be of single species parentage).

***Cornus florida* 'Spring Grove' Plant Patent #8500**

This selection of *Cornus florida*, located in Spring Grove Cemetery and Arboretum in Cincinnati, Ohio, has been under observation for the past two decades. The prolific flowering nature of this plant was recognized in the mid 1970s but it wasn't until the horrendous winters of 1976 and 1977 that we realized one of the hidden merits of this dogwood.

Cornus florida 'Spring Grove' withstood consecutive days of temperatures in the range of -25F. and sustained no freeze- related damage. This is true of floral buds and stem tissue. Most other selections or seedlings of this species received minor or serious damage after those two winters.

The flowering characteristic of this selection is probably the most notable feature. where most dogwoods of this species bear one terminal floral bud 'Spring Grove' will frequently exhibit two or three floral buds per terminal. This habit is not uncommon to *C. florida*, but coupled with hardiness and vigor of 'Spring Groves' these assets combine to form an outstanding landscape specimen.

The bracts measure, on average, a full 5 inches from tip to tip, very similar in size to those of the 'Cherokee Princess' selection.

The parent plant is currently 23 ft tall with an average drip line width of 33 ft. It is located in the understory of a large specimen of *Quercus rubra*.

The fall color is typically a reddish-purple somewhat consistent with most common dogwood.

To date we have not observed any signs of *Anthracnose* where this plant is concerned. However, this is not to imply an inherent resistance to the disease.

Overall, *C. florida* 'Spring Grove' forms a beautiful landscape specimen. The flowering and fruiting displays, along with excellent cold tolerance, combine to produce a superior selection of this species.

Cornus mas 'Spring Sun'

This selection of *Cornus mas* has several outstanding features when compared to several dozen other *C. mas* plants located in Spring Grove Cemetery and Arboretum.

Probably the first and most notable feature is this plants tendency to be non-suckering. In the six years that I have worked for Spring Grove I have only pruned two suckers from the base of this selection. In June of 1993 a large ash tree fell and crushed the back half of this plant. Even after sustaining heavy damage from that incident the plant still showed no signs of suckering in the latter half of 1993 or throughout the summer of 1994. This non-suckering habit makes this vigorous selection easy to grow in a small tree form. The growth habit to date is a broader than tall form. Currently the dimensions of this tree are as follows:

Height - 16 ft

Width - 23 ft

Diameter 12 inches from base - 8 1/2 inches.

The truly exciting feature of this selection is not recognized until flowering commences in March of each year. The flower buds are generally about 30% to 50% larger than many of plants of this species in our collection. As the buds open the flowers are proportionate in size to the bud. The overall effect is a dazzling display when few other plants are in bloom. Flower color is a bright golden-yellow and is a slightly deeper hue of gold than other *C. mas* plants at Spring Grove.

The leaves are slightly larger and a deeper green than other plants of the species. The foliage appears very "clean" as the leaves are much more glossy than any other *C. mas* that I have observed. The leaves then consistently turn a deep burgundy late in the Fall of each year.

I feel that *C. mas* 'Spring Sun' is a superior selection of this species and could fill several niches within the horticultural industry. The inherent hardiness of this species coupled with this selection's habit of being a tree form will result in great popularity and functionality within our industry.

***Fraxinus pennsylvanica* 'Johnson', Leprechaun™ green ash**. PPAF

Leprechaun™ green ash is a dwarf cultivar selected by Michael Yanny of Johnson's Nursery, Inc., Menomonee Falls, Wisconsin. It was found when it was a 3-year-old seedling growing in a row of budding understock. The original tree, now 11 years old, stands 7 ft tall by 7 ft wide and has a trunk diameter of 4 inches at 6 inches above the ground. A species green ash would typically have dimensions two to three times larger at 11 years old. The twigs on Leprechaun™ green ash have internodes about one-third as long as those on the species. The leaves and leaflets are dwarf as well, being about one-half normal size. This gives the tree a finer textured appearance.

Like the species, it is a tough, durable tree. It should prove most useful in restricted urban settings where conditions are harsh.

Topworking onto standard green ash in the spring has been the most satisfactory method of propagation.

The tree is being patented and the name trademarked. Leprechaun™ green ash is being introduced by Johnson's Nursery, Inc. and J. Frank Schmidt & Sons Co., of Boring Oregon. Contact Schmidt for licensing.

***Iris sibirica* 'Red Royale'**

This iris was hybridized by Hugh Pearson for the 50th anniversary at the Royal Botanical Gardens, Hamilton in 1991. The height is 18 inches (approx. 45 cm). Flower colour is dark red purple (RHS 71A) with bluish blaze on falls with red purple (72A) style arms and a slight fragrance. Parents are 72-P-3 × 'Royal Ensign'. Besides the superior leaf which lasts well into the fall, colour this iris displays good upright leaves which tolerate strong winds. The rhizomes bulk up quickly (5 rhizomes will produce 25 to 30 more in two growing seasons. This cultivar is registered with the American Iris Society.

***Iris sibirica* 'Sapphire Royale'**

This iris was hybridized by Hugh Pearson for the 50th anniversary at the Royal Botanical Gardens, Hamilton in 1991. The height is 17½ inches (approx. 45 cm). Flower colour is: styles dark violet blue (RHS 94A); style arms light purple (76B); falls darker violet blue (93A). Besides the superior leaf colour which lasts well into the fall, this iris displays good upright leaves which tolerate strong winds. The rhizomes bulk up quickly (5 rhizomes will produce 25 to 30 more in two growing seasons. This cultivar is registered with the American Iris Society.

***Picea abies* 'Perry's Gold'**

'Perry's Gold' was found in a planting along the road in East Orange, Vermont by Arthur Perry. Growth rate is slower than normal and the plant's most important feature is its bright gold to almost white new growth, giving the appearance of a plant in bloom and drawing much comment in the garden. The color fades to gold-green as the growth hardens off.

Propagation is by grafting and plants propagated from lateral shoots have remained prostrate for over 15 years without showing signs of developing a leader. 'Perry's Gold' is available in a number of commercial nurseries in the United States.

Pieris japonica 'Sweetwater'®

'Sweetwater' is a plant for all seasons. It is hardy, will grow in Zones 5 to 7, and with no disease or insect problems. It survived the winter of 1993-94 and the original parent plant is 35 years old.

Flowering starts in late March to early April (Long Island, New York) when the buds open to reveal white, bell-shaped flowers that have a sweet fragrance. Flowering period lasts 7½ to 8½ weeks. In open shade the flowers last longer. The long flowering period results because the flowers are sterile and therefore no seed capsules are produced. Therefore all the plants energy goes into the production of flowers for next year and foliage. The leaves are carried for four seasons and result in a dense habit.

In late summer the stems that hold the flower buds begin to turn a light red color, the color deepens to a bright wine red by late fall—this gives the plant a nice fall and winter appearance.

Propagation is possible from dormant cuttings, summer cuttings under mist and tissue culture.

Pinus strobus 'Louie'

This plant originated in a swamp near a Christmas tree plantation in northern Vermont. The plant was named after the property owner.

The parent plant is 7 ft high by 4 ft wide with a slower than normal annual growth rate of 6 to 10 inches. The outstanding feature of this pine is its bright golden color, which it retains throughout the year, making it a focal point in the landscape. So far, it has not burned in the harsh Zone 3 winters of northern Vermont.

'Louie' grafts easily and has been distributed to a number of commercial nurseries.

Pseudolarix amabilis, golden larch

This deciduous conifer is native to the coastal mountains of China. It was discovered by the British plant explorer Robert Fortune and introduced into European cultivation in 1852.

The golden larch is broadly pyramidal with whorls of branches whose tips have a weeping habit. It is slow growing and often will seem as wide as high, a 45 ft tree may be 40 ft across. For this reason it is often planted in larger spaces thus giving it the opportunity to stretch its branches unencumbered.

Beautifully graceful in all seasons, spring and fall are foliage high points. Spring commences with new growth a light yellow-green turning a green-blue at maturity. The fall is a time of stunning contrast with the foliage turning a strong clear golden yellow. It is no wonder this plant is considered one of the finest exotics in America.

Culturally no special care is needed. It does well in easily draining moist, fertile soils that are acid to neutral in nature. It transplants well balled and burlapped, preferring full sun to partial shade.

The best method of propagation is by seed. The difficulty is the availability of viable material. The Arnold Arboretum is fortunate in having trees that produce viable seed every 3 to 4 years. Some seed will germinate on its own, however, we have found that 60 days at 40F will result in more uniform germination.

Rhododendron 'P.M.A. Tigerstedt'

This plant grows to 6 3/4 ft and has an upright growth habit. Foliage is dark green and non-pubescent. Flowers are white with strong violet flecks in the upper part of the corolla. Selected from progeny of (*R. brachycarpum* ssp. *tigerstedtii* × *R. catawbiense* 'Album Glass'). This rhododendron has a hardiness of H1 (-35F).

Rhododendron 'Consolini's Windmill'

Among the most brilliant of all red and white bicolors (see photo in the winter 1993 issue of the ARS Journal, p. 3), this plant was the work of many hands. Hybridized by Tony Consolini, Charles Dexter's head gardener, it was recognized, bud-grafted, and saved by Jack Cowles; it grew for many nears near a windmill at Heritage Plantation and was introduced through our nursery in 1989. While the grafted plant at Heritage appears reasonably hardy, dense, and attractive, these qualities are still under evaluation in smaller specimens.

Finding such an extraordinary flower in Dexter territory seems reasonable, because Charles Dexter created many of the world's finest pink bicolors—including 'Sandwich', 'Appleblossom', 'Todmorden', and many others—and Tony Consolini was especially noted as a breeder of fine reds.

Rosa 'Winnipeg Parks'

'Winnipeg Parks' is a hardy, recurrent-blooming shrub suitable for use as a bedding landscape rose or specimen plant. It was introduced in 1990 and named for the City of Winnipeg Parks and Recreation Department Centennial in 1993.

Plants are dense bushes, which average 0.4 to 0.7 m in height and 0.3 to 0.7 m in width. The flowers are slightly fragrant and are medium red in color. They average 8 cm across, have 22 petals, and are produced in clusters of 1 to 4. Plants have moderate to good field resistance to powdery mildew and blackspot. 'Winnipeg Parks' has the most attractive foliage of the Parkland roses to date as well as interesting red-tinged leaves in the fall. This cultivar has survived winters in hardiness Zone 2b. It propagates very easily from softwood stem cuttings. 'Winnipeg Parks' is a complex hybrid that incorporates the cultivars Assiniboine, Adelaide Hoodless, Cuthbert Grant, Morden Cardinette, and Prairie Princess.

We have exclusive rights in the United States and will sub-license others. Royalty is $0.40.

Thuja 'Giganteoides' (syn. *T. occidentalis* 'Gigantea', 'Giganteum', 'Giganticum')

Thuja occidentalis (eastern arborvitae) is an industry foundation. *Thuja plicata,* western red cedar, has been important in forestry and recently has been receiving increased attention as a landscape plant with great commercial potential because of its relatively fast growth rate, disease and pest resistance (including deer resistance), and good winter color. A superior *Thuja* selection, *Thuja* 'Giganteoides', is a putative hybrid of *T. occidentalis* and T. *plicata* which was found in a block of seedlings in Denmark about 1935. 'Giganteoides' is a tightly pyramidal evergreen conifer with the habit of *T. plicata* and with foliage intermediate in character between *T. occidentalis* and *T. plicata* but retaining the slightly pendulous quality of the sprays of *T. plicata.* It will ultimately reach the stature of *T. plicata* at upwards of 60 ft. 'Giganteoides' combines the excellent foliage quality and tight habit of the best *T. plicata* cultivars (e.g. 'Atrovirens', 'Hogan') with exceptional, apparently hybrid, vigor. This combination translates to an unusually rapid growth rate, generally giving 3 ft a year for the first 5 to 8 years of growth, even in stressful landscapes and clay soils. Foliage remains an attractive green throughout the winter. 'Giganteoides' is a superior alternative to Leyland cypress (×*Cupressocyparis leylandii),* and is an excellent evergreen for screening or specimen use. It is reported to be hardy in parts of USDA Zone 5. 'Giganteoides' roots very readily under mist most anytime of year, appears indifferent to how or when it is containerized, and grows on rapidly thereafter. It is handsome even as a young plant in containers. *Thuja* 'Giganteoides' is an exceptional screening conifer that is simple to propagate and grow in diverse production and landscape environments.

Tsuga canadensis 'Vermeulen's Wintergold'

We have been watching this hemlock turn gold in the fall for 8 years now and it has not failed us. By November there is a new glow within the houses where they are contained, bright enough to turn your head on the chance you have forgotten them while they were in their summer green.

We cannot tell you the mature height. It was discovered by our former manager Ron Byleckie in a seedling batch in 1986. However, the growth is extremely vigorous (we've seen 18 inches in a year) and the habit is pyramidal. The intensity of the color varies with the pH of the soil.

'Wintergold' has been tested in Ravenna, Ohio and Wilkes Barre, Pennsylvania. Each location reports consistency in the seasonal color change.

Ulmus species (elms) are tough trees—adaptable to the rigors of the modern urban landscape, such as soil compaction and air pollution, while also valued for their beauty. Several elm selections with superior resistance to Dutch elm disease and/or elm leaf beetle have resulted from research efforts to identify and utilize pest and disease resistant species by A.M. Townsend at the U.S. National Arboretum, Washington, DC, and Delaware, Ohio sites. The following selections were evaluated in field inoculation and laboratory tests for Dutch elm disease resistance and response to elm leaf beetle. All can be propagated easily by softwood cuttings in late spring using 0.4% to 0.8% IBA in a powdered or liquid formulation.

Ulmus 'Frontier'

Ulmus 'Frontier' (*U. carpinifolia* × *U. parvifolia*) (USDA Agricultural Research Service/National Arboretum, 1992; Townsend et al., 1991a) is the first released cross of a spring-flowering by fall-flowering elm. Its small leaves emerge red, turn green and display a red-purple fall color unusual in elms. 'Frontier' grows more rapidly than *U. parvifolia*, and matures to an intermediate size-26.5 ft high × 16 ft wide in 19 years. It is hardy to Zone 5. 'Frontier' has shown high levels of resistance to Dutch elm disease (DED) and moderate resistance to elm leaf beetle (ELB). In areas with high elm leaf beetle populations, 'Frontier' will show less elm leaf beetle damage if planting close to buildings is avoided.

Ulmus parvifolia 'Pathfinder'

Ulmus parvifolia 'Pathfinder' (USDA Agricultural Research Service/National Arboretum, 1992) is a selection of the lacebark or Chinese elm. The bark of 'Pathfinder' displays the distinctive lacebark quality of the species and exfoliates to reveal a grey orange inner bark. It has a moderately vase-shaped crown that becomes pendulous at a much lower height than American elm, reaching 37 ft × 22 ft at 27 years. Glossy yellow-green leaves turn a pleasing grayed red in fall and red-purple fruit ripens in October. 'Pathfinder' possesses high levels of resistance to DED and ELB. It has been successfully grown from Washington, DC to Ohio. Propagation success was improved by utilizing a fine-textured medium.

Ulmus wilsoniana 'Prospector'

Ulmus wilsoniana 'Prospector', selected by A.M. Townsend and L.R. Schreiber (USDA Agricultural Research Service/National Arboretum, 1992; Townsend et al., 1991b), is a selection of a relatively new species to the nursery trade. 'Prospector' is a single-trunked, vase-shaped, deciduous tree growing to 23 ft × 20 ft at 11 years (estimated 50 ft × 25 ft when mature). It produces a dense canopy of large leaves similar to American elm. New leaves emerge orange-red, mature to green, and turn yellow in autumn. It is highly resistant to DED and ELB. Hardy to Zone 5 (4?). 'Prospector' deserves a good look as a relatively pest-free lawn or street tree.

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The Thursday morning session was moderated by Dan Studebaker.

Field Grafting of Conifers for Christmas Tree Seed Orchards

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INTRODUCTION

The practice of establishing seed orchards for christmas tree seed production has been used for some time in the northeastern United States. Several tree growers have established seed orchards of their own tree selections that produce top quality Christmas trees under their growing conditions. They are selecting trees for: good color, form, late frost resistance (late flushing trees), less shearing required (naturally dense), and resistance to insects and diseases (a more recent attribute). The trees are established in a seed orchard usually in an area isolated from other trees so they can be monitored, evaluated, and pollinated either naturally or controlled for the production of superior Christmas tree seedlings and transplant stock.

PROCEDURES

The following procedures have been used in my part of the country—in some cases from the mid 1960s. All have been done basically the same with slight variations. The dominate species used is balsam fir (*Abies balsamea*) and lately fraser fir (*A. fraseri*). However, other hardy species with desirable traits have been grafted for use in breeding programs. All grafters have done the grafting outdoors with inexpensive methods and equipment with good to excellent results. Briefly I will describe the methods of field grafting used by four growers.

Method #1. The grafter's understocks are seedlings established in the Christmas tree plantation for several years. Scions are collected while still dormant in March and placed in a plastic bag and stored in a refrigerator or freezer. Grafts are made using a cleft type before bud break; for sanitation and sharpness reasons a single edge razor blade is used for only 10 grafts. The scion (3 to 4 inches long and formed into a wedge) and understock (after being tipped to remove the terminal bud cluster and cleft about 1 inch) are joined following removal of the needles from the graft area of both parts. The cleft graft is wrapped with a cut rubber band (cut lengthwise) and the rubber band is covered with plastic electrical tape to retain moisture. Next the taped area is wrapped with a handful of fresh sphagnum moss and then covered with a piece of aluminum foil (approximately 5 inches × 10 inches) with the terminal buds of the scion exposed. The bottom aluminum is tightly rapped with the top slightly open to catch rain or allow the addition of water if the weather is abnormally dry. The foil and tape are removed the following year.

Method #2. This grower demonstrated the method his father and others used in the mid 1960s on trees that are mature and producing regular seed crops. Again the scions are collected early and stored, sometimes in the snow. The grafting is done in early May in northern New Hampshire. The scions are 4 to 6 inches long and grafted on established seedlings 12 to 30 inches tall. Using a sharp knife (cleaned frequently with alcohol), the grafter uses either a cleft or side graft, preferring a cleft graft only because it's easier. Grafting rubbers strips (3/8 inch × 8 inches) are overlapped, being careful not to wrap too tight. No other wrap is used.

Method #3. A major grower in Canada has several young cone producing orchards. This grower grafts on 3-2 transplants, 1 year in the field, in early spring until bud break when the sap is flowing. Scions 2 to 3 inches long are collected at time of grafting and a cleft graft with about 1-inch cuts is used. The diameter of the understock terminal is matched to the diameter of the scion. The union is wrapped with a wide grafting band and then covered with a wax-like product called Lac-Balsam. The band disintegrates and doesn't have to be removed. This grower gets up to 18-inches terminal growth the year of grafting with his cultural practices and has had up to 90% take some years. Pollination in seed orchards is controlled by the use of homemade Remay bags placed over the female flower. Pollen is collected with a small vacuum cleaner.

Method #4. This grower from the maritime Provinces of Canada has field grafted since the mid 1970s on many *Abies* species for the production of hybrids in his seed orchard trees. He collects 6-inch scions from the top section of the tree during April before the buds swell and stores them in a snow bank or refrigerator. A whip and tongue graft is used except for small thin scions which are grafted using a cleft type. Unions are covered with a 6-inch strip of Uniroyal electrical tape (cut in half length ways) and carefully overlapped. The tape is a self-adhesive type and the sun breaks it down so it does not have to be removed. This grower has also experimented with grafting in August with mediocre results and bud grafting in spring with no results.

CONCLUSION

If there were 10 grafters in a room, there would be 10 grafting methods. However, these are four methods that work for these growers. Some observations related to grafting successes by these growers are the following:

- In years with dry springs or late spring frost, the take is not as good.
- Blue balsam selections seem to be late-frost-damage prone.
- Care should be taken not to wrap the union too tightly.
- Scions should be selected from the top portion of a tree for good straight growth and for the more rapid formation of female cones.
- These methods could possibly be used for low-cost production of some ornamental conifers. I have observed plants of *Picea pungens* and *Pinus strobus* propagated this way.

Responding to the Increased Demand for Native Plants

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Over the last 10 years or so, a strong trend towards specifying native species has developed across the country. The origins of this trend date back to environmental movement of the 1970s. Today, practically every issue of the American Nurseryman has something about the subject. The push for native plants has understandably raised the ire of many growers who have spent entire careers developing and producing hybrids and exotic species. But for more and more nurseries, the move towards native plants is providing new opportunities.

With numerous introduced species, such as purple loosestrife and phragmites, taking over thousands of acres of native habitat, environmental regulators have attempted to stem the tide by legislating against the used of non-native species. Even the White House has gotten involved as President Clinton issued a memorandum calling for "environmentally and economically beneficial landscaping" practices at federal facilities and federally funded projects. The memorandum specifically equates the use of "regionally native plants" with such landscaping (Eco-Watch, 1994).

In addition, many landscape architects have discovered the beauty and hardiness of indigenous species and have begun specifying natives on commercial and residential projects. While this has led to a significant increase in the demand for natives, the most important factor has been the passage of the federal Clean Water Act of 1977. The result of this legislation is that in most cases, the loss or disturbance of wetlands in one area must be "mitigated" by the creation or enhancement of wetlands in another. From a growers standpoint, this legislation is wonderful news because it has opened up a totally new market for nursery stock.

One of the primary goals of wetland mitigation is to duplicate the values and functions of the disturbed site. Depending upon the area, various species of trees, shrubs and herbaceous plants are required. Certain native plants have been grown by the nursery trade for many years. Recently, a number of large, progressive nurseries have begun to grow some of the more popular wetland mitigation species such as *Clethra alnifolia, Ilex verticillata, Aronia arbutifolia, Liquidambar styraciflua*, and *Quercus palustris* (Table 1). During that same time span, many small, exclusively native plant nurseries have sprung up to meet the demand for some of the more obscure species such as *Salix nigra, Rhododendron viscosum, Sambucus canadensis, Cephalanthus occidentalis*, and *Chamaecyparis thyoides* (Table 1).

In regard to herbaceous wetland plants, few native species are available in the nursery trade other than those used in water gardening, such as *Iris versicolor, Pontederia cordata*, and *Nymphaea odorata*. Although grasses, sedges, and rushes are very common, most are not that ornamental. But since they are an integral part of the wetlands habitat, they are required on mitigation plans. Some of the herbaceous plants most often specified are *Schoenoplectus validus* (syn. *Scirpus validus*), *Carex crinata, Leersia oryzoides, Sagittaria latifolia*, and *Typha latifolia*. One obstacle to growers interested in propagating native herbaceous plants is that they can be difficult to identify. Field identification is crucial since there are few reliable commercial sources of seed. While there is a strong demand for these species, only those growers with the capability to identify and collect their own seed are able to propagate them.

Table 1. Wetland mitigation species of the mid-Atlantic states.

Trees	Shrubs	Herbaceous
Common in nursery trade		
Acer rubrum	*Amelanchier* sp.	*Hibiscus moscheutos*
Betula nigra	*Aronia arbutifolia*	*Iris versicolor*
Fraxinus pennsylvanica	*Clethra alnifolia*	*Lobelia cardinalis*
Liquidambar styraciflua	*Cornus stolonifera*	*Nymphae odorata*
Magnolia virginiana	*Ilex verticillata*	*Pontederia cordata*
Nyssa sylvatica	*Salix discolor*	
Quercus palustris	*Vaccinium corymbosum*	
Quercus phellos	*Viburnum dentatum*	
Not common in the nursery trade		
Acer negundo	*Alnus rugosa* (syn. *serrulata*)	*Asclepias incarnata*
Acer saccharinum	*Cephalanthus occidentalis*	*Carex lurida*
Chamaecyparis thyoides	*Cornus amomum*	*Carex crinata*
Platanus occidentalis	*Itea virginica*	*Carex stricta*
Quercus bicolor	*Lindera benzoin*	*Juncus effusus*
Salix nigra	*Rhododendron viscosum*	*Leersia oryzoides*
Rosa palustris	*Peltandra virginica*	
Sambucus canadensis	*Sagittaria latifolia*	
	Schoenoplectus validus	
	Scirpus cyperinus	
	Scirpus pungens	
	Typha latifolia	
	Verbena hastata	

Unable or unwilling to propagate, plant collectors readily harvest wild plants from their natural habitat. This practice is one of the greatest threats to legitimate growers. Often times plants are illegally taken from wetland areas or stolen from private property. Only rarely is the stock inspected for insects and diseases prior to shipment to the job site. Even when done legally, depleting one area to enhance another is not an environmentally sound practice.

Another major issue for growers is the philosophy of being "ecologically correct." This involves the concepts of seed source and genetic diversity. Many ecologists argue that in order for a plant to be truly native, it should be grown from seed collected very close to the planting site. For example, they feel it would be wrong to plant a pitch pine in New Hampshire that was grown from seed collected in North

Carolina. More and more frequently, planting specifications call for nursery stock to be grown from seed collected within a certain radius of the job site, such as 100 miles.

Clonal propagation is also very controversial, as some firmly advocate only using seed propagated plants in order to promote genetic diversity. As mentioned earlier, there are plenty of native species already in the nursery trade, but many of them are clonally propagated, such as *Betula nigra* 'Heritage' and *Itea virginica* 'Henry's Garnet'. While the issue is not black and white, in general, seed propagated plants do have more genetic diversity.

Ideally, plants for restoration projects should be propagated from seed collected as close to the planting site as possible. As for species that are difficult to seed propagate, cuttings should be taken from as many different individuals as possible to promote genetic diversity.

While indigenous species are not appropriate for all situations, there is sound logic behind advocating their use. At the present time, native plants are still a small segment of the nursery industry, but that segment is growing rapidly. Many of the largest nurseries in the country have already recognized the opportunity and are profiting from their decision to increase their production of native plants.

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The Marketing of New Dwarf Conifers

Jim Smith
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INTRODUCTION

As you know, almost everybody can grow plants. The hardest thing in this business is getting rid of them at a decent profit—right? That's where marketing comes in. There are many aspects involved in marketing and I would like to share a few of those with you today.

NICHE MARKETING

I call the type of marketing we do at Blue Sterling Nursery "Niche Marketing." We grow over 450 taxa of plants in many different sizes. We concentrate mainly on dwarf and slow-growing conifers but we also grow azaleas, Japanese maples, and Japanese hollies. However, even within the Japanese hollies we grow some unusual selections like *Ilex crenata* 'Dwarf Pagoda', 'Golden Helleri', and a real nice dwarf called 'Piccolo'. These plants are not the mainstay of your typical production nursery. We have carved a small niche in a very large market.

OUR APPROACH TO MARKETING

We have taken a unique approach to marketing. We don't advertise in any magazines or trade publications or at least haven't as of yet. To reach our clients, which are primarily garden centers, we rely heavily on trade shows, our catalog, great sales personnel, and word of mouth.

Trade Shows. Our main marketing method is through trade shows. We do seven trade shows a year, which is a lot for a small company. They cover our basic shipping area. We do the MANTS (Mid-Atlantic Nursery Trade Show) in Baltimore during winter and summer, PANTS (Penn Allied Nursery Trade Show), PLANTS (Pennsylvania Landscape and Nursery Trade Show) in Pittsburgh, CENTS (Central Environmental Trade Show) in Columbus, New England Grows in Boston, and the New Jersey Nursery & Landscape Association Conference and Trade Show in Somerset.

As you know, it is extremely important to make a good impression at a show. Sometimes it is the only direct contact you will have with a buyer or owner. We always prearrange our booth design and use a wide variety of colors, textures, and sizes of plants. We don't have to force plants for the winter shows because conifers have great winter color. We take as many different cultivars as possible to the trade shows because in most cases if the customers see it and like it, they buy it. Even the best written descriptions are difficult to buy from if you're not familiar with the particular rewards or outstanding features of a certain cultivar. In addition, high quality is very difficult to express in a catalog.

We always stay until the end of the show, even the bad ones, because it only takes one good sale to make the show worthwhile. We also never take our best quality material to the shows, only the average stuff. That way if customers like what they see at a trade show, they will be thrilled to death when the order arrives. That philosophy has worked very well with almost no complaints in the spring.

Catalog. Another way we market Blue Sterling dwarf conifers is with our catalog. Often it is the first introduction of a company to a potential customer. It should be done as professionally as possible. Also it should be easy to read, have good descriptions, and I feel that having the correct botanical names and spelling is also extremely important. I include as much detailed information as I can find on each cultivar. This includes hardiness, growth habit, size after 10 years, color, texture, outstanding features, and the date of introduction, if possible. I also include some information on the genus and species and maybe its native area. I feel it is very important to put out a high quality catalog because it promotes the best image for a company.

High Quality. High quality is an over-worked, worn-out phrase. Everybody either has it or thinks they have. When we first started in 1983 there were many nurseries in the Bridgeton, Millville, and Deerfield areas of South Jersey. Now we have over 100 certified nurseries in Cumberland County alone. That's a lot of competition! I soon discovered that a buyer can always buy it for a quarter cheaper just down the road. So I decided that we were going to offer only true to name cultivars that were just a step above the rest and at a price that reflects the quality. I have been told by a few buyers that when they first saw our catalog they thought our prices were too high, but once they took a tour of our nursery and saw the superior quality of the plants, they gave us an order. Everybody won't spend the extra money for higher quality plants, but, again, we filled a small niche in the market.

Quantity Produced. As everyone here knows most plant material is easy to propagate. It is often much more difficult to know how many of a particular item the market will tolerate and what the next trend will be. We produce many cultivars but the quantities vary from as few as 30, for some really rare types, to as many as 3500 of the more common cultivars. The average is probably about 100 to 300 per cultivar. These numbers seem to be increasing as the trend towards low-maintenance gardening increases and we attract more customers.

SPOTTING A TREND

In the marketing of plant material it seems there is always a cycle. One year there is a shortage of junipers, the next year everybody's got them for sale at a good price—if you are a buyer. The next year it's forsythia, then azaleas, and on and on. Interpreting these production cycles is further complicated by the development of trends to use different kinds of material, such as perennials, annuals, and so forth. Riding these trends can be both gratifying and profitable but they can be hard to predict.

One trend that is obvious to almost everybody is that of the small-sized building lot. People nowadays seem to have smaller yards than in the past. New style houses are larger in square feet than 50 years ago but they have first floor windows that are much closer to the ground, eliminating the need for large foundation plants. There has been an evolution of the buyer or gardener to locate a much wider diversity of plants for his or her landscape. They want plants with more color and less maintenance. Both perennials and dwarf conifers fill this need. We decided to concentrate our growing efforts on dwarf conifers. They come in many assorted forms like columnar, pyramidal, conical, prostrate, globose, and weeping, and they keep their shapes with a minimum amount of work. They can fill the needs of even the most discriminating customer. Dwarf conifers also come in many different shades of green, yellow, purple, and even blue and silver, and they offer the gardener a multitude of textures and shapes and year-round color from which to choose.

DWARF—WHAT DOES IT MEAN

The rate of growth is also very important. Everybody seems to want a plant that will grow to be 3 ft high and no more. In addition, they want it at an inexpensive price too. If anybody finds that variety please let me know. The term dwarf is often misunderstood. It means a plant that grows much slower than the species and its size is relative only to that species. It is confused by both the consumer and in the trade and with good reason. An example of this is the two *Chamaecyparis obtusa* cultivars 'Nana Gracilis' and 'Nana' one will grow to about 15 ft in 50 years the other only to about 3 ft. Both cultivars are considered dwarf Hinoki cypresses because the species will grow far taller.

TIME

Due to the hectic, fast-paced lifestyle that we all lead nowadays, time has become very important. Anything that can save time is in great demand. That is why the service industries were thriving even during the past recession. Services like housecleaning, window washing, and fast food are very popular. You just don't see many fast food business going bankrupt very often.

People love to garden, it is one of the most popular pastimes, but they don't want to waste time every other weekend pruning the hedge anymore when they could be spending quality time with their family. A premium has been placed on time. So any plant that doesn't require much maintenance in the form of pruning, separating, spraying, or cleaning adds to the fun and enjoyment of gardening.

Dwarf and slow-growing conifers offer the consumer the best of both worlds-very low maintenance and good year-round color.

With all of this in mind it is easy to see why gardening with dwarf conifers has become more popular—not quite a major trend yet, just a nice niche market.

Piedmont Flora Yields Outstanding Ornamentals

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There is probably no one here today who is unaware that we are in the middle of an enormous tide of interest in our own native plants. Native plant conferences have sprung up like mushrooms throughout the eastern half of the continent; meetings of landscape architects, foresters, horticulturists—and even plant propagators—frequently devote large segments of their programs to natives and their uses in the landscape. Even politicians are jumping on the bandwagon—witness president Clinton's advisory to government agencies to emphasize native plants wherever they are appropriate. Not only do natives fit into the present trend to garden naturalistically, but they have always been a significant part of more formal landscapes and are eminently suitable for traditional and contemporary gardens. In short, the native plant industry, for whatever reasons, is a growth market, and we should all realize the potential for our industry inherent in this flood of interest.

This potential can feed on three relatively recent developments in the nursery industry:

1) The most aggressive retailers have caught on to a marketing strategy which has built such American industries as the fashion industry, the cosmetics industry, the entertainment industry, and the convenience food industry. That strategy is **novelty**. Americans like to be first with what's new, and at last our industry is recognizing this. You can see it in the trade journals, in the growth of the mail-order specialty nurseries, and in the product lines of our best retail garden centers—novelty sells.

2) Micropropagation is coming of age. We use it where it is most valuable—to build up numbers of a particular clone quickly, either for direct sale as a high value novelty or to create a stockblock for traditional propagation methods. We need to create better ways of funding the research that is needed before a new plant can be successfully and routinely propagated.

3) This brings me to the third development that has contributed to the great potential for new plant introductions—the plug industry. Plug producers can quickly capitalize on micropropagation to produce large numbers of easily transported flats of reliable small plants. These can be sent across the continent and grown to liner size, with woody plants, or salable containerized plants in the case of herbaceous introductions.

All this translates into the potential to radically decrease the time it takes to get a new introduction to a public ready to buy it. Instead of a lag time of 10 to 20 years; we can, with proper marketing and coordination, get a good plant out in quantity within 5 years. Of course we can also get a bad plant out as quickly.

Now, I want to say a little about where these novelties come from, using Mt. Cuba Center as an example. We are a developing public garden whose mission it is to bring the public to an appreciation of our native flora; particularly that of the Piedmont region. We do not sell plants, but a part of our research is the finding, evaluation, and introduction of ornamentally or horticulturally superior forms of native plants. Our work to date has been to build up contacts throughout the Piedmont to work with us in discovering those plants; and to evaluate, under a variety of conditions, the performance of potential new introductions. We have emphasized that we do not want to introduce a plant which will later prove to be an inferior performer either in the nursery or in the garden. We are concerned that our introductions win the confidence and enthusiastic support of those who must propagate and distribute them. This is our answer to Denny Blew's question: "How do we know which are the really good plants?"

To date I believe we have been successful. We also work to create consumer demand that coincides with the appearance of the plant in catalogs and in retail centers. We do this through national periodicals aimed at consumers. This is how we act as advocates for good plants and for the nurseries that produce and sell them.

The following is a list of some of our introductions as examples of the process of discovery, evaluation, introduction, and publicity that I have outlined.

INTRODUCTIONS:

***Cornus sericea* 'Silver and Gold'**. (PHS Gold Medal winner). Originated as a sport of *C. sericea* 'Flaviramea' at Mt. Cuba, Greenville, Delaware. Leaves distinctively white variegated, other characteristics the same as 'Flaviramea'. Publicized as a replacement for variegated forms of *C. alba* in the hot and humid middle Atlantic region and southward. Cultivar registered in 1988.

***Aster novae-angliae* 'Purple Dome'.** Noted along Pennsylvania Route 100 below Allentown, Pennsylvania. Material provided to Mt. Cuba Center by Robert G. Seip of Lennilea Farm. 'Purple Dome' was publicized as the most compact form (18 inches tall × 36 inches wide) of the species.

***Aster laevis* 'Bluebird'.** Found in a private garden in Guilford, Connecticut, where it appeared as a volunteer seedling, this cultivar differs from the typical species in its freedom from mildew and other foliage diseases. It reaches 4 to 5 ft in height with gracefully arching stems bearing masses of 1-inch lavender-blue flowers with yellow centers. 'Bluebird' responds well to fertilization and good growing conditions, but is broadly tolerant of soil types and will grow in full sun or moderate shade.

***Heuchera americana* 'Garnet'**. Selected in 1984 from a variable group of colored-leaved H. americana growing at Mt. Cuba, Greenville, Delaware.

***Solidago sphacelata* 'Golden Fleece'.** Discovered in 1985 as a spontaneous seedling in a garden in Eden, North Carolina. It was evaluated under diverse conditions at Mt. Cuba Center and determined to be a low, compact form of the species suitable for groundcover use. Registered and distributed in 1989. Won the Internationale Stauden-Union's Award for an outstanding new plant in Switzerland in 1994.

***Leucothoe axillaris* 'Greensprite'.** A clone selected at Mt. Cuba in 1983. Evaluated for ease of propagation and for ability to quickly grow to salable size and quality under field nursery conditions. Registered in 1991 and publicized as a solid green leucothoe with narrow leaves with undulating edges and attenuated tips. Its light-catching ability is spectacular and its stiffly arching stems give it a graceful and elegant character.

***Pachysandra procumbens* 'Forest Green'.** Originally obtained from the teaching garden at Pennsylvania State University in 1952. This clone has been heavily propagated by the introducer and distributed. Its "surface" as a groundcover is more smoothly undulating and the leaf whorls are larger and more regular than the five other clones it has been compared to. Leaf mottling is not as prominent as in the five other clones.

SOME PLANTS UNDER EVALUATION:

***Trillium grandiflorum* 'Quicksilver'.** Originated in the wild, in Northeastern Pennsylvania in 1958. It has been observed and evaluated in many sites for rapid increase. This clone has a doubling time of approximately 1 year. Ornamental qualities are the same as the species.

Chamaedaphne calyculata a selection for green winter foliage.

***Gillenia trifoliata* (syn. *Porteranthus trifoliatus*)** (pink form).

The mid morning session on Thursday was moderated by Robert Gouveia.

Chicagoland Grows: A Marketing System for New Plants

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INTRODUCTION

Where do new plants for the green industry come from? First, botanic gardens and arboreta offer a great diversity of plants from their collections. Second, individual nurserymen, through their knowledge and experience in growing and observing plants, often have made their own outstanding plant selections. And last, organized breeding programs are developing new plants that otherwise would not naturally occur. For the green industry to benefit from these new selections, it must have access to them.

Often times, new and potentially useful plants remain unknown "pets" of botanical institutions or nurserymen because the plants have not been fully distributed or properly promoted; thus the green industry does not understand their ornamental attributes or horticultural use. A strong marketing plan and industry involvement are both essential in successfully introducing a new plant selection. Based on an introduction program initiated by the University of British Columbia in Vancouver, Canada, botanical institutions and the green industry in the Chicago region have teamed up to develop a successful plant introduction program called Chicagoland Grows.

PROGRAM GOALS AND ORGANIZATION

In 1986 the Chicago Botanic Garden initiated the Chicagoland Grows Plant Introduction Program. The program's mission is to introduce recommended plant cultivars that are well adapted to northern conditions. The long-term goal is a timely and regular introduction of new plants. Another important component of the program is to document correctly each plant introduction.

To achieve an effective working program, the Chicago Horticultural Society established, with the cooperation of The Morton Arboretum and the Ornamental Growers Association (OGA) of Northern Illinois, a separate not-for-profit corporation, Chicagoland Grows, Inc. The OGA is comprised of 14 retail and wholesale nurseries in the northern Illinois area that are known for their quality and diverse inventory of plants. The three organizations are partners in the venture, and each has members that participate on executive and operational committees. An important key to the success of the program is a dedicated, full-time staff member to coordinate its operations.

PLANT SELECTION AND EVALUATION

The direct participation of the nursery industry, particularly in regard to the selection of plants, is vital for the success of the program. Nurserymen have the best understanding of the kinds of new plants that are needed and those that are most likely to succeed in the marketplace. Plants entering the program must fit criteria defined by the industry, e.g., clonal selections for plants that are particularly variable when produced from seed, summer-blooming plants, shade-tolerant plants, small trees good for street tree use, and trees that are tolerant of clayey soils typical of urban planting sites.

Each new plant is tested prior to its release. The evaluation is centered in the upper Midwest, particularly in Illinois, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin. The plants are evaluated by plant professionals for their trueness to the selection criteria as well as reliable ornamental characteristics, cold and drought hardiness, and resistance to insects and diseases. Currently there are more than 115 different sites in more than 24 states in which plants are being tested. A group of 32 Chicagoland municipal evaluation cooperators tests the plants' performance under various urban and suburban conditions. In 1993, plants were shipped to Europe for evaluation by Selection New Plants (S.N.P.), a consortium of three major nurseries in France.

During this performance testing, the most practical and economical propagation and production methods are also established. In the past, the challenge to independent nurseries participating in introduction programs was to produce enough plants to test large-scale production methods without an end market. The corporate structure of Chicagoland Grows, Inc. allows this risk to be reduced significantly. The program has licensed a large number of Associate Nurseries (nurseries other than those directly related to the OGA) to purchase plants involved in production and performance testing before full-scale production and marketing are initiated.

PRODUCTION AND MARKETING

After testing is complete, full-scale production is initiated, and a marketing plan, including a market release date, is formulated. More than 50 production nurseries throughout the United States and Canada have been licensed through contractual agreements to produce and sell Chicagoland Grows plants. Although the testing has insured that the plant is worthy of introduction, the end-user, the customer, must be educated about its attributes and uses—a market must be created for the new plant. This is accomplished through publication of plant release bulletins, advertising in appropriate trade journals, lecturing to garden clubs and other educational programs, conducting workshops with wholesale and retail plant merchandisers, and releasing information to the members of both participating institutions. Successful marketing will insure a large demand for the plant. The full-time program coordinator leads this effort. The marketing goal is to peak consumer demand at the same time large quantities of plants are available. This guarantees a rapid and thorough distribution of the plant into the marketplace, insuring that the demand will continue to expand as more consumers become familiar with the plant. A growing demand for the plant will justify increased production by the licensed growers. Plants sold through the program are trademarked, so the cost of operating the program is supported.

CURRENT INTRODUCTIONS

To date, eight plants have been shown to fit the standard of the Chicagoland Grows program and have been promoted and released.

Marmo Freeman maple (*Acer* ×*freemanii* 'Marmo'). This red maple (*A. rubrum*) and silver maple (*A. saccharinum*) hybrid comes from a tree located near

Lake Marmo at The Morton Arboretum; it was cut down in 1993 due to previous beaver damage to the trunk. The Arboretum received this tree from an unknown nursery source in the mid 1920s, and it was 80 ft (24 m) tall with a spread of 35 ft (10.5 m) when it was propagated for this program. Its leaves are shaped like those of silver maple, but not as deeply lobed. Its foliage is an attractive medium green with a contrasting silver-gray underside and colorful red petioles. Fall color is often an interesting kaleidoscopic blend of scarlet and maroon, offset with tints of green. It has proven superior to the silver maple in branch structure and general strength. No seed is produced.

Chicagoland Green® boxwood (*Buxus* 'Glencoe'). A selection from the collections at the Chicago Botanic Garden. Selected for uniform oval-rounded habit, excellent cold hardiness, good dark green winter color, and ease of propagation. It is probably a hybrid of the Korean littleleaf boxwood (*B. microphylla* var. *koreana* and the English boxwood (*B. sempervirens*). The useful landscape size is 3 ft (.9 m) tall with a 5 ft (1.5 m) spread; this plant tolerates shearing well.

Fox Valley® river birch (*Betula nigra* 'Little King'). The dwarf, slow-growing selection of the popular river birch has been a longtime favorite in the Chicago landscape and nursery trade. The original plant, estimated to be 15 to 20 years old, was selected by King Nursery, Oswego, IL, in the late 1970s. The parent tree measured 10 ft (3 m) by 12 ft (3.5 m) wide with a dense, compact habit, and attractive exfoliating bark.

Hesse cotoneaster (*Cotoneaster* 'Hessei'). This cultivar is of uncertain parental origin (probably *C. horizontalis* × *C.* 'Nan Shan' [syn. *C. praecox*]) developed by H. A. Hesse, Weener, Germany, in the 1930s. The plant was introduced to the Chicagoland area by The Morton Arboretum in the 1950s. It is a slow-growing, low, deciduous shrub that attains a height of 1 ft (.3 m) to 1.5 ft (.45 m). It spreads as the irregularly bowed branches root as they contact the mulch/soil line. It has shown excellent resistance to spider mite and fire blight (a potentially serious bacterial disease); both of these maladies are common problems for dwarf cotoneaster species and selections. Through promotion and marketing, more than 12,000 plants are now sold annually.

Chicago Fire® euonymus (*Euonymus alatus* 'Timber Creek'). This shrub originated at Timber Creek Nursery, Woodstock, IL. It was selected for cold hardiness, fine-textured branching with mahogany-red stems, bright red fall color, and abundant, long-lasting orange-red fruit. The useful landscape size will be 8 to 10 ft (2.4 to 3 m) tall with a 6-ft (1.8 m) spread.

ARROWWOOD VIBURNUM SELECTIONS

All three selections were made by Ralph Synnestvedt, Sr. of the Synnestvedt Nursery Company, Round Lake, Illinois. Arrowwood viburnums grown from seed are highly variable; these clonal selections are consistent in form and ornamental attributes. All are large deciduous, multi-stemmed shrubs that are tolerant of local growing conditions. They possess creamy white flowers in mid to late June, followed by ornamental clusters of blue-black fruit in late September through October. The fruits are highly attractive to birds and other wildlife.

Northern Burgundy® arrowwood viburnum (*Viburnum dentatum* 'Morton'). Initially sold as *V. dentatum* var. *pubescens*, it possesses a broad, upright-rounded habit, and moderately glossy, dark green foliage. Fall color is a rich blend of wine-red and Burgundy from mid to late November.

Chicago Lustre® arrowwood viburnum (*V. dentatum* 'Synnestvedt'). The original plant was recognized as unique in the collections of The Morton Arboretum in 1967. Initially sold incorrectly as *V. bracteatum*, this selection has been correctly identified and registered with the appropriate taxonomic authority and trademarked. This selection has an upright, rounded habit with distinctively thick, dark green, glossy foliage throughout the growing season. Yellow fall color develops late in the fall season.

Autumn Jazz® arrowwood viburnum (*V. dentatum* 'Ralph Senior'). This selection offers a gracefully upright, vase-shaped habit that is accentuated by slightly pendulous, dark green foliage, and colorful red leafstalks. Fall color is an appealing kaleidoscope blend of yellow, orange, red, and Burgundy during late October.

PLANTS UNDER EVALUATION—POTENTIAL FUTURE INTRODUCTIONS

The following is a highlight of some of the plants that are in various stages of evaluation. Those with an asterisk with their name have not been evaluated thoroughly enough to be given a designated trademark name.

State Street™ Miyabe maple (*Acer miyabei* 'Morton'). The original tree is located in the collections of The Morton Arboretum. It has been a long-time favorite with the staff. It is selected for the ascending branching habit, excellent cold and drought tolerance, and clean, pest-free foliage. It is a medium- to large-sized tree with a planted height of 40 ft (12 m) with a 25 ft (7.5 m) spread. This selection has potential as a hardy alternative to hedge maple (*Acer campestre*), and a more drought-resistant alternative to Norway maple (*Acer platanoides*).

Prairie Flame™ shining sumac (*Rhus copallina* var. *latifolia* 'Morton'). This selection was made from a plant growing in The Morton Arboretum; the original seed source was Iroquois County, IL. This dwarf sumac was selected for compact habit, clean glossy foliage, and brilliant, red-orange fall color. Mature size is believed to be 5 ft (1.5 m) in height with a slightly larger spread.

Peking lilac* *(Syringa pekinensis 'Morton').* The original tree is located in the collections of The Morton Arboretum. It was grown from seed collected in China by Joseph Rock in 1926 in central Gansu province, People's Republic of China. It is selected for its upright, narrow form, cold and drought hardiness, and attractive "cherry-like" bark. The original tree is approximately 40 ft (12 m) tall with a 25 ft (7.5 m) spread. In landscape situations it will be useful as a small specimen or street tree. This species has proven highly tolerant of deicing salts.

Accolade™ hybrid elm (*Ulmus* 'Morton'. The original tree is located in the collections of The Morton Arboretum and is a hybrid of *U. japonica* × *U. wilsoniana* hybrid. It was grown from seed collected at the Arnold Arboretum, Jamaica Plain, Massachusetts, in 1924. It was selected for the graceful vase-shaped habit, vigorous growth rate, dark green glossy foliage, resistance to Dutch elm disease, adaptability to varied soils, and good yellow fall color. The original specimen is approximately 60 ft (18 m) tall with a 40 ft (12 m) spread.

Southern blackhaw viburnum* (*V. rufidulum* 'Morton'). The original shrub is located in the collections of The Morton Arboretum. It originated from seed collected in Webb City, Missouri. The species is rare in cultivation. This selection was chosen for cold hardiness, glossy foliage, excellent flower display, and superb Burgundy fall color. The useful size of this slow-growing plant is anticipated to be 8 to 10 ft (2.4 to 3 m) in height with an 8 ft (2.4 m) spread.

Birch* (*Betula* of hybrid origin). A selection growing at the Longenecker Horticultural Gardens of the University of Wisconsin—Madison. This plant originated from seed collected from an open-pollinated plant of *Betula utilis*, distributed by the U.S.D.A. North Central Plant Introduction Station in Ames, Iowa. Planted in the mid-1970s with several other sister seedlings, it is the only remaining specimen that has not been killed by the bronze birch borer. The tree also has a uniform pyramidal growth habit, beautiful satin-white bark, good foliage, and golden-yellow fall color. The original tree is 25 ft (7.5 m) tall with an 8 ft (2.4 m) spread.

Morning Sun™ crabapple (*Malus* 'Joy Morton'). The original plant is in the collection at The Morton Arboretum; consistently a top performer in annual evaluations. It is selected for excellent disease resistance, large, fragrant white flowers, abundant clusters of persistent golden-yellow fruit, and good fall color. The original tree, which is over 40 years old, is 25 ft (7.5 m) tall with an arching spread of 35 ft (10.5 m).

Data Collection System for Landscape Daylilies

Darrel Apps
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A not-for-profit research organization (All-America Daylily Selection Council) has been organized to evaluate daylily cultivar performance. Procedures for evaluating daylilies are described along with a list of high-performance cultivars.

INTRODUCTION

Stating the problem simply, we have too many daylilies. Since the turn of the century some 1,700 hybridizers have created millions of daylily seedlings—37,000 of them have been registered and introduced. Today, we estimate that approximately 13,000 of these cultivars are still in commercial circulation. To further complicate the issue 270 hybridizers are adding over 1,000 new cultivars to the inventory each year.

In questionnaires circulated in 1987, industry respondents pinpointed the problem. "We don't buy daylilies by name— just by color." Pressed further, they said, "How can you pick a winner with so many unknowns?" They had been burned by purchasing daylilies with poor performance.

In the late 1980s, 'Stella de Oro' changed much of that indifference to registered, named stock. It provided good, overall performance and a long season of bloom. Suddenly commercial interests began looking around for the next hot prospect. But as the 1987 questionnaires showed, only a few of those people even knew the names of the old standbys: 'Hyperion', 'Aztec Gold', 'Mary Todd'.

In 1987, using questionnaire responses to determine what various segments of the industry and its public were concerned about, a test program was devised and came to be known as called the All-America Daylily Selection Council. In 1988, it was reviewed by test specialists and horticultural statisticians at North Carolina State University. What emerged was a three-tiered screening and evaluation system.

SCREENING AND EVALUATION SYSTEM

Tier 1. You can think of our test program as a series of screens, graduating from coarse to fine. At Tier 1, some 50 cutting-edge daylily sites are regularly visited. These are owned by growers, hybridizers, and advanced collectors. At this level, the data taken is primarily concerned with five drop-dead criteria. Failure of any one of these is enough to condemn a cultivar. They are: bloom beauty, foliage appearance, sunfastness, bloom-stalk height (not in foliage) and spent blooms (appearance when closing).

At the Tier 1 level, all observations are noted and computer loaded. Often as many as 20 single sightings will be recorded. If, over time, a particular cultivar demonstrates worthy performance, it will be advanced to Tier 2. Unfortunately, 95% of Tier 1 plants are rejected. Most are beautiful enough but lack balanced performance. To date we have looked at over 6,000 daylilies at the Tier 1 level.

Tier 2. Qualifying daylilies go on to three Tier 2 test sites in North and South Carolina. These are located in USDA Hardiness Zones 6, 7, and 8. Tier 2 testing is a 2-year-long process. It's a continuous examination of some 52 performance characteristics.

In addition to the field trials, each cultivar is color verified using the *Royal Horticultural Society Colour Charts*. There are many major patterns to be found in daylily blooms. Between major and minor patterns, color readings are taken on 26 different features—right down to eyes, halos, veining, midribs, watermarks, and picotees. This is done to phenotypically fingerprint a daylily for possible patenting.

By the time this tier of testing has been completed, 97% of the candidates will have been eliminated. To date, 800 cultivars have advanced to Tier 2. Three hundred of those have gone on to Tier 3 testing. A portion of each award candidate's fans are sent to tissue culture labs for preliminary micropropagation suitability tests. The rest go to some 16 test sites located from USDA Zone 10 in California to Zone 3 in Edmonton, Canada. Each cooperator uses a handbook that establishes a common test protocol. What's more, each cooperator must sign a contract that outlines the test procedures to be respected and the penalties for failure to perform.

Tier 3. Tier 3 testing looks at some 26 performance characteristics. In addition, we're very interested in breadth of performance. That is, across how many USDA Hardiness Zones will this cultivar show top-notch, balanced performance? If a daylily gives us strong performance across five or more hardiness zones, it may qualify for our All-America Award. But we're also vitally interested in strong regional performances. If a cultivar finds its highest expression in three or more hardiness zones, it will become a candidate for our Star Performer Award.

Like Tier 2, this final tier of tests also runs for 2 years. At the end of these three evaluation tiers, over 99% of the plants will have been rejected. Based on our experience thus far, of the 13,000 daylilies in the marketplace, 12,000 probably will be rated average to poor, 1,000 good, and 200 excellent. Unfortunately, not all of those 200 cultivars will automatically become award winners. To reach that level, a daylily must be capable of high plant production through natural division or tissue culture.

CRITICAL PERFORMANCE CHARACTERISTICS

Performance Verification. The most important result of our work has been to establish a general, multi-zonal performance standard for daylilies. The chart labeled "AADSC Performance Verification Comparisons" focuses on the most critical performance characteristics. A comparison is made between an average daylily and 'Stella de Oro' and 'Black Eyed Stella®'. Note that average performance is determined from all of our computerized data.

Bloom Beauty. This can be a difficult category in that the definition of beauty is conditioned by the cultivars ultimate use. If the daylily is to be used within several feet of the viewer as a stand-alone specimen, then the end user will want to be close enough to see his/her share of those 17 gorgeous patterns that are to be found in the bloom face. If the daylily is moved back as little as 10 ft from the viewer, many of those subtle but highly enriching patterns and embellishments virtually disappear. At the extreme end of this spectrum, are the departments of transportation. DOTs are increasingly drawn to the daylily because of its low-maintenance/high performance values. However, at 55 mph and set back 20 to 100 ft from the roadway, beauty translates into "carrying power"—the ability to be seen.

Bloom Period. In our research we have found a very peculiar split in daylily performance that appears to run along genetic lines. It has caused us to make a distinction between "landscape" and "specimen" daylilies.

What we call a "landscape" daylily is most often rated only "Good" (that is, a cut below Excellent) on bloom beauty. But it will give you from 100 to 300 days of bloom in USDA Hardiness Zones 4 to 10, plus excellent foliage, and high fan increase rates. "Specimens", on the other hand, are selected primarily for bloom beauty. Unfortunately most "specimens" bloom for only 21 days. Our Council tries to advance only those "specimen" cultivars that will bloom for 40 to 80 days. Thus the sales opportunities are 2 to 4 times greater.

ADBI (Average Daily Bloom Intensity). It's one thing to announce that a daylily will bloom for 300 days, it's another to neglect mentioning how much bloom it carries each day over those 300 days. In this category, we're looking at first-year performance as that's what most of you will be dealing with. An ADBI of 1.0 means a bloom production of one bloom per day per plant. In their second year 'Stella de Oro' and 'Black Eyed Stella®'s' ADBIs will jump to 8.0 or as much as 600 to 800 blooms per season. We have tested several daylilies that will give an ADBI of 16 in the second year, but they can only sustain that show for 30 or 40 days.

Foliage Appearance. Hateful as it may sound, daylilies without bloom are simply tall grass to the casual viewer. During a single growth season, foliage can be without accompanying bloom for 10% to 90% of the time (depending, of course, upon the bloom performance of the chosen cultivar). The prudent buyer should look for good foliage shape, a rich green color, and high-density foliage.

Time to Achieve Mature Clump Shape. Maturity, in terms of overall plant performance, generally occurs in the third year of undisturbed growth. Maturity, in terms of clump shape, occurs earlier. In the latter case, we are concerned with how long it takes a clump's foliage to gracefully fill a gallon container. 'Black Eyed Stella®' demonstrates excellent clump shape. We know that some daylilies will never achieve this objective. If, for example, in 1985 you purchased 10 'Stella de Oros' and 10 'Cornwalls', today you would probably have over a million fans of 'Stella de Oro'. 'Cornwall' would not only have less than 100 fans but its foliage would be sparse as well.

Sunfastness. Bleaching degrades beauty. Generally, you will see this effect around five in the afternoon. With some cultivars it can occur as early as 10 AM We measure this phenomenon on a scale of 1 to 5. If a cultivar drops to a rating of 3, 4, or 5, it will not receive our recommendation nor will your customers want it.

Fan Increase Rate. If you want to destroy a grower's livelihood, sell him/her daylilies that drop below an annual 300% fan increase rate. The replacement rate simply isn't there for a good harvest plus follow-on crops. In large-scale landscaping jobs, a high fan increase rate combined with good foliage appearance will ensure that your daylilies will serve as excellent ground cover regardless of bloom performance. In many such situations, what the client may be searching for is anywhere from 500 to 100,000 daylilies. Given the right plant, a site will fill in much faster with high fan increase cultivars. It means that by the beginning of the second bloom season you will have a happy client whose project has reached virtual maturity.

We've also found that when you launch an All-America daylily, you'll need plenty of stock. Two weeks after 'Black Eyed Stella®' was introduced, the licensed growers had sold 160,000. Shortly thereafter they passed a half million. Two million are projected by 1996. And they are struggling to keep up with the demand from an aroused gardening public. To better gauge the depth of the marketplace for superior daylilies it is estimated that over 10 million 'Stella de Oro's' have been sold since 1975 and it is still very much in demand.

Spent Bloom Persistence and Messiness. It is worth dallying here long enough to show you some examples of good and bad spent bloom habit. Some spent blooms will drape over the buds below and prevent them from opening. Other cultivars will not drop their spent blooms for up to 5 days. In a short time, the plant will have a trashy look. We call those that drop their spent blooms in 1 to 2 days "self-cleaners."

Insects and Diseases. Daylilies for the most part do not have any real problems with insects or diseases. Nonetheless, we continue to screen for them.

Before discussing heat and cold tolerance we need to mention dormant and evergreen. A helpful rule of thumb that we use is: There are no evergreens in USDA Hardiness Zone 5 and northward; conversely, there are no dormants in the deep south. This is because the evergreens burn off in the cold north and the dormants die when they don't get adequate cold temperatures.

Cold Tolerance. Evergreens tend to be associated with cold tenderness much more often than dormants. In our test program we do not permit cooperators to protect their plants with foam blankets, mulch, etc. We rogue out tender stock through direct exposure. Unfortunately, in the popular literature, an unconscious but persistent linkage has been forged between all evergreens and cold tenderness. This has not been borne out in test. Recently, 'Persian Market', a well-known evergreen, was under heavy consideration for an All-America Award. It is successfully grown as far north as Zone 2. In North America the hardest places to grow daylilies are those areas that do not enjoy long periods of continuous snow cover, perhaps the two toughest zones in which to grow tender daylilies are Zones 4 and 5.

Heat Tolerance. This poses a different type of problem in daylilies. If one compares the performances of 'Stella de Oro' and 'Black Eyed Stella®' throughout most of their common range, they are very similar. This is not particularly surprising as 'Black Eyed Stella®' is the progeny of 'Stella de Oro'. The further south one pushes 'Black Eyed Stella®' the better its performance, whereas 'Stella de Oro's' bloom output drops once into Zones 8B, 9, and 10. Generally speaking, prolonged temperatures of 100 degrees will shut down bloom production in many daylilies. 'Stella de Oro' exhibits this problem.

Table 1. AADSC performance verification comparisons.

Category	Average daylily	'Stella de Oro'	'Black Eyed Stella®'
Bloom beauty	Fair-good	Good	Good-excellent
Bloom period (by USDA Zones of top performance	21 days (Zones 6-8)	100-180 days (Zones 5-10)	100-271 days (Zones 5-10)
1st year ADBI*	.4	.4	.4
Foliage appearance (Scale: poor-excellent)	Fair-good	Good-excellent	Excellent
Time to achieve mature clump shape	1 year plus	By onset of first bloom	By onset of first bloom
Sunfastness (scale: 1.0-5.0, 1.0=high)**	1.8	1.8	1.0
Fan increase rate***	200%	700%-1000%	800%-1200%
Spent bloom persistence (1-2 days=self-cleaner)	2.4 days	1-2 days	1.2 days
Spent bloom messiness	Good	Excellent	Excellent
Resistance to insect damage	Good	Excellent	Excellent
Cold tolerance	Good	Excellent	Excellent
Heat tolerance	Good	Fair	Excellent
Resistance to spring sickness	Good	Excellent	Excellent

* Average daily bloom intensity (or total bud count ÷ day in bloom ÷ number of plants). A "1.0" equals one bloom per day per scape.

** The Council will not recommend a daylily that consistently scores 3.0 or less due to "bleaching" or "slicking."

*** Fan increase rates of 300% or less are not productive enough for commercial enterprises. Interestingly, culitvars with such marginal fan increase rates also do poorly in tissue culture.

As mentioned earlier, there seems to be a genetic split between "landscape" and "specimen" daylilies. This very crowded, unconventional genealogical chart (Fig. 1) confirms the idea that "good parents are important." What do these 33 important landscape cultivars have in common? Almost everyone of them share these

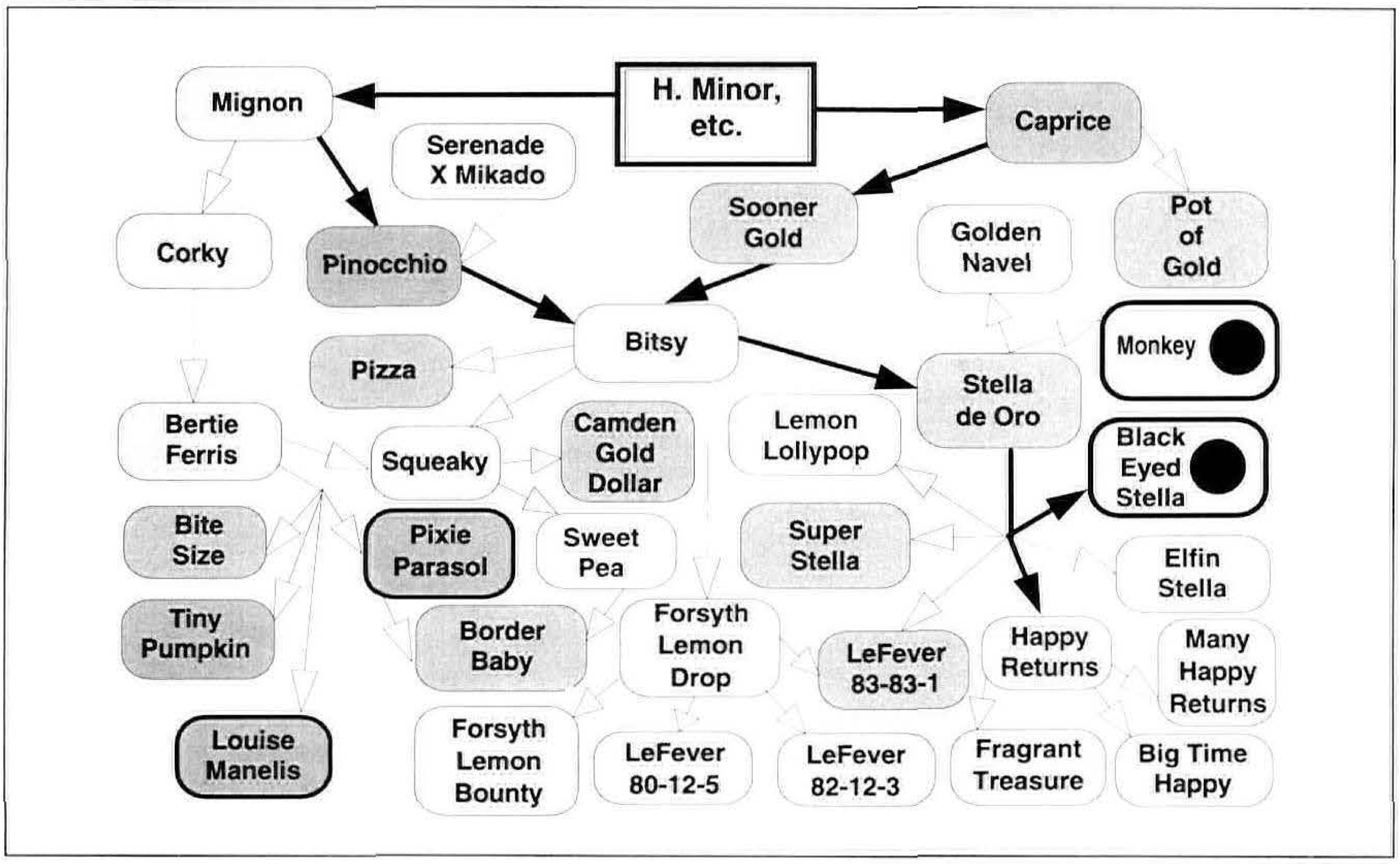

Figure 1. A family of high performance cultivars.

characteristics: as depicted, their carotene-based pigments usually produce only yellows, oranges, and golds; they have fibrous root systems; they have very long bloom periods; and they have very high bud counts. They also are very reluctant to transfer these admirable qualities to other non-landscape lines.

Nonetheless, four of the cultivars shown ('Louise Manelis', 'Pixie Parasol', 'Monkey', and 'Black Eyed Stella®') are color breakthroughs. 'Monkey' and 'Black Eyed Stella®' because of their red eyezones. 'Louise Manelis' is a shrimp pink and 'Pixie Parasol' is an apricot peach pink. This fact gives us hope that hybridizers will eventually bring a richer variety of color into this high performance genetic matrix. Because the difference in performance today is so extreme, we have had to create two different categories of cultivars: specimen and landscape. Each may contend for our two main sets of awards: All-America and Star Performer.

PICKING A WINNER

Once we have tabulated all of the test results, our computer program assigns weighted multipliers to the most critical performance characteristics. Seventy percent of our weighting is assigned to four performance features: Bloom Beauty (25%), Foliage Appearance (15%), Bloom Period Length (15%), and Fan Increase (15%). For commercial enterprises, those are the predominant make or break factors that determine success in the marketplace. The other factors are Spent Bloom (5%), Abscission (5%), Average Daily Bloom Intensity (10%), Sunfast (5%), and Fragrance (5%).

According to our charter, it is our purpose to locate, test, and publicize not only our All-America Award winners but top regional performers—our Star Performers. The industry and the gardening public need to know about both.

An All-America daylily must have an overall composite score of 85% and span at least five contiguous hardiness zones and show balanced performance throughout its range. A Star Performer must score at least an 80% in our rating system throughout its range. In sharp contrast, the average daylily tested to date will have a peak performance that spans two zones but will not get much above 50%. Out of our first test cycle we found that these daylilies qualify as award candidates. The first group are landscape cultivars: 'Bitsy', 'Forsyth Lemon Drop', 'Lemon Lollypop', 'Leprechaun's Wealth', 'May May', 'So Sweet', 'Stella de Oro', 'Yellow Bouquet', and 'Yellow Lollipop'. Among the specimen, these have proven to be top-notch daylilies: 'Becky Lynn', 'Brocaded Gown', 'Charles Johnston', 'Chorus Line', 'Jen Melon', 'Lullaby Baby', 'Persian Market', 'Tender Love', and 'White Temptation'.

Question Box

Moderated by Ralph Shugert and Bruce Briggs

Question: What is the best way to prune *Sciadopidys verticillata* to keep a nice tight shape?

Bruce Briggs: There are selected forms that are tall and narrow and you should get those. Also, we have sheared them hard and have had no problem.

Question: Why does it take so long to get herbaceous perennials from Europe into the U.S.A.?

Bruce Briggs: Up until the last few years, herbaceous perennials have not been as popular as they are today.

Steve Still: Bruce, you are correct. The Perennial Plant Association was started in 1983 when we began to see interest in this group of plants. Interest in herbaceous perennials has also been cyclical. I have a student doing a study on perennials in the U.S.A. and it has shown that grasses, for example, were listed in catalogues in the late 1800s but that interest died down and again increased in the 1980s.

Dave Bakker: Canada as well as the U.S.A. has a quarantine system and the hassle of importing plants has additionally limited their importation.

Question: How does the NACPEC organization benefit China?

Rick Lewandowski: I participated in one of the NACPEC tours this year, although I am not an official member. One of the ways it helps is to provide funding to institutions in China to support research. In addition the last few trips have involved a contractual relationship with China at their request. The National Arboretum is currently looking at a program to bring new plants from China and seeing that royalties for such plants go back to China. I can tell you that the Chinese colleagues feel that they have benefited from this association.

Question: Could Darrel Apps comment on daylilies as a food plant and what parts are eaten?

Darrel Apps: We have not been assembling data on that subject but if you look in the book by Cathy Lilkinson Barash (1993, Edible flowers: From garden to palate, Fulcrum Publishers, Golden, Colorado) it has some information.

Ralph Shugert: In the culinary section of a bookstore might be a good place to start. I know in California there is interest in using them as food.

Bill Barnes: I have been know to taste them and red flowers are terrible; 'Happy Returns' is sweet and one of the best.

Question: For Don Knezick. Are there any compact or dwarf forms of*Cephalanthus*? It is nice for wet sites but as it gets older it become ungainly.

Don Knezick: We grow lots of that plant but I do not look for dwarf forms because we are interested in genetic diversity. I will look for it now. I have not seen any.

Question: For Shelley Dillard, Morris Arboretum. Why do you say to use ziplock bags, and not freezer bags? What difference does it make?

Shelley Dillard: We use ziplock bags because they are easier than the twist type.

Bill Barnes: Don't buy cheap bags, the ziplock will not hold. I just wanted to add to what Shelly said yesterday. Put the perlite in a container that has holes in the bottom. This will allow water to percolate out the bottom and prevent one batch of perlite being wetter that another batch. If you are concerned about mold forming on the seeds, put manzate in the water used to wet the perlite. This will stop mold from forming in the bag.

Robert Herman: I tried vegetable ziplock bags but the seeds dried out and I switched back to the normal type.

Mark Widrlechner: I have noticed that our milled sphagnum can have spirea seedlings germinate in some batches as weeds. If you are doing any spirea seed germination it is a good idea to get away from sphagnum and use perlite.

Question: Should you fertilize dwarf conifers like normal conifers? I have heard that you should not?

Jim Smith: We are in the business of selling plants, and we fertilize them like crazy.

Dave Thompson: For our dwarf conifers in the field, we fertilize in March, July, and November. We take the total nitrogen needed and divide it into thirds.

Question: How should *Cercis canadensis* be treated before sowing?

Cameron Smith: I asked that question 5 years ago, and Ralph gave the correct answer. Hot water is best and sulfuric acid is not good because seed coats vary and it will kill some embryos before others are properly treated.

Dick Bir: Take the water off the heater and don't use it until it stops bubbling.

Ralph Shugert: Always test a small lot before using any treatment. Seed source may influence the results.

Joerg Leiss: Another treatment I have used is ethylene glycol (antifreeze). Soak the seeds overnight and then wash them free of ethylene glycol.

Bruce Briggs: The use of gasoline has come up in the Western Region. Check the Western Region for details. Be careful not to start fires around it.

Question: Addressed to Rick Lewandowski, Paul Meyer, Dick Bir, and Tim Brotzman. Should we not be spending an equal amount of time, money, and effort to look for and discover new or better forms of North American native plants as we do Asian exotics? What about expeditions to our mountains, deserts, wetlands, and prairies?

Dick Bir: There is a wealth of plants out there and a lot of people searching for better native plants. It is not that one flora is better than another, it is fadism that is the problem. People jump on bandwagons and the eastern Asian plant flora are in now. Our thrust has been to make up for the neglect of the last 70 to 80 years in our eastern flora.

Ralph Shugert: If you have the interest in natives they are there. It is just that matter of looking for them.

Phil Roslyn: At the present time we are evaluating 200 selections of native plants.

Question: How do you address the challenge of using exotic plant species when government agencies are specifying native species? How do you put the two together?

Dick Lightly: You are always going to have a market for the total array of plants. There may be shifts but no one is going to go out of business overnight. There is a trend towards naturalistic gardens and the plants that fit into them. But there are always going to be those people who will like callery pear or dwarf conifers.

Dick Bir: There are lots of different people, styles, and ways to do things in this world and I don't think that there is any right way to do anything when it comes to plants. Even though I have written a book on natives, because a publisher saw a need for such a book, two-thirds of the plants I work with are non-natives and hybrids. We look for good plants in the landscape not just natives. The fads will change.

Dave Thompson: This all started out with the need for drought-tolerant plants. The need was there, to replace native plants with native plants in those areas. The need was generated because of increasing population in the U.S.A. This is a chance to make change.

Dale Deppe: The native plant thing has gotten out of hand. People want a perfect plant not a one-sided plant. I think this is related to the aging population with people wanting to go back to the way things were.

Dale Hendricks: I do not think that the native plant interest has hurt the existing plant business. A lot of this demand is a new market not the same market sliced thinner for the existing plant producers. We also do not have the luxury of dictating to our customers what they want. I don't think the tail wags the dog.

Don Shadow: I don't want anyone telling me what I can grow or what plant material can be utilized.

Bruce Briggs: Just one closing comment. I have a problem with what is native. We have road projects that utilize a lot of kinnikinick. Our native plants have a lot of blight, and die out in a few years. We have a native in Massachusetts that is just beautiful. How do we get them to choose the one from Massachusetts? They are both native.

Question: What is the hardiness (specifically to Ohio, Michigan, and Illinois)of *Cephalotaxus koreana* and other species in this genus?

Chris Backtell: In the case of *C. harringtonia* we have had them since the mid fifties. We had 24 below and did not suffer any problems. Protecting them from the winter sun is important. When you consider the deer resistance, it is a great area for testing.

Rick Lewandowski: We have had plants of *Cephalotaxus* since the early 1900s on the Philadelphia area. We have had temperatures of close to 20 below for short periods of time. We grow in both sun and shade. They take our warmer conditions well also.

Kim Trip: I am from Arnold Arboretum and have done considerable looking around on the East Coast and I think that there is a greater degree of variation in hardiness than we have recognized. We are most often dealing with*C. harringtonia*. Some clones are reliably hardy towards the boarders of Zones 6 and 5. If you do not have the right clone you will get a false reading on how hardy the plant is. We don't know how hardy the other asian species are. We need to increase our collecting in native populations so we get a better breadth of the diversity that exists. So, don't take a pat answer to that question. You need to know the origin of the clone you have. In a cold region avoid *C. fortunei* and *C. sinensis*.

Mark Widrlechner: About 10 years ago in the NC-7 ornamental trials we distribute a seedling population of *C. harringtonia* from Hakito to 20 sites in the upper Midwest. Within 2 to 3 years all the sites had lost their plants except Manhine Botanical Garden in Michigan and they had it in a protected site against a building. Therefore citing in the Midwest is important.

Question: Will we be losing Simazine and can Basamid serve as a substitute for methyl bromide, which will be banned in 2001 as a seed-bed fumigate.

Ralph Shugert: I removed methyl bromide about 5 years ago and substituted Basamid. I have been very satisfied with it. The nice thing about it is that it does not need a cover. It will inhibit or kill 60-65% of the nuttlets of yellow nutsedge. Soil temperature should be 60F and up.

Bruce Briggs: On the Simazine, use the lowest level you can. I would recommend that you stay under 1 lb. Our state is considering banning it. At the low level it will almost be broken down by bacteria.

The Thursday afternoon session was moderated by Jim Johnson.

National Plant Collections: Source of New and Unusual Plant

Barry Glick
Sunshine Farm and Nursery, Rt. 5, Renick, West Virginia 24966

All of us who collect plants for our personal gardens or for commercial purposes know that many good plants have become difficult if not impossible to find. Not because they have been superseded by better plants, but simply because they are no longer in fashion. Typically, long after these plants have disappeared from commercial catalogs, a new generation of gardeners becomes interested in them and begins to write and talk about them. The demand for these plants increases. Nurseries search for sources, and if we are lucky, the plant becomes a good commercial item. In many cases, however, the plant may have disappeared entirely and exists only as a memory. Many victorian plants, such as, *Rosmarinus officinalis* 'Flore Pleno' and *R. officinalis* 'Argentia', the double-flowered and silver rosemaries, and *Myrtus communis* 'Leucocarpa' and *M.communis* 'Flore Plena', the white-berried and the double myrtles, have gone this route. The true *Rosa* ×*centifolia* is only seen in old paintings.

In 1978, several members of the Royal Horticultural Society who were lamenting the loss of centuries of historic British plants decided to form a group that would prevent this tragic loss from continuing. They banded together and combed the English countryside in search of gardeners and nurseries who had a deep interest in a particular genus of plants. That group, The National Council for the Conservation of Plants and Gardens, now has more than 600 collections listed in their directory and 40 local groups. Similar councils have been formed in France, Australia, New Zealand, and now North America.

Four years ago here in the United States of America, a group of 20 committed plantsmen consisting of authors, lecturers, academics, and gardeners, with diverse backgrounds in botany, horticulture, taxonomy, and agriculture, decided to form the North American Plant Preservation Council (NAPPC). The NAPPC has listed over 100 collections to date!!

Like its British counterpart, the NAPPC has five primary goals:

1) To encourage the conservation of uncommon plants which are valuable because of their historic, aesthetic, scientific, or educational value by propagating and distributing them as widely as possible.

2) To list plants held in important collections at different nurseries and gardens.

3) To encourage the widest possible cultivation of uncommon and endangered plants by arranging conferences, exhibitions, discussions, and visits to gardens, specialist plant collections, and nurseries.

4) To encourage the reintroduction and distribution of uncommon and endangered plants.

5) And most important, to establish and support collections of specified genera, selected species within genera, and other defined collections of plants for the enjoyment and information of the public and the benefit of science.

The NAPPC not only brings people to plants, but people to people who share similar interests. There has already been much exchange between our council and the NCCPG. While the NAPPC concentrates its efforts in the nursery and private sector, a similar group has been formed to register collections at public institutions. Under the auspices of the American Association of Botanic Gardens and Arboreta, The North American Plant Collections Consortiums goals are similar to ours.

Now the fun part—I've brought some candy for your eyes. We'll take a whirlwind tour around the continent to visit some of the exciting collections that the NAPPC has registered to date.[Editor's Note: The author showed a series of slides depicting examples of the collections listed below.]

Collection holder	Collections held
Terra-Nova Nursery; Portland, Oregon	*Heuchera, Tiarella, Pulmonaria*
Perry, Leonard; University of Vermont	*Aster, Solidago*
Waddick, James; Kansas City, Missouri	*Iris*
Starhill Arboretum; Petersburg, Illinois	*Quercus*
Royal Botanic Gardens; Hamilton, Ontario, Canada	*Syringa*
Hosta Hill; Tucker, Georgia	*Hosta*
Geraniaceae; Kentfield, California	*Geranium, Erodium*
Fancy Fronds; Seattle, Washington	Pteridophytes
Pine Knot Farms; Clarksville, Virginia	*Campanula*
Appalachian Wildflowers; Reedsville, Pennsylvania	*Phlox*
Spangle Creek; Spangle, Washington	*Cypripedium*
Stonecrop Gardens; Cold Springs, New York	*Salvia, Primula, Saxifraga*
Squaw Mountain Gardens; Estacada, Oregon	*Sedum, Sempervivum, Jovibarba, Rosularia, Orostachys*
Scott Arboretum; Swarthmore, Pennsylvania	*Ilex, Magnolia*
Bluemel, Kurt; Baldwin, Maryland	*Miscanthus, Carex*
Foster, Steven; Eureka Springs, Arkansas	*Echinacea*
Daffodil Mart; Gloucester, Virgina	*Narcissus, Hyacintha, Tulipa*
Long Lane Farms; Spring Mills, Pennsylvania	*Astilbe*

Think about it—a botanic information super highway engineered to preserve plants for future generations to enjoy. Those of you here who are ready to register a collection or want to learn more about the mechanics of plant preservation, please come talk to me, we'd love to have you participate.

Overwintering Perennials

Marc Laviana
Sunny Border Nurseries, Inc., 1709 Kensington Road, Kensington, Connecticut 06037

Sunny Border Nurseries, Inc. grows, in containers, over 2000 taxa of perennials with another 500 or so in trial development. Overwintering perennials is a broad subject and the type used depends upon the species in question. Several different methods are used. Most of our container crop is overwintered in the field. Unheated hoop houses with two layers of air-inflated plastic are used for marginally hardy genera, such as *Anemone, Delphinium, Lupinus,* and *Stokesia.*

Field covering begins during the second week of November and is finished by Thanksgiving. Several years ago the temperature reached -6F on the Friday following Thanksgiving. At this time there were 5 inches of snow which saved thousands of dollars of plants. Experience has shown that most container perennials growing above ground in pots will not survive if root temperatures reach 10F. Care must be taken to ensure that the soil temperature in the pot is maintained above this critical level. Weather is very unpredictable in New England. Because temperatures were so warm in the early weeks of November this year, 1994, covering was delayed. Covering too early can heat up the plants and make them more susceptible to cold temperatures by inducing a flush of both roots and shoots. The crop is allowed to go through a hardening off period before covering. Generally a few frosts of 20F to 25F are needed to complete this process.

The week prior to covering is spent on clearing away dead leaves and flower stalks. Taller foliage is cut back to pot level with a weed-whacking machine. All previously spaced pots are brought together into a tight row. Plants within a row are consolidated so that they are pot-to-pot. The majority of our crop is grown in square pots. Growing pot-to-pot increases the insulation factor. Round pots are grown pot-to-pot with the exception of the vine program that has a 3-ft bamboo stake in the pot. In this instance the pots are tipped on their sides to allow for covering. Two different mouse baits are applied in the field because mice and vole can become tolerant to a single form of rodenticide. Two or three forms of active ingredients are preferred. The products are purchased from exterminating supply companies rather than nursery or farm supply companies to give us more options. These creatures can have a very damaging effects on many types of plants. They will have a feast during the winter months if not kept in check. Plants such as *Astilbe, Baptisia, Clematis, Dianthus, Hosta, Liatris, Papaver,* and *Sempervivum* are susceptible. When mice and voles damage is first sighted in September, mouse bait is applied to reduce the population in that specific area. Just prior to covering, mouse bait is placed in every row at 30- to 40-ft intervals. To prevent water rot due to excessive moisture during the winter months, a fungicide spray is applied before covering. Spraying applies only to items that have previously experienced winter rot or any of the winter molds and mildews. Plants covered with microfoam and plastic are more susceptible to rot because the material does not breath. The winter of 1994 generated 17 to 18 storms and with this came increased amounts of moisture. A lighter soil mix which retains less moisture is optimal for rot-susceptible plants. It is not advisable to have the growing medium too wet at time of covering.

Covering is accomplished with two types of covers: white polyethylene with ¼-inch microfoam and a white non-woven polypropylene material (cloth). The overwintering cloth-like product can be purchased in light, medium, or heavy grade. Sunny Border Nurseries, Inc. only uses heavy grade fabric for overwintering. This material will let moisture in while retaining heat. The product can be reused for several years. Some cloth-like material has been used at Sunny Border for 6 years with more to go. A simple rule of thumb is used. If plants are evergreen or pseudo-evergreen, use cloth, or fleece as it is termed in Europe. This is an effective cover on *Achillea, Arabis, Aubrieta, Coreopsis, Echinacea, Gaillardia, Iberis, Leucanthemum, Phlox, Rudbeckia,* and *Sedum* to name a few. If the plant is prone to smothering or is very brittle during the winter, set up temporary hoops before applying the cloth with either conduit or concrete rebar bent to the width of the row. Upside down flats are another option which allows an air space between the plant and the cover. If a plant goes completely dormant and is deciduous during the winter, apply 1 to 2 layers of ¼-inch microfoam with an outside layer of white polyethylene. This method is effective on *Asclepias, Clematis, Dicentra,* Ferns (dormant), *Hemerocallis, Hosta, Miscanthus,* and *Platycodon* to name a few.

There are exceptions to this rule. Plants that have repeatedly died over winter are now grown in holding houses through the winter. These houses may be totally unheated or marginally heated to maintain a higher temperature.

There are several factors to be aware of during the winter months.

1) Freezing and Thawing. Some plants can handle this better than others. Any plant that is susceptible should be overwintered in a hoop house.

2) Excessive Moisture with a Layer of Ice. This can have a smothering effect. Excessive moisture can also lead to rotting of the crown of the perennial plant. A well-drained medium along with a preventative fungicide spray or drench can reduce this crown rot effect.

3) Wind. The wind can cause the covering material to blow off the plants. Sand bags are placed every 4 to 5 ft along the side of the row to hold down the over wintering material. The cloth fabric rarely blows up because the wind penetrates the material. The polyethylene-microfoam combination is sometimes a nightmare and a messy situation if the coverings are not secured properly. Another method for securing the coverings is to use 1 inch × 3 inch × 48 inch furring strips with a 6- to 8-in. landscape spike pounded into the ground. If the ground softens during thaws, weakening the spike, the plastic loosens. Try a longer spike or move them if this does occur. A combination sand bag-furring strip works well.

As new cultivars become available, test blocks are placed in the field and different overwintering methods are tried and evaluated for success. There are some cultivars which require minimal protection over winter while others have been much more difficult. There are few sources of information due to the lack of research of this subject. Most of our techniques have been developed through the trial-and-error method. The average survival rate at Sunny Border is 95%. A 90% success was seen in the extreme winter of 1994.

Cultivar Mixes

Dale G. Deppe
Spring Meadow Nursery Inc. 12601 120th Ave Grand Haven, Michigan 49417-9621

INTRODUCTION

Few things in life frustrate me more than buying mixed or misnamed plant cultivars. When was the last time you noticed a cultivar mix-up? If it's been more than a few months, then you should start looking ASAP. The professional credibility of our nurseries is at risk because we sell misnamed, and cultivar-mixed-up plants. Our employees are comfortable with things as they are. They do not even recognize mixed up or misnamed plant cultivars. Cultivar mix-ups have become so common in the industry that few nurseries are even trying to solve this "rapidly growing" problem.

Think About the Following Examples

- A landscape site is planted with specimen trees. After review it is determined that the trees are misnamed. The cost to replace these trees with the proper cultivar is thousands of dollars. Both the contractor and the property owner are upset with your company.
- A wholesale nursery has 50,000 boxwood plants die in the field from a hard winter. Then it discovers that every plant was misnamed. The true-to-name cultivar would have survived the winter conditions. After assessing lost plant sales at over 1 million dollars, the nursery owners are ready to sue. This suit is not only for lost sales but also for damaging the reputation of the nursery as a hardy boxwood supplier.
- A national chain store is changing suppliers because nursery inspectors noted that many plants sold by them were mixed, misnamed, and or mistagged. The store's credibility and good name are severely damaged after this problem is revealed on a national TV show about consumer fraud.

Lawyers can take these cases to court and win big money for their clients. The idea that nurseries are only liable for the plant purchase price is not true. Nurseries that sell misnamed or mixed plants are not having an accident, or experiencing an act of God, or just making a simple mistake. Your liability insurance is not going to cover your loss when they find out that you knew about the fraud all along. The size of this problem indicates that every nursery knows about it. As "nursery professionals," we can not say we did not know; it's our job to know. A lawyer can prove in court that these cultivar switches or mix-ups happen with the full knowledge of nursery management. Therefore, we and all nursery owners are at serious risk of losing our businesses in a lawsuit.

PLANT LIST—MIXED-UP PLANTS WE HAVE PURCHASED

In order to give you an idea of the size of this problem, I have compiled a shortened list of mixed-up plants we purchased for stock block planting at Spring Meadow Nursery Inc. in the last few years:

***Aronia arbutifolia* 'Brilliantissima'**	All plants varied because they were propagated from a seedlıng block
***Berberis thunbergii* 'Atropurpurea Nana'**	Many were rapid growers with a taller growth habit than true 'Atropururea Nana'
***Buddleja davidii* 'Dubonnet'**	Mixed flower color
***Chaenomeles* ×*superba* 'Cameo'**	Some had white flowers instead of pink
***Cornus alba* 'Argenteo-Marginata'**	Mixed with *Cornus alba* 'Variegata'
***C. sericea* 'Isanti'**	Plants grew rapidly and were obviously not compact
***Hibiscus syriacus* 'cultivars'**	Mixed colors in seven cultivars
***Ilex verticillata* 'Late Male'**	Male plants with berries
***I. verticillata* 'Winter Red'**	A mixture of four different cultıvars none of which was 'Winter Red'
***Philadelphus* 'Minnesota Snowflake'**	Some plants flowered single and some were double
***Potentilla* 'Gold Drop'**	Every nursery is growing a different selection all with yellow flowers of course
***Rosa rugosa* cultivars**	We bought four cultıvars, each one was mixed by flower color
***Rhus aromatica* 'Konsa'**	Plants were not uniform in habit or form
***Ribes alpinum* 'Green Mound'**	Four plants out of 100 flowered and varied in habit
***Spiraea japonica* 'Shibori'**	Every plant had only pink flowers
***S. japonica* 'Anthony Waterer'**	Two completely different growth habits
***Syringa* 'Aladdin', 'Pocahontas', 'Isabella'**	All three of these were mıxed by flower color
***S. reticulata* 'Ivory Silk'**	Fifteen out of 50 have a different branch structure, but it took more than 4 years to notice
***S. vulgaris* 'Madame Lemoine'**	Many of these white lilacs had red flower buds
***S. vulgaris* 'Sensation'**	Some had green dormant buds instead of red buds
***Taxus* ×*media* 'Densiformis'**	Every nursery is growing mixed up plants with big fat needles, calling them 'Densiformis'
***T.* ×*media* 'Runyon'**	Mixed with other 'Densıformis' types
***Thuja occidentalis* 'Hetz Midget'**	Mixed with a taller faster growıng globe form
***Thuja occidentalis* 'Woodwardii'**	Grew too tall and narrow for Woodwardi
***Viburnum dentatum*, Autumn Jazz™ viburnum**	100% misnamed
***V. opulus* 'Compactum'**	We received a selection of *V. trılobum* 'Compacta' that never flowered
***V. opulus* 'Roseum'**	Only two out of 100 had a snowball type flower; the rest had a flat flower
***V. prunifolium* cultivar selection**	25 identical plants of a cultivar turned out to be different seedlings
***V. plicatum* f. *tomentosum* 'Mariesii'**	We received three different cultivars from three different sources

***V. plicatum* f. *tomentosum* 'Pink Beauty'**	Two sources, two different plants; one source had never even seen the plant flower

The above problems have been identified and corrected at Spring Meadow.

Please try to understand what could have happened if we did not bother to look at these plants on a continual basis. Every stock plant must be evaluated season by season and proven to be correctly named. Do not assume, I repeat, do not assume that the plants you buy are correctly labeled.

HOW DOES IT HAPPEN?

Plant Cultivars Become Mixed up When Cuttings are Taken From:

- Plants growing in parks or yards.
- Plants growing at the nursery down the street.
- Plants bought at retail.
- Mixed stock plants.
- Plants grown from seed.
- Plant cultivars we have never seen before.
- Plants the nursery salesperson brought back from wherever.
- Plants that have not been verified as unmixed.
- Multiple sources which will almost always yield mixed material.

Cuttings are Mislabeled and Then Mixed up Because:

- Old tags are reused by writing on the other side.
- The writing on the tag has faded away so someone guesses at the cultivar name.
- "We don't label them, everyone knows what they are."
- The crew sticking the cuttings didn't know the plants were different.
- Every container, box, flat, or bundle wasn't tagged as it should have been.

Rooted Cuttings are Mixed During Pulling When We:

- Handle cultivars that look alike on the same day.
- Pick up cuttings from the floor when grading.
- Have a shortage and make a substitution.

Plants are Mixed at Planting Time When We:

- Handle too many cultivars at one time.
- Try to plant like-plants together instead of separating them.
- Forget to label at planting and try to do it later.
- Do a poor job of ending one cultivar before starting the next cultivar.

Plants are Mixed at Shipping Time When We:

- Ship more than one cultivar in a box.
- Label plant material after it gets to the loading dock.
- Substitute cultivars without proper tagging.
- Fail to properly separate cultivars in the truck because we can tell them apart.
- Buy plant material for reshipment without verifying its true name.

Plants Continue to be Mixed up Because No One will Throw Away Mixed-up or Misnamed Plants.

- "Let's take care of that cultivar mix-up next year, for now we just have to fill these orders."

- "I'm not going to worry about it because no one complains."
- "We need 5000 of these so take cuttings from every plant we have, mixed or not."
- "Sell it at a discount and get rid of it. Don't you dare throw those away, that's money."
- "When those new cultivars come along we just change the names of the old stuff in our catalog."
- "The customer decides to buy. If they don't want it, they don't have to buy it."
- "The customer saw the product when we delivered it and they said it was 'OK' so who cares?"
- "If the customer can't tell the difference, why should we care at the nursery?"
- "Our customers like this plant; we sell out of them every year."

SOLUTION

What do we do as propagators to solve this problem?

1) Agree that we are responsible.
2) Assume that every plant we propagate from is mixed or mislabeled.
3) Refuse to propagate from mixed plants or unknown cultivars.
4) Hold nurseries to their guarantee that plants are true to name.
5) Refuse to sell plants that are mixed or mislabeled.
6) Change the way we work.

How Greenbrier Nurseries Develops and Promotes New Plants

Jim Monroe
Greenbrier Nursery, HC 62, Box 31, Talcott, West Virginia 24981

"What makes Greenbrier Nurseries different from other nurseries?" is a question that we must ask ourselves at least once a year. We all, as wholesale growers, need to examine this question individually. The term wholesale grower is a dangerous term for us. We prefer to be called a wholesale marketer. Growing is unfortunately the easy part of our business. "Growing" new markets and maintaining market share is the more difficult part.

Greenbrier Nurseries is in our 5th year of container production. Being a new player in the nursery business we realized that we definitely had to be different or no buyer would have reason to consider us as a new vendor.

We grow for two very different markets. The first is for 1-qt and 1-gal rare and unusual trees, shrubs, conifers, and perennials. These plants are sold mainly to larger nurseries for shifting and lining out and for mailorder retail nurseries for catalog sales. Our second market area is in specialty items for upscale retail garden centers on the East Coast. These items are predominately unusual generous 4-qt perennials and hard to find flowering trees, shrubs, and dwarf conifers in a 3-gal size.

In keeping with the theme of this meeting—"New Plants: Discovery, Development, and Delivery"—bringing new plants to the market has been the key to our growth since 1989. Our nursery is a good study of what building a market based on better plant material means to the success of a "niche nursery."

Our most important and largest product line is 30,000 1-gal Japanese maples. These maples are winter bench grafted and we propagate about 50 cultivars. Understock maple plugs are purchased from the West Coast in December in 64 count trays, returned to a cell tray, and put into a greenhouse for root forcing. The understocks are side veneer grafted and placed into humidity chambers. These grafts are ready for potting by mid May. Lighting is used to extend the photoperiod from June 21st until August 20th. Incandescent 100-watt bulbs are placed 12 to 18 inches form the crops and are timed to come on for 5 min every 30 min. They come on a 9:00 PM and go through the last cycle at dawn. We also use a very strict spray program to keep *Botrytis* and other fungal problems out of the trees. At bud break the trees are sprayed with Agrimycin at the suggested label rate. Truban is also used as a soil drench twice a year to control root rot. At leaf drop in the fall the plants are sprayed with KOCIDE to clean up any problems that may be caused by decaying organic matter. A few of the culitvars that we are most excited about from a growing standpoint and from a retail perspective are Red Dragon, Shigitatsu Sawa, Osakasuki, and Tsuma Gaki.

Since, we grow so many plants in 1-gal containers, we can very quickly change with evolving market trends. One particular group of plants that has had a new resurgence of popularity is the hydrangea. Our 1993 production totals on hydrangeas was about 500 units. This year our 1995 saleable totals will top 50,000. This group of plants has great growth potential but, as is true for all plants, needs to have better point-of-purchase material, such as tags, posters, and description cards. We are currently working with several companies in an attempt to produce these materials. Some of our best selling cultivars include *Hydrangea macrophylla* 'Blue Wave', *H. serrata* 'Pink Beauty', and *H. paniculata* 'Tardiva'. Unrivaled interest has come from a dwarf oakleaf hydrangea called *H. quercifolia* 'Sikes Dwarf'.

Some of our other top selling plants produced for the 1-gal market are *Stewartia pseudocamellia* (a wonderful new cultivar from Polly Hill is 'Milk and Honey'), *Aesculus parviflora*, *Hamamelis* ×*intermedia* cultivars, *Ilex verticillata* 'Nana' [syn. 'Red Sprite'], and a fantastic new item for 1995 is *Euonymus alatus* 'Rudy Haag'.

Our 1-gal market is supplemented by a 1-qt, dwarf-conifer program. We are currently producing in excess of 40,000 units of unique and useful *Chamaecyparis*, *Picea*, and *Tsuga*. These plants predominately go to wholesale growers for shifting but we have also found a good market for these in bonsai growers and retailers. An interesting product note is that we recently switched to a taller square pot from the traditional round quart pot and increased our production area by about 20%. This allows us to produce more plants per square foot and therefore more dollars per square foot.

Turnover is the key to profitability in our business. We have geared our production to help our profitability by virtually growing most of our plants in a year or less. If necessary we seek out the proper liner to produce that plant within this 1-year time frame. As in any nursery space is at a premium so we make every attempt to use it wisely.

Our most interesting and challenging market is the East Coast retail garden center. For this market we grow and evaluate over 300 new cultivars of trees, shrubs, vines, and perennials to come up with 20 to 30 new retail offerings for our customers. We experiment with many new cultivars with our own retail customers at our garden center before growing large product numbers for the trade.

Among the items we grow for the retail market are: *Magnolia grandiflora* 'Edith Bogue', an exceptionally hardy southern magnolia that we are successful with in our Zone 5; *M. virginiana* 'Henry Hicks' a floriferous, fragrant, evergreen sweetbay; the new *Camellia oleifera* hybrids and the diverse *Cercis* cultivars, such as 'Forest Pansy', 'Flame', and 'Silver Cloud'. Numerous hydrangeas, winter-blooming witchhazels on trellises, and two very important new barberries, *Berberis thunbergii* 'Helmond Pillar' and 'Bagatelle' round out the list. By selecting improved cultivars we have also cut production costs. Two products that exemplify this are the 'Bagatelle' barberry and 'Jean's Dilly' dwarf Alberta spruce. Unlike the more commonly grown 'Atropurpurea Nana' [syn.'Crimson Pygmy'] barberry and *Picea glauca* var. *albertiana* 'Conica' which both require multiple pruning to produce that perfect plant for the retail market, these two new cultivars are never touched after potting. Another plant where production costs have been greatly reduced is *Corylus avellana* 'Contorta' produced on its own root. This eliminates the unattractive and very labor intensive sucker removal that grafted plants require. Not only do we have a more cost-effective plant but we are also giving the average homeowner or avid plant lover wonderful plants that they will be more successful with.

One of industry's strongest trends currently is that color sells—all year! Perennial color items must meet similar criteria to new woody plants. Our customer look to us for new plants period—whether they are woody or herbaceous. Their expectations are high so we find ourselves evaluating more and more plants every year, One key contact we have made is with Dan Heims from the West Coast.

His breeding work has brought us such great new plants as *Corydalis* 'Blue Panda', *Heuchera micrantha* 'Pewter Veil', and *Pulmonaria* 'Excalibur'. Other new perennial items we are excited to offer are *Brunnera* 'Hadspen Cream' and *Phlox paniculata* 'Norah Leigh'. One difficulty we do have is that we really love plants and the differences between the large number of cultivars in the genus *Heuchera* can sometimes yield a real dilemma. What we try to do is pick a few really exceptional plants that are very different that a retail customer can appreciate. I can tell you that most retail customers look for something that is: unique, easy to care for, of a good perceived value, and named with a name that they can pronounce.

From a marketing standpoint these color items are of great value to us. Many large garden centers have separate buyers for woody and herbaceous plants so we have an opportunity to make two sales with each sales call. In the summer, previously a slow time, we now have the ability to run deliveries continuously. With two buyers our convenient low minimums are easy to meet.

Greenbrier Nurseries has been successful in bringing to our customers new plants and marketing assistance so that they in turn will be successful. Developing and bringing new plants to the market is vital to our success and hopefully to yours.

Tissue Culture's Potential for Introducing New Plants

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INTRODUCTION

Methods to modify and improve plants have been practiced for at least 10,000 years. Early farmers produced better crops simply by selecting the seeds of desirable plants. During the past century, plant breeding has become a refined art due to technological advancements. Today, the plant breeder may use genetic engineering to add diversity to plant characteristics and to develop superior plants.

Successful plant development and improvement are dependent on genetic diversity followed by genotype selection and evaluation. Plant tissue culture and plant biotechnology offer new and efficient ways to expedite genetic selection. Plant tissue culture is the art and science of aseptically growing plant cells, tissues, organs, protoplasts, and whole plants on a nutrient medium under controlled environmental conditions. Micropropagation is a major part of plant tissue culture.

Although genetic engineering is more complex than traditional plant breeding both procedures introduced new DNA into the plant's genome. In 1992, the U.S. government determined that genetically engineered products do not pose any unreasonable risk; as a result, the government decided that these products should not be subject to additional federal regulations.

This paper will briefly review the in vitro techniques of micropropagation, somaclonal variation, fertility restoration, gene transfer, embryo culture, anther culture, and in vitro fertilization. All of these procedures can be utilized to develop and introduce new plants.

MICROPROPAGATION

Micropropagation is the mass propagation of plants in vitro under controlled environmental conditions. The goal of micropropagation is **not** to develop new plants but to rapidly multiply clones while maintaining their genetic stability. Micropropagation is indirectly involved with new plant development, since it assists with the production of the new cultivars.

In order for plant micropropagation to be a viable method propagules must retain their developmental integrity and chromosome stability as they grow. In order to accomplish stability, explants that have organized growing points are used as propagules. Two types of organized explants used are: (1) meristems from shoot tips, axillary buds, or rhizome tips; and (2) zygotic embryos from seeds. These kinds of explants are used for regeneration of true-to-type plants and for germplasm preservation because they retain their developmental integrity and chromosome stability as they grow (Murashige, 1974). However, a significant degree of genetic variation can be produced if a high rate of multiplication is used, if inappropriate techniques are used, or if a variant is produced and subsequently propagated in large numbers.

SOMACLONAL VARIATION

When plant tissue culture was in its infancy, it was thought that since plant cells are totipotent (able to regenerate into whole plants from single cells), they would regenerate plants that are identical to the mother plant. However in the 1980s, this was proven not to be true.

Somaclonal variation is variation that occurs as the result of using tissue culture; the variation may be preexisting or induced (Skirvin et al., 1994) Somaclonal variation can be heritable or epigenetic. Usually the term refers to heritable genetic variation, unfortunately, it is not always possible or feasible to verify the heritable nature. Heritable variation is stable through the seed progeny or repeated asexual propagation. Epigenetic variation is not genetically stable and may not manifest itself when plants are asexually propagated. Although somaclonal variation is a problem for micropropagators, the process can be an asset for plant breeders because it is easy, safe, rapid, economical, and a rich source of genetic variability.

Organized growing points, such as shoot tips and axillary buds, are the most genetically stable explants in tissue culture. Adventitious shoot production systems such as organogenesis or somatic embryogenesis from single cells of unorganized explants such as callus, cell suspensions, and protoplasts are the least genetically stable systems. These adventitious systems are useful for producing genetic variants in vitro through somaclonal variation.

The three ways somaclonal variation may arise in vitro are: (1) pre-existing variation, (2) spontaneous mutations, and (3) induced mutations.

Variation in cells may arise from pre-existing variation from chimeral plants. Chimeras consist of cell sectors or tissues that differ in genetic constitution. Adventitious shoot production from single cells is especially good for chimeral dissociation. Chimeral plants grown in tissue culture can yield variants in high percentages (Skirvin, et al., 1994).

Somaclonal variation can occur as a spontaneous mutation (Brand and Bridgen, 1989). Adventitious plants or somatic embryos arising directly from explants or indirectly from a callus intermediate are especially susceptible to spontaneous mutation. Mutations can also occur either by using high-chromosome or polyploid species or by inducing cultures to grow at high proliferation rates. High concentrations of "strong" growth regulators such as 2,4-dichlorophenoxyacetic acid (2,4-D) and 6-benzylaminopurine (BAP) will also increase the frequency of variability. Cultures that have been maintained for long periods will also demonstrate higher degrees of variation.

Somaclonal variation can also be induced as a form of mutation breeding with the use of mutagenic agents and selection pressures. Either physical mutagens or chemical mutagens may be used to induce mutations. Examples of physical mutagens are gamma rays and x-rays. Chemical mutagens include colchicine, ethyl methanesulphonate (EMS), methyl methanesulphonate (MMS), sodium azide (NaN_3), ethidium bromide, ethyl nitroso urea, methyl nitroso urethane, and diethyl sulphate (DES).

FERTILITY RESTORATION

Colchicine is a chemical that can be used without difficulty to double chromosome numbers. Historically, it was applied to the growing points of whole plants or seedlings. It is now being applied in vitro to double chromosome numbers for somaclonal variation or fertility restoration of sterile diploids.

Our laboratory has successfully used colchicine in vitro to double chromosome numbers of *Alstroemeria*. Young, vigorously growing cultures of either rhizomes or shoots and buds with 2-3 shoots/buds each are treated with 0.2% to 0.6% colchicine in 2% DMSO (a penetrant) solution for 6 to 24 h. The cultures are shaken periodically during treatment.

After the treatment, cultures are rinsed five times with sterile deionized/distilled water to remove surface colchicine; each rinse lasts 30 min. The explants are then cultured on a normal proliferation medium.

Proof of chromosome doubling can be shown by: (1) observing the ploidy level of the regenerated plant with root squashes followed by cytological examinations, (2) examining the morphological characteristics, (3) determining the leaf stomatal index [stomatal density divided by (stomatal density + epidermal cell density)] ×100, (4) measuring the guard cell size, or (5) estimating the fertility of the plants by examining pollen viability.

GENE TRANSFER

Plant biologists created the first transgenic plants about 10 years ago and since then, genetic engineering has been applied to more than 50 plant species. This technique has helped researchers gain critical insights into the fundamental processes that govern the development of plants. Now, the first commercial introduction of such genetically modified plants has been accomplished.

The first practical system for genetic engineering of plants relied on the bacterium *Agrobacterium tumefaciens*. This bacterium is able to transfer a portion of its DNA into plant cells by introducing a set of genes into one or more DNA fragments. The fragments, called transfer DNA (T-DNA), integrate into chromosomes of infected plant cells and induce the cells to produce elevated levels of plant hormones. These hormones cause the plant to form novel structures, such as tumors or prolific root masses, which provide a suitable environment and nutrient source for the *Agrobacterium* strain. The bacterial infections are called crown gall disease and hairy root disease, respectively (Gasser and Fraley, 1992).

For the bacterium to be an effective vehicle for DNA transfer, the disease-causing genes are removed or "disarmed". This was first accomplished in 1983 by using traditional DNA recombination to delete the genes that cause tumors. Disarming eliminates the bacterium's ability to cause disease, but the mechanism of DNA transfer remains intact.

Although the method previously described is simple and precise, many plant species, especially monocots, are not natural hosts for *Agrobacterium* and are not readily transformed. As a result, extensive efforts have been made to develop alternative systems. One of these systems was to introduce free DNA into plant protoplasts. Protoplasts are plant cells that have had their cell walls removed by enzymes. Cell walls must be removed because their pores are too small to allow the easy passage of DNA. Polyethylene glycol can penetrate the only remaining barrier, the plasma membrane, to transport DNA. It is the most commonly used chemical delivery agent. Electroporation can also transport DNA across the plasma membrane. Short, high-voltage pulses briefly produce pores in the protoplast membrane so that DNA molecules can enter through these spaces. Unfortunately, the regeneration of plants from isolated protoplasts has proven to be very problematic.

To increase the efficiency of gene delivery Dr. John C. Sanford (1990) has developed a method to bombard many plant cells with genetic material. This process is known as the Biolistic™ bioparticle delivery system, the microprojectile bombardment method, the gene gun method, and the particle acceleration method. Sanford surmised that small metal particles about one or two microns in diameter could be coated with DNA and then sufficiently accelerated to penetrate the walls of intact cells to deliver the DNA. Because small holes in cell walls and membranes rapidly heal by themselves, the punctures are temporary and do not irreversibly compromise the integrity of the cells. The nucleic acids and other substances that are introduced into the cells remain in the cytoplasm but are too small to interfere with any cellular functions. The introduced DNA is expressed within days after transfer and becomes, to a low extent, stably integrated into the plant genome. Diverse applications for the biolistic process are rapidly being found for research with genetic engineering.

The Biolistic™ bioparticle delivery system (a term coined from biological and ballistics) offers wider applicability than existing gene transfer technologies including direct DNA uptake, cell fusion, microinjection, and *Agrobacterium*-mediated transformation (Table 1) (Kikkert, J.R. 1993).

EMBRYO CULTURE

Intervarietal and interspecific crosses followed by selection have accounted for the improvement in quality and yield potential of practically all major crops. One biotechnological technique which has been very beneficial in this area is embryo culture.

Embryo culture involves the sterile isolation and growth of an immature or mature zygotic embryo on an aseptic nutrient medium with the goal of obtaining a viable plant. The basic premise for this technique is that the integrity of the hybrid genome is retained in either a developmentally arrested or an abortive embryo and the embryo's potential to undergo normal growth may resume if it is supplied with the proper growth substances. The technique is dependent on the isolation of the embryo without injury, formulation of a suitable nutrient medium, and the induction of continued embryogenic growth and seedling formation.

The culture of immature embryos is used to rescue embryos that would normally abort or not undergo the progressive sequence of ontogeny. This process is difficult due to the tedious dissection necessary and the complex nutrient medium requirements. The chance of success of this type of culture depends strongly on the developmental stage of the embryo when isolated.

The culture of mature embryos from ripened seeds is used to eliminate inhibitors of seed germination; to shorten the breeding cycle if, for example, dormancy is a problem; and to prevent embryo abortion of inter- or intraspecific hybrids. The culture of mature embryos is easy and only requires a relatively simple nutrient medium with agar, sugar, and minerals.

ANTHER CULTURE

With sexual reproduction, the number of chromosomes in a cell are reduced to half as a result of meiosis and then doubled again by fertilization when the male and female gametes fuse. Culturing the flower's anthers which contain haploid pollen can produce androgenic embryos in vitro. The number of chromosomes of the

Table 1. Methods of gene transfer into plant cells and their advantages and disadvantages.

Technique	Advantage	Disadvantage
Biological transfer (*Agrobacterium* mediated)	High probability T-DNA will integrate into plant genome.	Only a small number of cells integrate & express introduced DNA.
	"Markers" are available.	Bacterium needs disarmed.
	Relatively simple.	Many plant species are not readily transformed (success primarily with dicots).
	May not require callus phase.	
	Relatively "clean" insertions into the plant genome.	DNA sequences are essential for T-DNA replication and transfer.
		False positives from growth of *Agrobacterium*.
Direct gene transfer: (naked DNA transfer)		
A. Microinjection of protoplasts	PEG mediates transfer into protoplasts.	Difficult to regenerate plants.
B. Electroporation	Does not need to use protoplasts.	Special equipment is needed.
C. Microprojectile bombardment (Biolistics)	Adaptable to most species.	Low probability of integration into genome.
	DNA introduced into intact cell and tissues.	Multiple rearranged copies of the DNA may be inserted.
	Improved recovery of transformed plants.	Special equipment needed.
	Very useful for transient expression studies. Plasmic construction is simplified. No false positives.	
Protoplast cell fusion	Simple	Difficult to regenerate plants.

sterile haploid plant can doubled spontaneously or be induced with colchicine to produce a fertile homozygous diploid individual with two identical sets of chromosomes. Homozygous inbred lines are valuable for breeders because they give rise to identical gametes by meiosis. When two genetically different homozygotes are crossed, the progeny will be identical but hetorozygous.

In anther culture, flower buds are removed from the mother plant when the anthers are at the uninucleate stage. Buds are surface sterilized with bleach, rinsed in sterile water, and the anthers aseptically removed. Anthers are checked under the microscope to confirm the stage of development and then cultured. In 4 to 8 weeks, haploid plants form from the microspores.

The success of anther culture depends on several factors. (1) The stage of development of the anthers at the time of culture is important—pollen within anthers should be at the late uninucleate to early binucleate stage. (2) Genotype is also important since certain plant families, such as the Solanaceae, respond better than others. (3) Anthers should not be damaged before culture. (4) Pretreatments, such as cold or hot thermal traumas, sometimes enhance the androgenic response. (5) A simple nutrient medium with 0.5% to 1% activated charcoal and 2% to 4% sucrose is best.

Although the promise of anther culture for new cultivar development seemed great 20 years ago, its impact on cultivar release is just now being realized (Veilleux, 1994). In addition, problems have been associated with anther-derived haploids, such as reduction in vigor, gametoclonal variation (somaclonal variation of haploids), and elevated DNA contents. However, as the procedures for anther culture become more conventional, more applications to cultivar development will be seen.

IN VITRO FERTILIZATION

Fertilization fails to occur when the pollen does not germinate on the stigma, pollen tube growth stops or stagnates, the fertilized egg aborts, the embryo and endosperm are incompatible, there is poor endosperm development, or ovaries abscise prematurely. In vitro pollination and fertilization appears very promising to overcome pre-fertilization barriers and generate new genotypes.

In vitro fertilization of the egg inside the ovule can occur by test tube fertilization, the development of seeds through in vitro pollination of exposed ovules, or in vitro stigmatic pollination of cultured whole pistils. This process is used when self incompatibility or cross incompatibility are problems.

Two decades ago, there was interest in this technique, but little research. To date, there is still little research for a very promising procedure.

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The Gold Medal Award of the Pennsylvania Horticultural Society

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The purpose of my talk is to introduce you to the Gold Medal Plant Award of the Pennsylvania Horticultural Society. You may be familiar with this under its original name, the J. Franklin Styer Award of Garden Merit, named after the Pennsylvania nurseryman who provided the impetus and the initial funding to create the program.

How did this come about? Dr. Styer had always believed that plants should receive the same kind of recognition as people in the horticulture field. Many really superior plants, both old and new, were ignored by the buying public for lack of widely available information about their merits. So in 1978 he made a grant to the Pennsylvania Horticultural Society (PHS) to develop an awards program to identify, evaluate, and promote outstanding but under used woody plants. Ernesta Ballard, then president of the Society, asked Jane Pepper, then of the Haverford College Campus Arboretum, to head up the Styer Award Committee.

Members for this new committee were chosen foremost for their enthusiasm for, and knowledge of, woody plants. The 15 or so landscape architects, botanical garden professionals, nurserymen, educators, and fine gardeners who comprised the first committee brought to the evaluation process not only their own experiences but varying viewpoints. This helped assure that eventual award-winning plants would have wide appeal not only because of obvious ornamental traits (the "gotta have it!" urge) but also because they performed well in mass production and in landscape settings (the "it roots on a wet sidewalk and survives in a planter at McDonald's" phenomenon).

Plants receiving the Styer Award had to be free from serious pests or cultural problems, be somewhat but not widely available in the trade, show promise of being **distinct** improvements over similar plants and show potential for broad landscape use in the mid-Atlantic region (an area roughly from New York City to Washington, DC). Also, potential award-winners could not be eligible for an award from another society (for example, the Rose Society), as it was felt that additional evaluation and promotional efforts were not needed for these categories of plants. It was intended that the award be given only to woody plants.

The initial process involved two stages. Plants were submitted to the Committee by early December for consideration of merit. At a January meeting, those determined to be worthy of further evaluation for the Styer Award were given an Award of Preliminary Commendation. Submitters were required to distribute plants shortly thereafter to evaluators on the committee to grow and observe. After several years' evaluation, a consensus would be reached by the committee, and plant candidates were either given the Styer Award or dropped from the program. In this way large number of applicants could be weeded out early, while plants showing early promise would have to prove themselves superior over time to get the award.

Over time, modifications have been made to the program. In 1990 the Styer Award became the Gold Medal Award to help those not familiar with the program to grasp the award's intent. The composition of the Committee has shifted somewhat as original members have retired and new members with different areas of experience have joined. Other changes have greatly speeded the process. The requirement of growing and evaluating the potential award-receiving plants by committee members was deemed too time-consuming. Now at least three landscape-sized specimens of plants under consideration must be accessible (within 150 miles of Philadelphia) for committee members to observe. A second meeting, usually in early June, is now held at the Scott Arboretum of Swarthmore College, whose collections usually contain specimens of potential award-winners. Voting is done at this meeting to determine Gold Medal winners for the upcoming year after viewing plants and subsequent discussion. Final suitability for the award is determined by a plant's being rated as outstanding in:

- **Cultural Considerations**: broad garden and landscape adaptability.
- **Commercial Factors**: ease of propagation, marketing, and economic feasibility of production.
- **Aesthetic Considerations**: overall appeal.

Any plant not meeting these standards does not receive the award and is dropped from the program.

Is the Gold Medal program a success? The staff of PHS has conducted surveys of its membership and commercial nurseries and garden centers. Results indicate that more than 90% of PHS members responding believe the program to be making a worthwhile contribution to horticulture in the Delaware Valley, and more than 75% have looked for Gold Medal plants when visiting area nurseries. PHS has been contacted by nurseries wanting to be listed as sources for Gold Medal plants, and several firms have indicated they use PHS's source lists to obtain propagating stock or plants for their own operations. In 1994, PHS received 550 requests for information about the program or its plants. Since 1988, 42 plants have received the Styer/Gold Medal Award; 86 have been rejected. Each year's winners are profiled in the January issue of *The Green Scene*, a PHS publication. There are now over 10 plants under consideration for future Gold Medal Awards. If you are a regular reader of *American Nurseryman*, you will find recent Gold Medal award winners profiled in the annual new plants issue.

You are strongly encouraged to contribute to this process of recognizing and promoting outstanding woody plants by submitting entries. Applications are available from the Pennsylvania Horticultural Society, 325 Walnut Street, Philadelphia, PA 19106 (Atten. Kathy Mills). You will need to submit approximately 5 slides illustrating specific qualities which you believe makes your plant superior and to cite locations of at least 3 landscape-sized specimens within 150 miles of Philadelphia which are accessible to evaluators for observation. It is also important to identify any sources you may know to help the committee assess potential availability. Remember that any woody plant not eligible for other awards can be submitted: species, cultivar, hybrid, old or new; the goal is to promote superior plants deserving greater use. Also note that while the Gold Medal Award Program targets the mid-Atlantic region, its award winners are equally valuable wherever they can be successfully grown. Please consider the Pennsylvania Horticultural Society a resource if you are now, or are considering, growing, selling, or buying

Gold Medal plants. Source lists are available as are slides for illustrating catalogs. I hope you will agree that these plants are not only fitting tributes to the vision of Dr. J. Franklin Styer but are truly first-rank additions to landscapes both in and out of the mid-Atlantic Region.

Editor's Note: Philip Normandy showed a series of slides of Gold Medal winners. Gold Medal winners shown included the following: *Aesculus pavia, Betula nigra* 'Heritage', *Callicarpa dichotoma, Cephalotaxus harringtonia* 'Prostrata', *Clematis* 'Betty Corning', *Deutzia gracilis* 'Nikko', *Halesia diptera* var. *magniflora, Hedera helix* 'Buttercup', *Hydrangea macrophylla* 'Blue Billow', *Itea virginica* 'Henry's Garnet',*Magnolia* 'Elizabeth',*M.* 'Galaxy',*Malus* 'Donald Wyman',*M.* 'Jewelberry', *Prunus* 'Okame', *P.* 'Hally Jolivette', *Viburnum dilatatum* 'Erie', *V. nudum* 'Winterthur, *Zelkova serrata* 'Green Vase'.